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# Incentives for deployment of biojet fuels. Benchmark of policy instruments

- FINAL REPORT –

ORIGINAL / CONFIDENTIAL

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# EXECUTIVE SUMMARY

**Rationale for the study**

The use of sustainable biojet fuels has large potential to reduce emissions. However, deploying cost-effective biojet fuel on a global scale is limited by:

1. Technical constrains: Biojet fuels are only possible as drop-in fuels in the foreseeable future; therefore their potential to reduce emissions is limited to the drop-in share.
2. High costs: In the absence of any economic incentive and with the current situation of production only at intervals, biojet fuels are 3 to 5 times more expensive than fossil jet fuel.
3. Price and competing uses for feedstock: Feedstock represents the largest share of the biojet fuel price, 50% to 90%. In the current global transition to more bio-based products, competing uses appear constantly in the food, chemistry and energy industries. This drives the prices of traditional and less conventional feedstock towards commoditisation.
4. Production capacity: Existing production capacity is limited. Synergies exist with second-generation biofuels developed for road transport, and both types of fuels could be produced in the same facilities; however, biodiesel for road transport are usually more strongly subsidised, allowing for higher margins with respect to biojet fuel.
5. Non-uniform or lack of policy incentives: While incentives aiming to bring the price of biojet fuel closer to the price of fossil jet fuel are being introduced in some jurisdictions, they don't exist in others. It is also unclear if governments will keep incentives (especially the ones addressed to keep feedstock price low) when large production of biojet fuel is reached. This situation may potentially create global differences in price and availability of feedstock and biojet fuel. Producers expect that without support, prices will only drop to two times the price of fossil jet fuel not earlier than in 20 years.
6. Waste and residues potential: Biojet fuels produced from waste/residues have higher greenhouse gas (GHG) emissions reduction potential; however the availability of waste/residues is limited, their potential is difficult to unlock, and the pre-treatment needed for their use with the Fischer-Tropsch technology still needs technical maturation.

Current high prices for biojet fuels causes that airlines cannot afford to buy large quantities of biojet fuel. This results in (mainly oil) companies having little incentive to invest, and consequently the cost reduction from learning effects and from scaling up production does not take place (vicious circle).

Given this situation, successful deployment of biojet fuels is difficult to achieve with market forces alone. Policy instruments are required to bridge current limitations. Some combinations of instruments have proven more effective than others to incentivize production and to narrow the price gap. IATA is proactively supporting policy developments aiming at improving conditions for the implementation of biojet fuels. This study has been performed in order to understand the advantages and disadvantages of different policy instruments by learning from the biofuels sector in general (mainly the road transport sector), and their impacts to airlines in an international context.

**Contents of the study**

The study comprises the following subjects:

1. State of the play of the biojet fuel industry and market: Techno-economic analysis of feasible technologies and feedstock, and price forecasts are presented. Three technologies are explored in more detail: Hydro-treatment of vegetable oils (HVO), Fischer-Tropsch (F-T), and Alcohol-to-Jetfuel (ATJ). Feedstock considered are Camelina, Jatropha, Algae, waste and residues, and woody biomass.
2. Policy instruments to support the use of biofuels in other sectors, mainly road transport, are classified in four types: 1) command and control, 2) economic, 3) co-regulation and 4) voluntary instruments. The effectiveness of policy instruments in different countries is measured by the developments of consumption, production and installed capacity for biofuels. Special focus is given to instruments applied in the two largest markets for biofuels: the US and the EU. A thorough comparison of market impacts is presented.
3. A selection of most relevant policy instruments is evaluated in depth to better understand their applicability to and the international impact on the biojet fuel market and industry. Special attention is given to the suitability of those instruments to choices of feedstock and conversion processes of interest to the aviation sector, and their feasibility for international regulation and cross country implementation. Combinations of policy instruments are analysed in view of incentivising the production and use of biojet fuel, under criteria such as acceptable economic, technical and logistic conditions.
4. An economic simulation model is developed to deliver the quantitative backbone for this analysis. The model includes IATA's forecasted demand for air travel and calculates supply and demand of biojet fuels under different combinations of policy instruments. Sensitivity analyses have been performed to demonstrate the impact of a range of blend percentages, $CO_2$ prices, jet fuel prices and feedstock.

**Main aspects found for the success in the applicability of policy instruments**

International regulation will most likely not be introduced simultaneously in all relevant countries. To be successful a long transitional period is required for success. Regulation for biojet fuel deployment cannot be seen separately from policy developments in other related sectors (agriculture, forestry, bio-based economy, road transport).

Administrative barriers can limit the production and use of biojet fuels substantially. It is important to develop international technical standards and sustainability standards from the start.

1. *Command and control instruments*. Command and control instruments are defined as the regulation establishing what is permitted and what is not permitted in a specific industry or activity. The command part establishes the obligations to be complied with, and the control part establishes the sanctions that result from non-compliance. Examples include blending and emissions mandates. In order to make these instruments more effective in the deployment of biojet fuel, they would need to be designed as flexible and tradable across countries to create sufficient international scope. Feasibility of obligations is complicated when they are not agreed upon between countries (airlines potentially regulated under different types of mandates).
2. *Economic instruments*: Economic instruments use markets, price, and other economic variables to provide incentives to a specific industry or activity. Examples include taxes (or the exemption of them), charges, incentives, subsidies, public loans and emissions trading.

For a successful global biojet fuel deployment, these instruments should provide long-term certainty and avoid international incoherence for the successful deployment of biojet fuel. Ideally, these instruments shall be developed to maximize synergies with biofuels for road transport and potentially other relevant sectors. International approaches that safeguard a level playing field for airlines shall be required.

3. *Co-regulation instruments*: Co-regulation refers to the recognition of industry voluntary initiatives or programs as part of the public regulation. Co-regulation is especially useful when there is a need to regulate economic activities performed across the geographic borders of different countries. While co-regulation builds upon the combined strengths of public regulation and industry initiatives, it also requires extensive negotiations and finding agreement between conflicting interests from all participating stakeholders and governments.
4. *Voluntary and collaborative instruments*: These instruments refer to voluntary and collaborative programs within the private sector or between the private and public sectors. These instruments are classified as either "supply-push" (supporting research, development and demonstration of technologies) or "demand-pull" (changing market conditions like voluntary private procurement). For the effective deployment of biojet fuel, these instruments should have an international scope and be an integral part of airlines' long-term strategic vision. Cooperation between competitive sectors, such as biofuel for road transport, bio-refineries, bio-chemistry industry, the so-called bio-based hubs, is desired to strengthen innovations and promote coherence in regional development

**Options of policy instruments and scenarios studied**

Four options with different combinations of policy instruments were selected based on discussions with IATA and lessons learned from other biofuel sectors:

1. Price driven option: Direct financial support for R&D, production capacity build up, and feedstock.
2. Obligation driven option: Blending mandate as cornerstone instrument.
3. Co-regulation and carbon trading option: International industry initiative to set blending targets and rules for accomplishment at supranational level, translated into national regulation.
4. Voluntary driven option: Voluntary agreements are set by the aviation sector itself.

Four market scenarios establishing jet fuel and $CO_2$ prices were also selected, three of them are based on the IEA global energy outlook 2012:

1. Current policies scenario (IEA): Regulations will not change, small role for renewable energy.
2. New policies scenario (IEA): Current plans will be implemented, role for renewables grows.
3. 450 scenario (IEA): All efforts to maintain global CO2 emissions below 450 ppm, renewables play a large and increasing role
4. Forward market prices scenario: Based on today's market prices and extrapolations where markets don't provide data.

These scenarios were complemented with three different levels (low, base, high) for future feedstock price and rates of learning curves for the conversion processes.

The study presents a selection of results for eight combinations of scenarios and policy options. This selection is made for illustration purposes to cover the broadest set of impacts possibilities:

| Policy option instruments | | Market scenario | Feedstock prices | Learning curves | Carbon market | Investment incentives | Feedstock incentives |
|---|---|---|---|---|---|---|---|
| Option 1: Price driven | 1A | Market forwards | High | High | No | 50% | 50% |
| | 1B | New policies | High | High | Yes | | |
| Option 2: Obligation driven | 2A | Market forwards | Low | Base | No | 25% | None |
| | 2B | New policies | Base | Base | Yes | | |
| Co-regulation and carbon trading | 3A | 450 | Low | Base | Yes | None | None |
| | 3B | 450 | High | Base | Yes | | |
| Voluntarily driven | 4A | Market forwards | Low | Base | No | None | None |
| | 4B | New policies | Base | Base | Yes | | |

**Conclusions and recommendations**

1. Production of biojet fuels is considerably more expensive than production of fossil jet fuels. Feedstock price represents the largest share in the final cost of biojet fuel (50%-90%); technology related fixed cost is the next important component. Large cost reductions, especially on feedstock, are needed to make biojet fuels feasible.
2. There is no clear winning technology. Cost reductions in capital investments may be achieved through learning and up-scaling. Secure demand (a market) is needed to create an investment environment that supports innovation and large scale facilities. No one single instrument can produce these benefits by itself. A well thought combination of instruments is needed to deal with all barriers.
3. Key to realise competitive production of biojet fuels is:
   - Sufficient supply of feedstock at low cost in order to maintain reasonable prices. Competition for feedstock from other industries is large (food, feed, chemicals, power, road transport) and this competition is expected to keep increasing.
   - To reach economies of scale, technology (R&D, investments) investments are needed.
   - Only very high $CO_2$ prices, or equivalent other biojet fuel incentives, in combination with low feedstock prices will possibly result in competitive biojet fuels; this combination is not likely in the foreseeable future, and a very high $CO_2$ price is not desirable because it puts a strong financial burden onto the airlines as long as a large part of fuel used is still conventional.
4. A recent study performed by the Midwest Aviation Sustainable Biofuels Initiative (MASBI) "Fueling a Sustainable Future for Aviation" shows that an economic incentive of US$ 2 per

gallon of biojet fuel would be needed for bringing HEFA biojet fuel to a US$ 2.92 per gallon which is cost competitive with current fossil jet fuel price. This calculation is under the assumption of a relatively optimistic price of feedstock. The model developed in our project produces a similar result (incentive of around US$1.50 per gallon of biojet fuel) when modelling under similar assumptions. Our model estimates that for a more conservative cost development of feedstock, the incentive needed would be of US$ 2.7 per gallon of biojet fuel. A 3% blend would thus increase the blended jet fuel price by 2.5% if the underlying biojet fuel price is 40 US$ per ton.

5. Main quantitative results from our model show that for a conservative forecast of feedstock price, the US market would require incentives amounting US$ 540 million annually for each 1% of blending (on the basis of an annual consumption of 20 billion gallons of jet fuel a year by the US military and commercial aviation, MASBI report). A global blending of 1% would require annual incentives of the order of US$ 1.8 billion. The relevant question from everyone in the industry is the likelihood of assumptions, e.g. feedstock price, technology cost, and jet fuel price. While comparing our research with the MASBI report, it gets clear that the most sensitive assumption is future feedstock price just because of the growing other competing uses for biomass in the many different industries (food, chemistry, biofuels for road transport). This is where it lays the largest risk for the competitiveness of biojet fuel prices. For technology costs, basically the assumptions in this study and the assumptions made by MASBI are quite similar.
6. Analysis of selected policy options:
   - Option 1 (price driven) establishes how much economic incentives are needed for an optimal market start-up and global deployment of biojet fuels with a 2% blending mandate reached in a time horizon of 10 years (2015-2025). This option shows that 50% of direct incentives for the construction of production plants (regardless feedstock/conversion technology) would be required for initial up-scaling. Additionally, for Camelina/Jatropha HVO biojet fuels up to 66% of subsidies to feedstock would be needed in the first 10 years of deployment (depending on the price of feedstock). The Fischer-Tropsch route would require less subsidies to feedstock (up to 40%), but more subsidies to technology development as Fischer-Tropsch plants are still very expensive.
   - Option 2 (obligation driven) facilitates the discussion with governments to receive economic support. Economic support needed is similar to option 1, but can be more tailor-made if adequate consensus negotiations take place. However, with this option, the biojet fuels sector will evolve following the ambition level of governments rather than the one of airlines. Additionally, mandates in the aviation sector would require flexible compliance rules. Blending mandates cannot be applied upfront to a nascent market in which biojet fuel prices have not yet reached certain stability. Stability of prices usually comes after learning and certain up-scaling has already happened. Mandates should therefore be implemented after economic incentives alone have resulted in this up-scaling. Mandates should also be designed to change gradually according to careful monitoring of achieved goals; otherwise the risk of excessive economic pressure on airlines and final users is not properly mitigated.
   - Option 3 (co-regulation) gives the aviation sector the possibility to demonstrate commitment and to receive economic support. In essence the economic incentives to make this option viable are similar to option 1 as well, but the pace and place of their

introduction would be first discussed by the aviation sector. This option may also include an international trading mechanism for biojet fuels certificates. This mechanism may also involve other sectors (such as road transport), similar as RINs in the US or the biotickets in the Netherlands. Trading and compliance rules can be tailor made to accommodate the aviation industry specifics, e.g. the global perspective which risks level-playing field issues.

  This option can partially build on voluntary agreements. With the co-regulation option, the aviation sector retains control in the setting of its own targets and compliance rules, opposite to the obligation driven option in which those are established by governments. The difficulty of this option is the complexity of its negotiations as they involve different interests from several parties.

- Option 4 (voluntary driven) is basically the business as usual case. It has become clear by now that voluntary agreements alone are not sufficient to break the vicious circle of market start-up and cost reductions. There will always be airlines that are leading the deployment of biojet fuels. They will use more biojet fuels than committed to. They voluntarily go one step further than the majority with innovative solutions and new forms of cooperation. Examples are the KLM Corporate programs, and procurement initiatives or the formation of strategic alliances. These types of initiatives can well exist next to the other policy options and have minimal financial risk.

7. A consistent international framework to maintain a level-playing field is required; preferably based on international negotiations. The risk of creating a disturbed market due to a variety of diverging policy instruments exists.
8. While all researched options would bring different advantages and disadvantages for the deployment of biojet fuels, the order of implementation of instruments is crucial. A market start-up will only happen if firm support to technology development and technology commercialisation is given (in the way of economic incentives). Only then, other policy instruments will be effective in shaping the biojet fuel market and its evolution. It is especially relevant to mention that blending mandates would cause more harm than benefits if they are applied in an immature market when biofuel prices have not yet reached stability.

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# PART 1: BACKGROUND ANALYSIS

# 1 Rationale of the study and definition of the problem

Aviation contributes greatly to the world's economy. Its total economic impact is estimated to be nearly 8% of global economic activity and it carries about 40% of the value of freight. As a major growing industry strongly dependent on fossil fuels, aviation has been dealing with many mostly economic problems in the past years. Its dependence on fossil fuels makes aviation account for 2-3% of total global emissions today. Aviation is therefore also expected to face increasing challenges when it comes to reduction of emissions over time. The International Air Transport Association (IATA) predicts that commercial aviation will grow with5% per annum until 2030; however, emissions are believed to grow only by approximately 3%, mainly due to savings by fuel efficiency improvements.

The combination of increasing passenger demand, fluctuating fuel costs, and the pressure to reduce emissions, has led IATA to achieve carbon neutral growth for the sector from 2020, and to a 50% total net emission reduction by 2050. IATA represents 240 airlines in 118 countries; this amounts to 84% of the total air traffic.

The IATA four-pillar strategy provides the building blocks to achieve IATA's goals and vision. A multi-faceted approach is required with a strong commitment from all aviation stakeholders: airlines, manufacturers, fuel suppliers, airports, and air navigation service providers to reach success. This four pillar strategy is translated into complementary actions to mitigate emissions:

Pillar 1: Technology. Enhancement to existing in-service fleet, efficiency of aircrafts, new technologies and aircraft designs, and drop-in biojet fuels;

Pillar 2: Operations. Improving operation and promoting airline environmental management systems;

Pillar 3: Infrastructure: Addressing airport and airspace inefficiencies;

Pillar 4: Economic measures: Market-based measures that are global, cost-effective and prevent market distortions and carbon leakage

The first three pillars involve direct carbon emissions reductions in the sector. Efficiency improvement of aircraft and airport related operations are certain to happen. They are limited by the availability of new materials, fluid mechanics constrains, and thermodynamic laws in the case of aircrafts, and limited by systems operations, organisation and procedures in the case of airport related operations.

Efficiency improvements are expected to lead to a net reduction in related emissions of 40% by 2050[1.] These improvements will not be sufficient to lead to an absolute reduction in demand for fuels due to the global growth in demand for air transport.

The use of sustainable drop-in biojet fuels offers potentially a larger possibility of emissions reduction. However, deploying this potential is nowadays limited by technical constraints on its use in aircrafts, the high costs of biojet fuels, and the limited existing production capacity.

[1] SWAFEA report, 2011

Aircraft engines are currently designed, produced and tested for safety for the characteristics of conventional jet fuel. Design of aircraft engines cannot be restricted to the different technical characteristics of various particular fuels (at least in the next few decades). The logistics of fuels with different technical characteristics would also require dedicated infrastructure to avoid fuel contamination. Therefore, the extended use of pure biojet fuels in aircrafts seems not feasible in the short term, though research effort is being put to overcome technical obstacles for certified blends higher than 50%. From a technical point of view, the only current alternative for the broad use of biojet fuels in aviation is as a "drop-in" fuel in jet fuel, which has to meet technical specifications. The technical specifications of biojet fuels depend on the feedstock and the conversion process used for their production.

The cost of biojet fuel production has two important components: Feedstock production and conversion costs. The feedstock cost is in general the largest component (50% to 90%), depending on feedstock and conversion technology (see sections 2.1 and 2.2). In the current global transition to more bio-based products, competing uses appear constantly in the food, chemistry and energy industries. This drives the prices of traditional and less conventional feedstock towards commoditization. Cost of feedstock is therefore crucial for the economy of biojet fuels. Most feasible feedstock for biojet fuels has other competing uses as well, including food, bio-chemistry and other energy uses.

Existing production capacity is limited. Synergies exist with second-generation biofuels developed for road transport, and both types of fuels could be produced in the same facilities; however, biodiesel for road transport are usually more strongly subsidised, allowing for higher margins with respect to biojet fuel.

The amount of greenhouse gas (GHG) emissions reduction in biojet fuels depends substantially on the feedstock used for their production. Biojet fuels with higher reduction of GHG are made from lignocellulosic biomass, waste, residues, and in general from non-food crops. Biojet fuels from these types of feedstock are even scarcer than the ones made from conventional feedstock, as the supply is not fully unlocked yet and/or the proven technologies for their production are not yet in commercial stage of maturity.

The above combination of factors results in only a small amount of biojet fuels available in the market, and only at very high prices, resulting in only a limited market demand. Oil companies see little incentive for investing in biojet fuel production and in its supply chain. Airlines fear reduction of their economic competitiveness due to the high prices of biojet fuels. These bottlenecks are difficult to reverse in the current market conditions.

5. Non-uniform or lack of policy incentives: While incentives aiming to bring the price of biojet fuel closer to the price of fossil jet fuel are being introduced in some jurisdictions, they don't exist in others. It is also unclear if governments will keep incentives (especially the ones addressed to keep feedstock price low) when large production of biojet fuel is reached. This situation may potentially create global differences in price and availability of feedstock and biojet fuel. Producers expect that without support, prices will only drop to two times the price of fossil jet fuel not earlier than in 20 years.

Achieving the following objectives will support a successful and cost competitive deployment of the more sustainable biojet fuels:

1. Make feedstock available at a large, economic and sustainable scale;

2. Reach commercial stage maturity of the second generation technologies for the ramp up of biojet fuel plants;
3. Improve the cost competitiveness of biojet fuel production by walking the technology learning curve;
4. Engage an international growing market for biojet fuels;
5. Favourable policy instruments to incentivise production and consumption of biojet fuels;
6. Engaging Banks, venture capitals, and other investors through feasible business cases.

Successful deployment of biojet fuels is difficult to achieve with market forces alone. Policy instruments are required to bridge current limitations and to achieve more competitive costs for the deployment of large amounts of biojet fuels. However, at an international level incentives are being introduced in some jurisdictions, but they don't exist in others. Decision-makers have therefore to deal with selecting an optimal mix of policy instruments. A wide range of considerations have to be taken into account however to avoid unnecessary public expenditure. It is for instance unclear if governments will keep incentives (especially the ones addressed to keep feedstock price low) when large production of biojet fuel is reached. This situation may potentially create global differences in price and availability of feedstock and biojet fuel. Producers expect that without support, prices will only drop to two times the price of fossil jet fuel not earlier than in 20 years.

Some combinations of instruments have proven more effective than others to incentivize production and to narrow the price gap. Policy instruments can be effective in reducing production costs, de-risking new investments and accelerating the learning curve for new technologies. Policy instruments can, on the other hand, work counter-effective (for some stakeholders groups) when not carefully designed.

In this context, IATA aims to anticipate proactively which policy instruments, or any combination of them, could improve or alter the economics of biojet fuels in aviation. IATA wants to thoroughly understand advantages and disadvantages of different policy paths at an international level and forecast their impacts on the aviation sector, in particular to its members. This study has been performed in order to understand the advantages and disadvantages of different policy instruments by learning from the biofuels sector in general (mainly the road transport sector), and their impacts to airlines in an international context.. The study starts with a benchmark of existing policy instruments (mainly implemented to promote biofuels in the road transport sector), and their effectiveness in terms of costs and volume. A selection of these policy instruments is evaluated in more detail to better understand their potential effects over the biojet fuel market. Different combination of options for policy instruments are analysed in the mind frame of incentivising the production and use of biojet fuels, under criteria such as acceptable economic, technical and logistic conditions.

The study is divided in 2 parts:

- Part 1: Background analysis;
- Part 2: Evaluation of options.

Part 1 of the study comprehends chapters 1 through 5. This chapter 1 presents the study's rational and defines the research problem. Chapter 2 describes the state of play in the current use of biojet fuels. Chapter 3 provides an overview and inventory of policy instruments for the promotion of biofuels around the world. Chapter 4 analyses the impacts and effectiveness of those policy instruments. Finally Chapter 5 discusses the applicability of instruments to the aviation sector.

Part 2 of the study comprehends chapters 6 through 9. Chapter 6 evaluates different combinations of instruments and their impacts on relevant stakeholders. Chapter 7 describes the modelling tool developed for this evaluation. Chapter 8 presents the economic results for the different options under different scenarios. Chapter 9 presents the conclusions and final recommendations for IATA on best policy instruments based on the study's findings. Finally, chapter 10 presents the reference list on which this study has been performed.

# 2 Background: State of play of biojet fuels

## 2.1 Technology pathways and cost expectations

Aviation fuels require stringent fuel specifications. They also require stringent rules for their handling to minimise the safety risk caused by fuel contamination. Consequently, drop-in biojet fuels must essentially have the same performance properties as conventional jet fuels.

There are currently three promising technology conversion pathways which potentially can produce drop-in biojet fuels: 1) Fischer-Tropsch (F-T), 2) Hydro-treated Vegetable Oils (HVO) or more generally called Hydro-processed Esters and Fatty Acids (HEFA), and 3) Sugar conversion technologies such as Alcohol-to-Jet fuel (ATJ). The general characteristics of these technologies are shown in Table 1. With exception of the ATJ pathway, the F-T and HVO/HEFA pathways require one additional step in the refinery to convert the "bio-crude" into biojet fuel.

*Table 1: General characteristics of current feasible technologies for the production of biojet fuels*

| Technology | Feedstock | Products | Certification |
|---|---|---|---|
| **F-T** | Any material containing carbon (wood residues, agricultural residues such as straw, municipal solid waste) | Straight alkanes | ASTM (2009)<br>DEFSTAN (2009)<br>NB: Max. 50% blend with fossil jet |
| **HVO/HEFA** | Vegetable oils and animal fats. For sustainable biofuels, oils not having land use change effects (Jatropha and Camelina), or algae oil | Straight alkanes | ASTM (2011)<br>DEFSTAN (2011)<br>NB: Max. 50% blend with fossil jet |
| **ATJ** | C6 sugars (from starch or cellulose), or directly ethanol | Alcohols, alkanes and other hydrocarbons including biojet fuels | Currently in the process of ASTM certification |

Next to these three technologies, Pyrolysis is also a technically feasible pathway, however it is currently deemed too costly. Other production pathways also yield liquid fuels, although it is uncertain, or even unsuitable due to their properties, that these fuels can be used as drop-in alternative to fossil jet fuel. These include:

- Fatty Acid Esters (of which FAME is best known)
- Alcohols (of which ethanol is best known)
- Furane derivatives
- Succinic acids derivatives
- Cryogenic fuels (LNG & liquid Hydrogen)

### 2.1.1 Fischer-Tropsch (F-T)

F-T synthesis is a catalytic chemical process used to produce a synthetic fuel by processing a gas obtained from the gasification of a feedstock. Within the F-T synthesis, the conditioned synthesis gas is converted into liquid and solid hydrocarbons. The resulting products can be classified into naphtha, diesel or jet fuel and waxes as well as combustible gases like propane and butane. With regard to the conversion efficiency, about five to six million tonnes of biomass is required to produce one million tonnes of F-T-liquid fuel.

F-T has been selected in this study for two reasons. Firstly, the core of the production route is already certified to produce jet fuels from coal, biomass and natural gas feedstock (when blended 50% with conventional jet fuel). Secondly, current developments show that F-T fuels from biomass are technically feasible. Note that F-T can be used to generate various final products, making it also an interesting technology for the production of biobased materials.

### 2.1.2 HVO/HEFA

The HVO/HEFA technology is based on the hydro-processing of vegetable oils and animal fats. Approximately 1.2 tonnes of vegetable oil is required for 1 tonne of HVO fuel. One of the main advantages of this technology pathway is the possibility to integrate this process into an oil refinery (with an additional step), avoiding the need to develop a dedicated production facility.

HVO/HEFA has been selected in this study for similar reasons as F-T: Firstly, the production route is proven and already certified for blend ratios up to 50%. Secondly, current investments in infrastructure suggest that the route is, or will be, economically viable today or in the near future.

Another oil that can be converted to biojet fuel via the HEFA technology is the algae oil. Algae biofuels are not yet produced commercially. There are still fundamental R&D challenges to solve. It is expected that biojet fuel from algae is technically possible using the HVO process. The GHG associated with algae biojet fuel production are uncertain though they are expected to be quite promising.

### 2.1.3 ATJ

The ATJ process converts C6 sugars or alcohols into different hydrocarbons, including a fraction of biojet fuels. Contrary to F-T and HVO/HEFA processes, this catalytic process does not require hydrogen or hydro processing. This process consists of ethanol dehydration, oligomerization and distillation for the production of biojet fuel.

ATJ has been selected in this study because it is a technology close to be certified.

### 2.1.4 Cost expectations technology pathways

Each of the technology pathways selected in this study involve conversion costs that will decrease during the next years while walking their learning curve. Various sources state that with the right up-scaling of production and technology, the production cost in 2015[2] will likely amount to 750 US$/tonne for F-T biojet fuel (excluding woody biomass price), 200 US$/tonne for HVO/HEVA biojet fuel (excluding the vegetable oil price), and 300 US$/t for ATJ biojet fuel (excluding the alcohol price). For an overview of feedstock prices, see section 2.2.6. Current producers of biojet

[2] For comparison, jet fuel prices in 2015 are expected to be in the viccinity of 1000US$/tonne

fuels expect that these indicative production costs decrease by 20% and 50% in the next decade thanks to technology maturation and production capacity enlargement.

HVO/HEFA technologies pathways are therefore the least expensive conversion alternatives, and possibly close to become available for the supply of biojet fuels. In March 2013, the biojet fuel supplier SkyNRG became the first, and only, biofuel operator, worldwide that is certified by the Roundtable on Sustainable Biofuels (RSB) for their entire supply chain ("feedstock to flight"). SkyNRG is currently producing biojet fuels from used cooking oil via the HEFA conversion pathway.

## 2.2 Availability and economics of feedstock worldwide

The availability of different biomass feedstock varies greatly among the different regions of the world. Future production potentials depend on variables such as the development of the agricultural system (productivity level) and the governance of land use. Regions that stand out for high production potentials are Latin America, North America, Sub Saharan Africa and Eastern Europe (including Russia). Next to dedicated crop production, forest rich countries and key agricultural production areas can also contribute substantially through the supply of primary forest and agricultural residues. Figure 1 lists a number of key biomass resources for advanced biojet fuel production around the world.

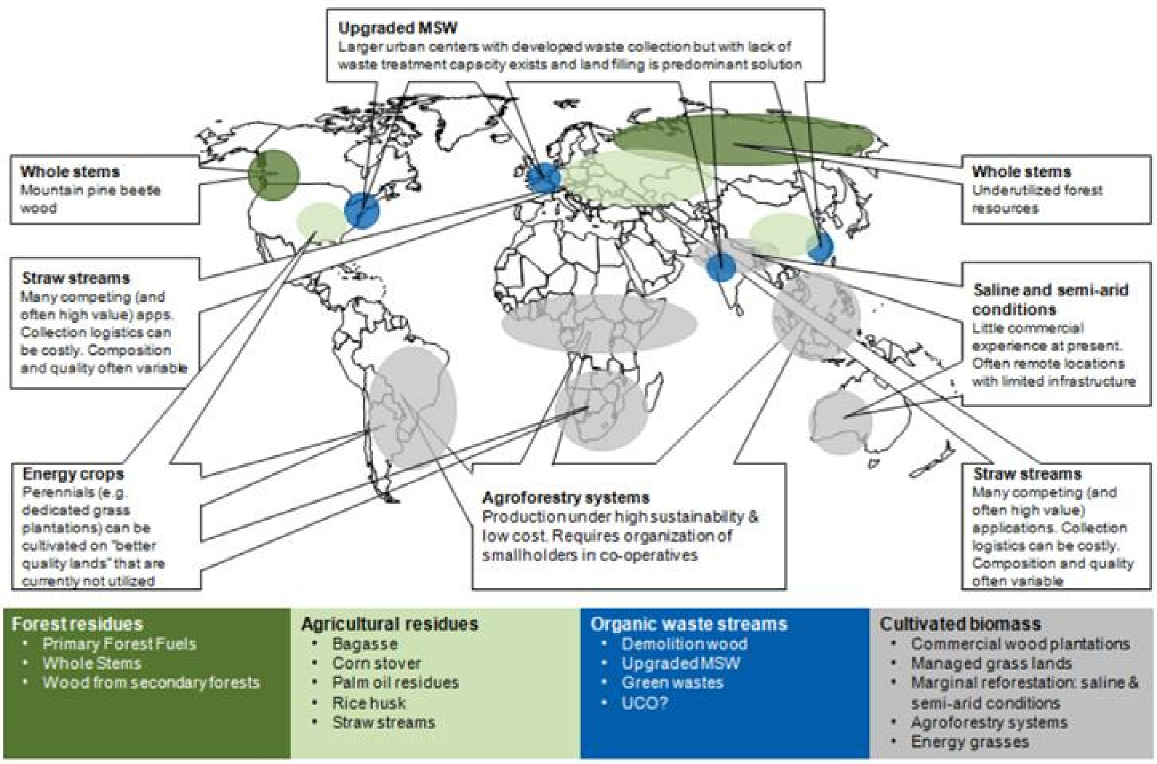



*Figure 1:* Key (potential) biomass resources and regions for *the production of advanced biojet fuels. Source; SKYNRG (2012)*

According to the potential volumes that can be made available, the following biomass types appear to be the most relevant for the different technologies selected:

1. Wood and forestry residues (F-T)
2. Agricultural residues, especially straw (F-T)
3. Municipal solid waste (F-T)
4. Jatropha oil (HVO)
5. Camelina oil (HVO)
6. Used cooking oil and animal fat (HEFA)
7. Alcohols from sugars, like ethanol from sugarcane or from maize (ATJ)
8. Algae (HVO)

### 2.2.1 Wood and forestry residues

Forests cover 3.95 billion ha, approx. 30% of the Earth's landmass. The German Biomass Research Centre (DBFZ) estimates the technical potential for wood based fuels to about 34 EJ in total in 46 countries by 2020. The technical potential is shown in Figure 2. The most densely wooded countries and/or the largest producers/consumers of wood are: China, India, Indonesia, Japan and Malaysia in Asia; Ethiopia, D.R Congo, Nigeria and South Africa in Africa; the European Union (EU), Norway, Russia and Switzerland in Europe; Canada and the United States (US) in North America; Argentina, Brazil and Chile in South America; Australia and New Zealand in Oceania.

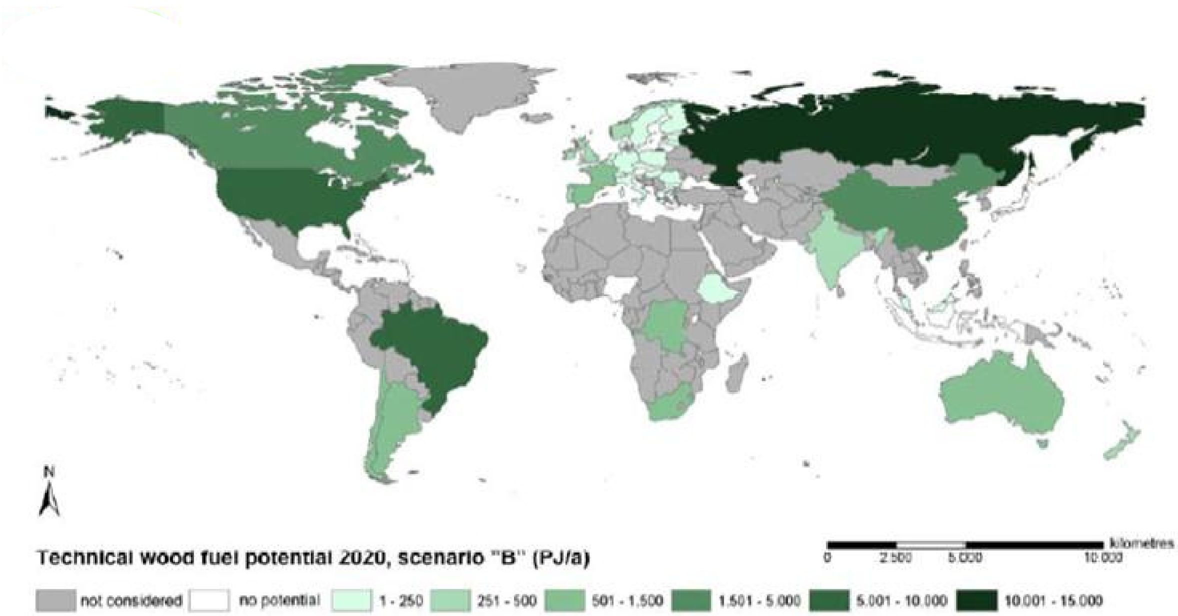



*Figure 2: Technical wood fuel potentials in year 2020. Source: DBFZ (2011)*

### 2.2.2 Agricultural residues (straw)

According to the global straw potential research done by the German Biomass Research Centre, about 783 millions of tons (dry matter) of straw were available for the use of energy in 134 countries in 2011. Straw largely comes from the cultivation of maize, sugar cane, rice and wheat, with China having by far the largest theoretical potential, followed by India, the USA, and Brazil. Figure 3 shows the technical potential of straw for the years 2003-2007.

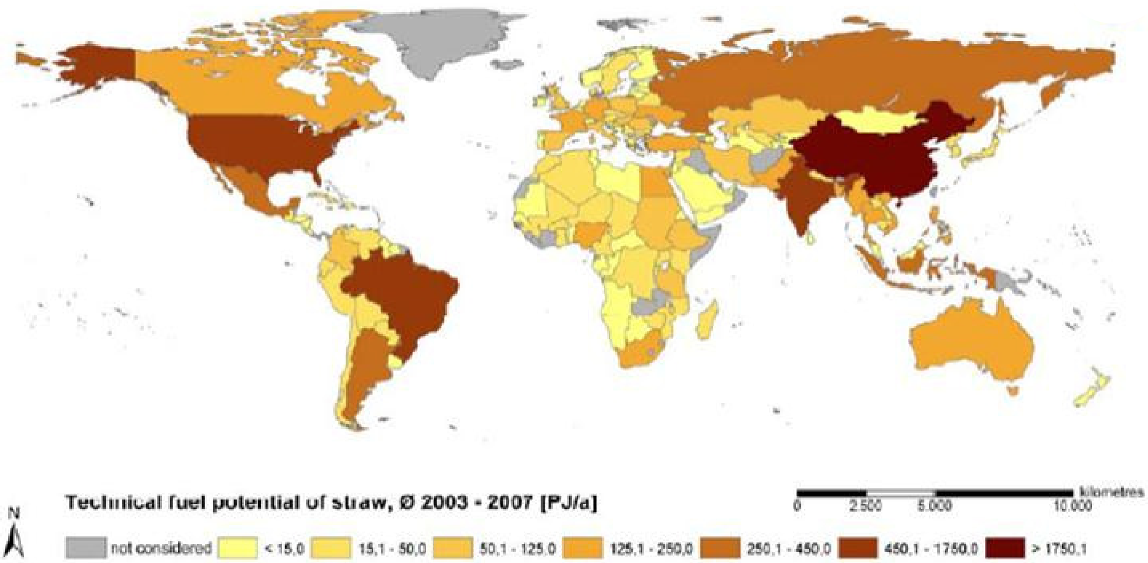



*Figure 3: Technical fuel potential of straw during the period 2003-2007. Source: DBFZ (2011)*

### 2.2.3 Agricultural biomass

The availability of agricultural biomass for producing energy depends on the future availability of areas, which are not required for food production (the so-called non-food areas). Figure 4 shows the technical potential of agricultural biomass in year 2020 around the world. This is the theoretical potential based on a set of land exclusion variables (e.g. food production should be fulfilled), non-dependent of economic, policy or society constrains.

Brazil (approx. 3,800 PJ, mainly sugar cane) and the USA (about 3,150 PJ, mainly corn) have by far the largest theoretical potentials. Both countries are already the largest ethanol producers in the world and are, therefore, relevant candidates for the production of ethanol for ATJ processes. These two countries are followed by Indonesia and Russia. Furthermore, the European Union, Canada, Argentina, Australia, Pakistan and South Africa also have large a potential for biomass crops.

All these countries have land available for the production of biomass feedstock for biojet fuels (Jatropha, Camelina, sugars for alcohol). Jatropha can grow in the more tropical areas, whereas Camelina is more suitable for the colder weather areas.

Other countries such as China, India and many others in Africa and Central America do not have surplus land due to the high demand for food.

A number of characteristics of Jatropha and Camelina are described below.

**Jatropha:** It is a non-edible evergreen shrub that produces oilseeds with 30-40% of oil content. Its lifetime is of 30 years and it is resistant to drought. It can grow on marginal land and as a hedge. However, marginal land means also marginal yields, which has impact on the profitability and its potential to produce large volumes. This effect has been in the past often not considered by Jatropha crop growers for energy uses.

**Camelina:** *Camelina sativa* has been traditionally cultivated as an oilseed crop to produce vegetable oil and animal feed. It is an edible oil crop that requires little water and fertilizer. It has a short growing season and it can be grown in rotation with wheat. Until the 1940s, Camelina was an important oil crop in Eastern and Central Europe, and it has continued to be cultivated in a few parts of Europe for its seed oil. Camelina oil was for example used in oil lamps (until the modern harnessing of natural gas, propane, and electricity) and as edible false flax oil (nutritional supplement).

HVO biojet fuel from Camelina has been approved recently (February 2013) as Renewable Fuel within the RFS2 regulation (Renewable Fuel Standard) by the Environmental Protection Agency (EPA) of the United States.

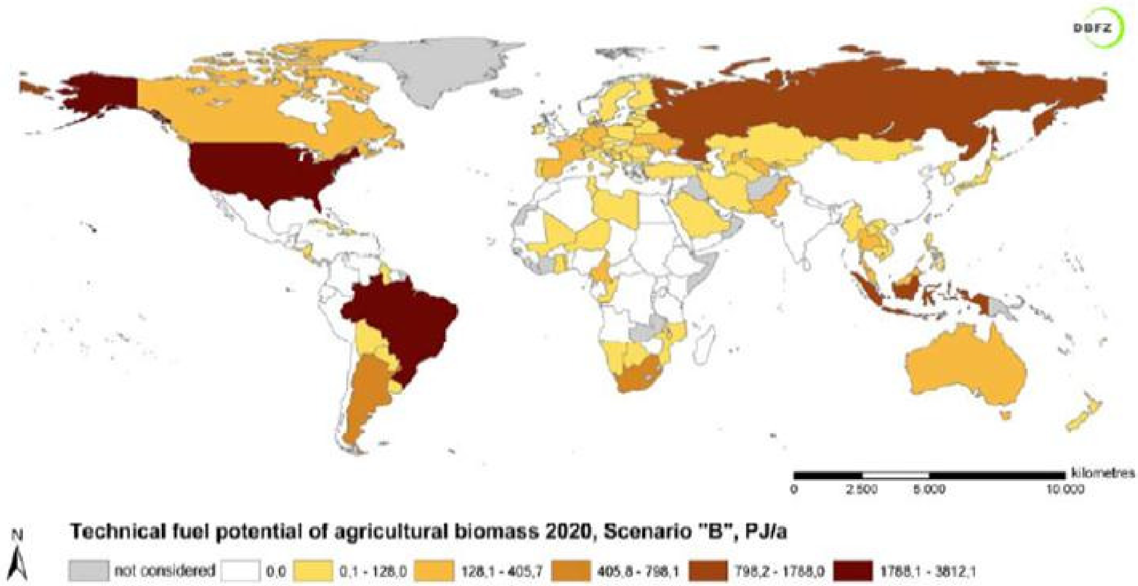



*Figure 4: Technical fuel potential of agricultural biomass in year 2020. Source: DBFZ (2011)*

### 2.2.4 Algae

Algae can grow in so-called photo bioreactors or open raceways; they can also grow on non-arable land with various water sources. Algae have high growth rates, high photosynthetic efficiency and high value co-products. Algae can be genetically modified to produce specific by-products (lipids) as a result of their metabolic activity. The economics entail a high degree of uncertainty, high capital costs, and require long-term investments. Oil extraction is complex and still faces several technical problems.

### 2.2.5 Waste and residues

Waste and residues can also be used as feedstock for the production of biojet fuels. The most viable residue for the production of biojet fuels is Used Cooking Oil (UCO) through and HEFA process. UCO is used in many businesses all around the world. It is used to feed livestock, and to make soap, make-up, clothes, rubber, detergents, and as fuel directly. Its price fluctuates greatly with the dynamics of the local markets and availability. In most countries, its collection is a sensitive subject because it is a very valuable by-product with high energy content. Most of the time the accessibility to UCO is difficult given that a few players only control the market, limit new entrants and set the market price. The US commodity market of UCO is the largest existing market for it. Most of the UCO imported to Europe comes from the USA.

Municipal Solid Waste (MSW) can also be used for the production of biojet fuels via an F-T process. However the technology for doing so is not yet mature and it is quite unclear when it will be commercially available. While the potential and geographic spread of MSW is relative high, it is complicated to unlock its technical availability for production of biojet fuels at large scale

### 2.2.6 Cost expectations feedstock

Feedstock is the largest cost item of biojet fuel production. Its share in the total biojet fuel cost may range from 50 to 90%. The cost competitiveness of biojet fuels therefore depends largely on the price of feedstock.

The cost of feedstock includes the price of raw material and its eventual pre-treatments. Transport costs from the feedstock supplier to the biojet fuel plant must be added too. Table 2 shows a selection of the wide range of variables influencing feedstock, logistics and pre-processing costs:

*Table 2: Variables influencing feedstock, logistics and pre-processing costs*

| Feedstock costs | Logistics and pre-processing costs |
|---|---|
| • Geographic origin<br>• Feedstock type<br>• Seasonality (droughts) and availability<br>• Level of mechanization and inputs<br>• Scale | • Distance<br>• Accessibility<br>• Mode of transportation<br>• Technology level<br>• Scale |

Projects and strategies to increase feedstock yields and to optimize logistics in terms of availability and infrastructure are required to ensure the provision of feedstock at competitive prices.

**Feedstock for F-T pathway**

In the case of F-T technologies, the market price of wood residues and straw varies substantially. It depends on factors such as mentioned above and, very importantly, competition by the use for other purposes. These purposes include the secondary wood industry, the pulp and paper industry, pellets and briquettes for electricity and heating, animal feed and other agricultural uses (in case of straw), and in the nearby future, also biochemistry uses such as the production of bioplastics.

According to various sources, the global average FOB price of wood residues and straw is around 90 US$/tonne; transport costs are considered to be on average 15% of the feedstock cost. These prices can be affected by the eventual large demand for these residues for the production of energy pellets.

**Feedstock for HVO/HEFA and ATJ pathways**

The impact of feedstock prices in the cost of biofuel production is most evident for the HVO/HEFA and ATJ technologies, which strongly depend on the large fluctuations of commodity prices for vegetable oils and ethanol.

Prices of Camelina oil and Jatropha oil are expected to behave very much like other vegetable oil commodities (soybean oil, rapeseed oil, palm oil) once they become produced and traded on large scale, because they will behave similar to oil markets for other competing uses as well. Different to Jatropha oil, Camelina oil is edible. Camelina oil is also well suited for use as cooking oil, and it is nowadays being researched due to its exceptionally high levels (up to 45%) of omega-3 fatty acids, which is uncommon in other vegetable sources.

Camelina and Jatropha oils will also probably replace some of the most important "food oils" (e.g. soybean oil) in non-food uses such as in the oleo-chemical industry. These competitive uses make it plausible that both oils will behave as commodities similar to the rest of vegetable oils

Prices of vegetable oils in the commodity market has ranged from 800 to 1300 US$/tonne during the past year.

Ethanol is also a commodity with competitive alternatives. Ethanol is used as fuel, as ingredient for alcoholic beverages, and as chemical base for many different organic compounds (solvents, antiseptics, etc.). The price of ethanol in the commodity market has ranged from 1500 to 2500 US$/tonne during the past year.

Commodity prices are set globally and largely dependent on macro-economic factors (welfare levels, economic growth or recession). Price spikes are often caused by unexpected unbalances in demand and supply,

The prices of these commodities are volatile mainly as they are (indirectly) indexed to oil prices, and at the same time influenced by supply and demand imbalances created in the various end user markets. Finally commodities that play a potential role in the energy markets are also impacted indirectly (through oil prices) and directly by carbon markets. At the low prices of the last few years that impact is relatively minor. However if carbon prices would at any time reach levels that enable low carbon investments, the impact can be substantial.

The price of Used Cooking Oil (UCO) has also adopted the characteristics of vegetable oil commodities. This has occurred since the European Union enforced the Renewable Energy Directive (RED). The RED considers the biofuels made out of residues at double its energy content towards the achievement of the national targets. Since then, UCO's price has jumped from 450 EUR/tonne to almost 900 EUR/tonne in 2011. (see Figure 5), basically reaching the price of the rest of vegetable oil commodities. Trade and imports of UCO is expected to keep increasing along with full implementation of double counting in all EU Member States.

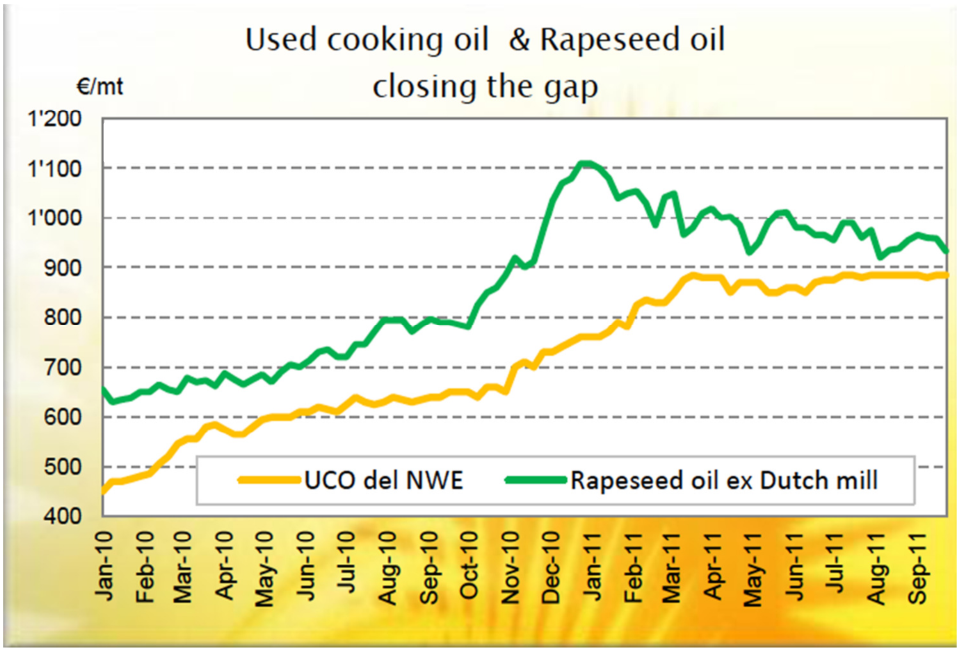



*Figure 5: Comparison of price of UCO and Rapeseed oil. Source: Kingsman*

The case of algae oil is different because of its initial phase of commercial development. The current price for algae oil for energy purposes is estimated at as high as10000 US$/tonne. Algae oil is not yet produced and commercialised in significant amounts. The general consensus is that it will take more than a decade to solve these technical issues.

## 2.3 Biojet fuel efficiencies and associated lifecycle emissions

Biojet fuels can be considered sustainable only if they have a substantially better GHG balance than their fossil alternative (jet fuel), do not harm the environment, or involve any negative socio-economic impacts. Not all biomass feedstock are fit to produce sustainable biojet fuels (see Figure 6).The type and origin of the biomass feedstock largely determines the overall sustainability of the biojet fuel, including the lifecycle of its GHG. Some types of biomass feedstock actually may cause more GHG than conventional fossil jet fuel especially when considering indirect land use change impacts.

Contrary, waste and residues produce the most sustainable biofuels. Used cooking oil for instance, can be converted into biojet fuel with 84% reduction of GHG.

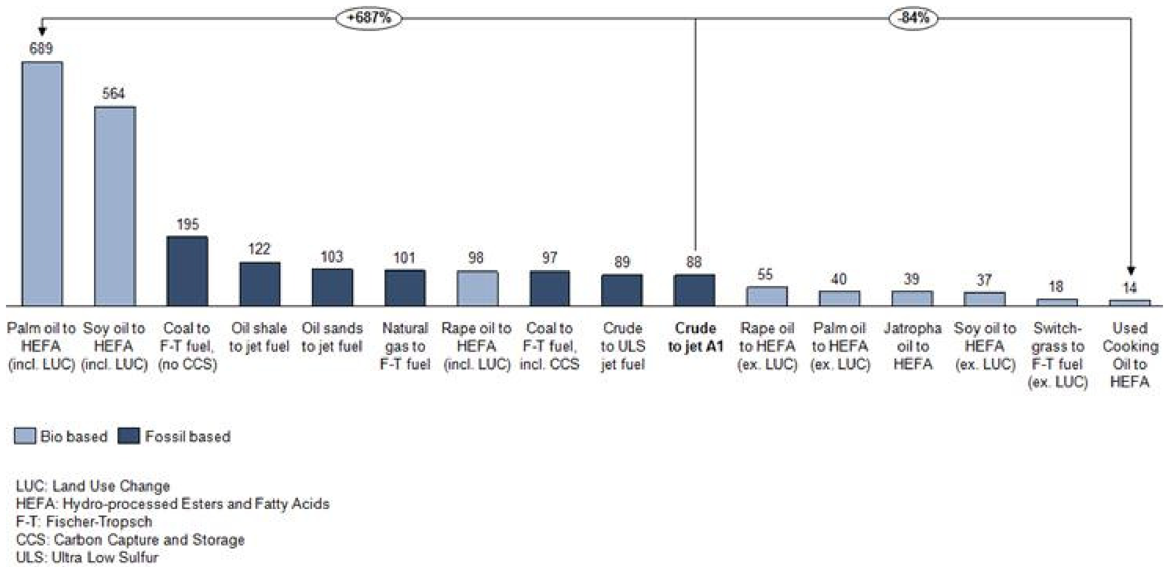



*Figure 6:* Well to Wing emissions different jet fuel production pathways ($gCO_2$/MJ), including renewable options. *Source: SKYNRG White paper on sustainable jet fuels*

Table 3 shows a summary of the emission reduction for a number of feedstock. Biojet fuels based on wastes (such as animal fat), or based on wood and agricultural residues (such as straw) have significantly lower emissions than those based on conventional oil crops. Biojet fuels from algae can potentially be carbon neutral or even produce a reduction on GHG. Note that these are general numbers; actual GHG reductions are in the end dependent on the design of each specific project.

*Table 3: Greenhouse gas emissions of biofuels for aviation. Source: E4Tech (2009)*

| Technology pathway | Feedstock | Emissions ($gCO_2$/MJ fuel) | Savings $CO_2$ vs jet fuel (baseline) |
|---|---|---|---|
| | Jet fuel (average value) | 87.5 | |
| **F-T** | Wood residues/straw | 4.8 | 95% |
| **HVO/HEFA** | Conventional oil crops (palm oil, soy, rapeseed) | 40-70 | 20%-54% |
| | Jatropha | 30 | 66% |
| | Camelina | 13.5 | 85% |
| | Animal fat | 10 | 89% |
| | Algae (from open ponds) | -21 (best case)<br>1.5 (realistic case) | 124% (best case)<br>98% (realistic case) |
| **ATJ** | Ethanol (from C6 sugar) | NA | NA |

## 2.4 Biojet fuel supply chain

The biojet fuel supply chain for the aviation sector has a number of similarities and differences compared to the biofuel supply chain for road transport. Second generation biofuels for road transport and biojet fuels may be produced in the same production plants at expense of each other. However the biofuels market for the road transport sector are largely more developed and subsidised than the market for biojet fuels for aviation. This means that production of biojet fuels can be in direct competition with production of second generation biofuels for the road transport sector. Figure 7 illustrates schematically the biojet fuel supply chain.

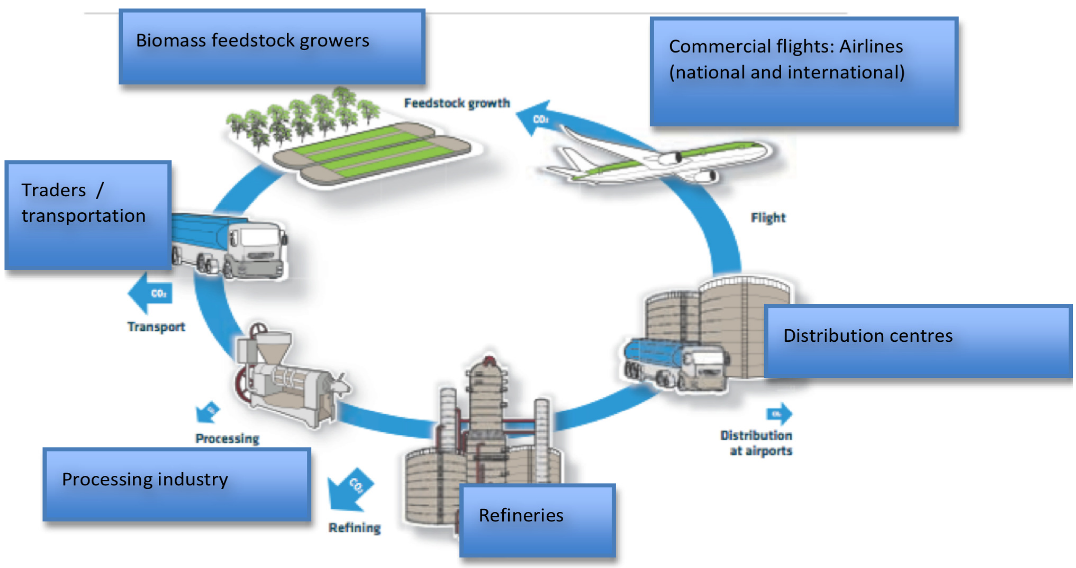



*Figure 7: Supply chain cycle of biojet fuels*

- The biojet fuel value chain starts at the feedstock grower that produces the biomass. Eventually, various on-site pre-processing steps of the feedstock are involved prior to transport. For example, on-site pre-processes include the pressing of oil seeds or chipping of wood residues. The role of feedstock producers is to grow sustainable feedstock that meets the requirements of the buyers;
- The biofuel producers buy the feedstock as input for the biojet fuel conversion. Various intermediary stakeholders, who distribute or trade the feedstock from the grower to the biojet fuel plant;
- Refineries and/or oil supply companies buy the biojet fuel from producers and refine it further if needed. The biojet fuel is a drop-in fuel, which means that a relatively small percentage is blended with jet fuel;
- Airlines buy the blended fuel from fuel suppliers usually at airports. Airlines make agreements with each airport for their use. Airlines vary from those with a single aircraft doing regional flights, to full-service international airlines. Airline services range from domestic to intercontinental;

* The role of airports is mainly to provide and maintain the depots and logistics that are needed to supply airlines with the blended fuel.

## 2.5 Ramp-up of new biojet fuel production sites

**F-T:**

* Carbo-V-technology with an annual fuel capacity of 23000 tonnes (solid biomass to fuel) commissioning 2014;
* Solena concept with an annual fuel capacity of 47,000 tonnes (waste to fuel) commissioning 2014;
* Rentech concept with an annual capacity of 70,000 tonnes (biomass to fuel) commissioning 2015.

**HVO/HEFA**

Neste Oil Oyj, under the name NExBTL, has made a large investment of 1.5 billion EUR in four HVO plants that could eventually produce biojet fuels:. Capacities are so far in a range of:

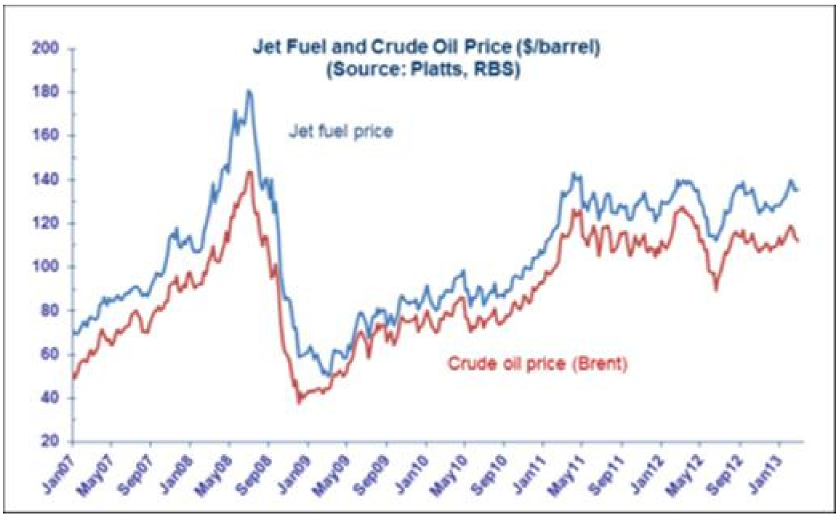
* Two plants in Porvoo, Finland, each with a production capacity of 170 KTonnes/year
* One plant in Rotterdam, The Netherlands with a production capacity of 820 KTonnes/year
* One plant in Singapore with a production capacity of 820 KTonnes/year

There are at least four other HVO plants operating: Sweden (SunPine), Ireland (Conoco Phillips), Australia (British Petroleum), and Italy (UOP/Eni Ecofining).

## 2.6 Biojet fuel price

### 2.6.1 Evolution of fossil jet fuel price

Historically, fuel costs have accounted for up to 35%[3] of airlines operating costs, and much more (even double) for low-cost carriers. Crude oil prices have been high and volatile over the past ten years. In spite of discrepancies, there seems to be an upward trend in prices of oil-based products during the last four years. The price of jet fuel has roughly doubled compared to the price in 2007.




[3] "Meeting the UK aviation target – options to reduce emissions by 2050"

*Figure 8: Evolution of jet fuel price since 2007. Source Platts, RBS*

## 2.6.2 Price forecast

In the current situation of no developed market for biojet fuels, with production only at intervals, and without any economic incentives, biojet fuels are 3 to 5 times more expensive than fossil jet fuel. Biofuel producers and airlines run their scenarios considering that incentives will disappear after some time, and that this will happen quicker when volumes increase due to any sort of obligation for example. The risk of no incentives when volume increases, is because governments may find that incentives put too much pressure on national budgets.

A different situation is expected though if up-scaling of production takes place. A recent study from June 2013 performed by the Midwest Aviation Sustainable Biofuels Initiative (MASBI) "Fueling a Sustainable Future for Aviation" has found that Under current economics and with relatively optimistic feedstock prices, the cost to produce HEFA renewable jet fuel would ranges from 4 to 6 US$/gallon. This study recognizes that this price is mainly driven by the price of feedstock. However with a variety of incentives, the price per gallon can be under 3 US$, which is cost competitive with today's refined fossil fuel products. Figure 9 shows that an economic incentive of US$ 2 per gallon of biojet fuel would be needed for bringing HEFA biojet fuel to a US$ 2.92 per gallon which is cost competitive with current fossil jet fuel price.

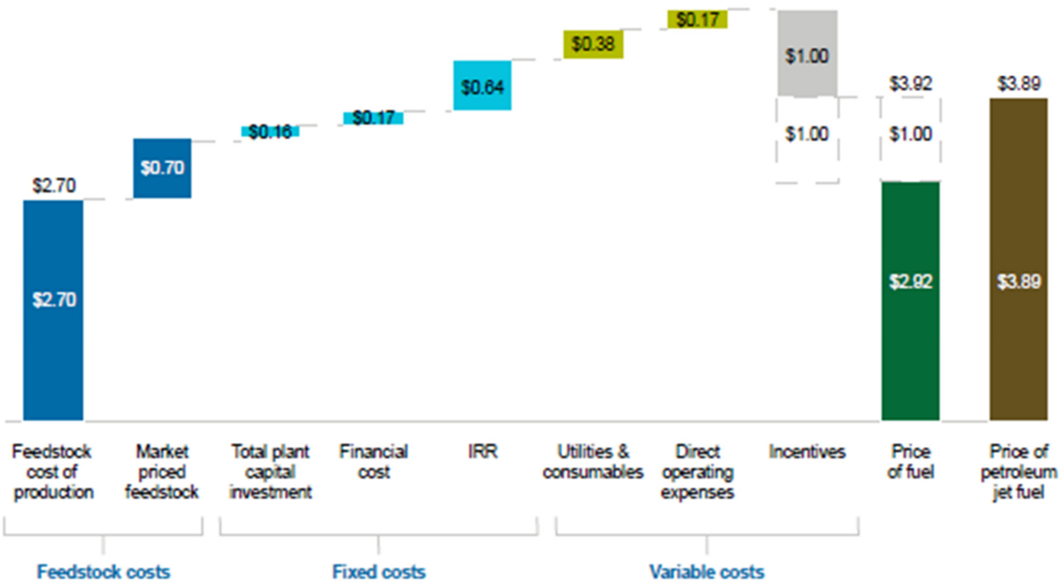



*Figure 9: Expected cost structure of HEFA biojet fuel in the United States (incentives included). Source:MASBI 2013*

## 2.6.3 Price comparison between biojet fuel and second generation biofuel for road transport

According to different interview with biofuel producers, the difference cost between biojet fuel and second generation biofuels for road transport is in the order of 10%. This price differential corresponds to the extra refining step needed to produce biojet fuel with drop-in quality. The price differential may be reduced to 5% in the next two decades of operation depending on successful up-scaling production of biojet fuel.

### 2.6.4 Links between the prices of biofuels and food

A key characteristic of the production of biobased materials for energy (including biojet fuels) is its link to both the agricultural and energy markets, and its complex dynamics in price and demand. Energy markets and agricultural markets are connected. Generally, the following three different relationships between energy and agricultural markets can be distinguished (see Figure 10):

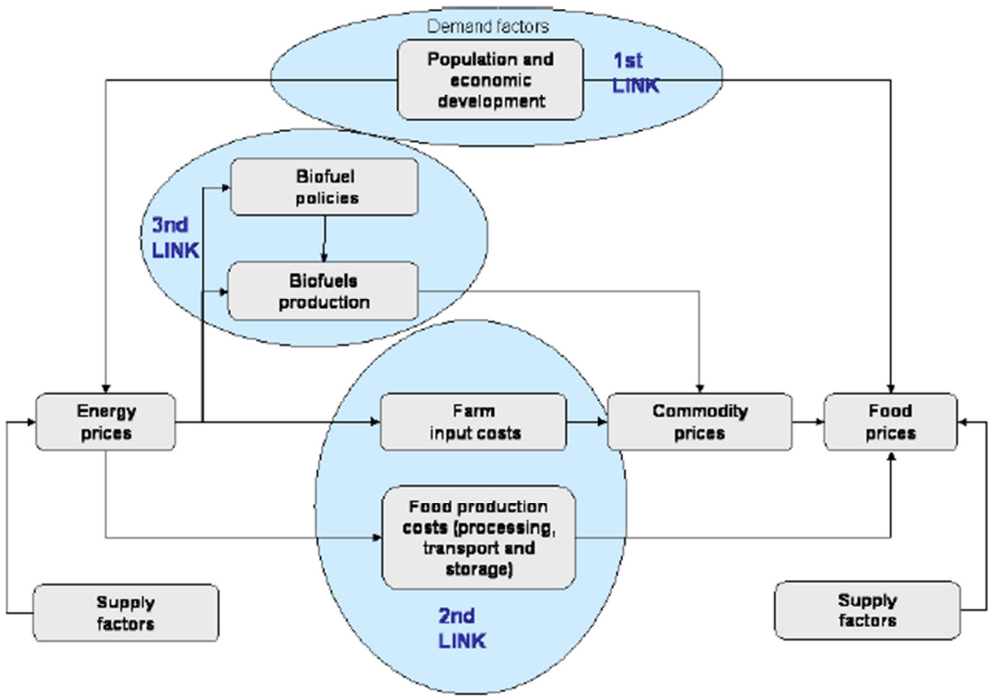



*Figure 10: Link between energy and food markets. Source LEI (2010)*

1. Link 1 includes common demand driving factors through macro-economic trends such as population growth and economic developments. Macro-economic links to the agricultural market include for example increase in food demand or dietary changes; increased energy use or demand influences the energy markets. Both markets need time to adjust for increased demand (resulting in price increases) and react on sudden demand and supply shocks explaining for example the spikes in food prices in the last years. Also, speculation plays a role in both markets;
2. Link 2: Energy as input for agricultural production (e.g. farm input costs, transportation and storage costs). Energy is a key input factor in the agricultural supply chain: a high energy price influences agricultural commodity prices. In the US agricultural sector (USDA), the energy share in total crop production expenses is for example about 15% of

which 5% is direct and 10% is indirect expenses. Energy costs affect some agricultural activities more dramatically than others: Intensive cropping production (e.g. level of mechanization) requires more energy. There is also a mitigation effect: productivity increases and increased yields mitigate the increase in higher commodity prices by energy prices.

3. Link 3: Agricultural production as input for energy sector. Biofuels production for the road transport is currently largely driven by mandates. Therefore, and because of relatively limited supply (1.5% of global transport fuel), the link between biofuel prices and energy markets is still small. The relationship between crude oil price and biofuel demand depends to a large extent on governmental interventions (incentives, mandates).

   The LEITAP model (from the Agricultural Environment Institute at Wageningen University, the Netherlands) has estimated that with a crude oil price increase of 80% in real terms, food prices will increase in the long term with about 8% (remaining below year 2000 levels), largely due to technology and productivity improvements;

   Cost of biofuels production, and its competitiveness, is also affected by the volatility of crop prices; high feedstock prices make biofuels less profitable. The demand for increased (first-generation) biofuels affects agricultural markets through direct competition with other crop uses and competition with land. Second generation biofuels can decrease the competition between food, feed and fuel. On the short term, both energy and agricultural prices may fluctuate largely as both markets are inelastic in supply. More demand than supply of biofuels, without adjustment in the market, implies an increase in agricultural prices.

## 2.7 Differences, competition and synergies with the road transport biofuels industry

### 2.7.1 Differences

There are a number of differences between the biojet fuel industry and the biofuels for road transport. The most relevant differences are:

**Maturity of the sector**

- The market for biofuels for the road transport sector has been developed for years now. Current efforts are in using the experience and inertia of an already functioning market to develop second generation technologies at a commercial level. Contrary to this situation, the market for biojet fuels is almost non-existent and therefore technology developments happen at slower pace

**International scope**

- It is a characteristic that both, biofuels and biojet fuels and their feedstock can be produced anywhere independently of their place of consumption; both products can be transported and traded internationally. The road transport consumer though, typically buys fuel in one single jurisdiction, in contrast to the aviation consumer who buys fuel at different jurisdictions due to the international dimension of flights. Different jurisdictions usually have (or will potentially have) different support mechanisms towards biojet fuels if any. This may result in large differences in the competitiveness of the industry, and in the availability and price of biojet fuels.

**Taxation**

- An additional important difference is the exemption from taxation for international (and some national) jet fuels

**Risk factor due to safety and security**

- The jet fuel supply chain has stricter quality standards than road transportation fuels because of safety reasons. In many cases, the distribution infrastructure operates at exclusivity to avoid any sort of contamination of the final product. Blending with biojet fuels is therefore a critical operation. Biojet fuels must meet these stricter quality and safety standards at the gate of the refinery plants, and they must be handled with the care to avoid contaminations before blending with jet fuels. Transporting biojet fuel from the refinery to the blender requires special transport and storage as current specifications only allow for blended product to be certified for transport in existing pipelines and other logistics infrastructure. At a first stage, while initial volumes of biojet fuel will be relatively modest, this should not represent a barrier to commercialization.
- Fuel quality monitoring needs to be properly integrated into the production chain. Strong involvement of jet fuel suppliers is needed in the production of the biojet fuel and posterior blending with conventional jet fuels in order to meet all these quality requirements. This involvement may occur via partnerships or direct participation of the refineries and/or fuel suppliers who will most likely remain responsible of the blending. Distribution operators will most likely remain responsible for supplying the blended jet fuel.

**Volumes needed per end-use facility**

- Volumes needed at (international) hub airports are much larger than volumes needed at gas stations; this implies supply chains that can handle larger volumes to a limited number of facilities. The number of stakeholders involved in the jet fuels chain is smaller and operate internationally. This all means less distribution complexities compared to distribution of road transport fuels;

### 2.7.2 Synergies and competition

The production of sustainable biojet fuels and second generation road transport biofuels can be linked. The same facilities are in many cases capable to produce simultaneously, from the same feedstock in different ratios depending on their market interest (see Figure 11).

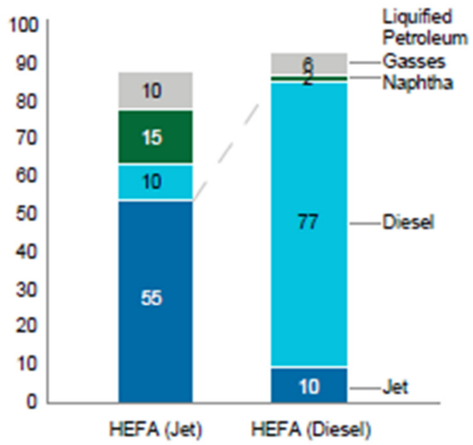



*Figure 11: HEFA production possibilities (output as a % of input weight). Source: MASBI 2013*

If price of ethanol is low enough, conventional ethanol plants could in the future add an ATJ process to produce biojet fuels as well.

This capability for participating in both production chains represents the largest synergy between both industries, but it also introduces a factor of competition. Producers will produce the product that has the highest margin with the largest guaranteed market share. The market for road transport biofuels has already developed (mainly through mandates), whereas a similar market does not exist yet for the aviation sector. The biofuels market for road transport is strongly supported by different policy instruments around the world. In the case of the European Union, this market is already pursuing towards second generation biofuels. Since the production of biojet fuels requires an extra refining step compared to second generation biofuels for road transport, the biojet fuel cost will most likely be always higher than biofuels for road transport. This means that support incentives needed for bringing prices to competitive levels are larger for biojet fuels compared to incentives needed for second generation road transport biofuels. This situation potentially affects the margins that biojet fuel producers may expect.

As major capital investments are required by both industries over the next decades, a common strategy between the automotive and the aviation biofuel sectors would be beneficial given the market demand for both products.

Different synergy aspects of both industries are worth mentioning:

- Both industries are sensitive to oil price, and carbon price if applicable;
- Some overlap exists in technology use and development, especially when focusing on advanced biofuels. Both industries also deal with similar technological and commercial challenges;
- Both industries are sensitive to the availability of feedstock and thus price and competition. Though they also can make a common strategy to produce feedstock for both sectors;
- Logistics, storage and pre-processing facilities largely overlap, especially upstream. Consequently, stakeholders coincide and participate in both supply chains;
- Sustainability requirements are expected to be the same for the upstream supply chain;

- Both industries are facing the same public perception and, in some cases, negative sentiments on biofuels (e.g. due to competition in land use and impacts on food prices and other industries).

### 2.7.3 Conversion of conventional biodiesel plants into biojet fuels plants

There is considerable excess capacity of conventional biodiesel production in Europe. The conversion process used in a conventional biodiesel facility is (completely) different than the technology pathways for the production of biojet fuels. Hence the refinery plant is of biodiesel is not directly suitable for producing biojet fuel. However, biojet fuel plants could take advantage of most of the ancillary equipment and systems.

The most promising technology pathway for the conversion of conventional biodiesel plants into biojet fuel plants is the HVO process. The HVO process produces biofuel from vegetable oils. Chemically, it entails direct catalytic hydrogenation of vegetable oils, which are triglycerides, into the corresponding alkanes. The glycerol chain of the triglyceride is hydrogenated to the corresponding C3 alkane, propane — there is no glycerol side stream. This process removes oxygen from the oil; the diesel is not an oxygenate like conventional transesterified biodiesel. Unlike the yellow transesterified biodiesel, the product is colourless paraffin, with a good cetane number (85 to 99). HVO diesel has an easier ignition and more efficient combustion, lower cloud point, better storage stability, better cold properties, less tailpipe NOx emissions, have higher renewability fraction of the fuel (97%–98% renewable mass inputs versus 90% renewable mass inputs of transesterified lipids). A drawback for the HVO process is that lubricity is in most cases poorer. Due to the chemistry of the process, the renewable diesel is pure alkane and contains no aromatics, oxygen or sulfur.

HVO plants may take advantage of most of ancillary equipment and systems from a conventional biodiesel plant. Both type of plants use vegetable oils as feedstock, therefore most of the logistics infrastructure can be saved during the conversion. Also the product distribution infrastructure would be of use, especially if the location of the production plant is convenient for the production of biojet fuels. The HVO process though, requires higher temperatures and pressures compared to the conventional transesterification processes. This means that the equipment used in the core process of a conventional biodiesel production plant cannot be converted into an HVO plant and should be newly installed.

The savings due to the re-use of the ancillary systems of a conventional biodiesel plant being converted into an HVO plant are roughly estimated to amount to about 20% of the total investment cost. Other benefits in the reconversion of plants may be the saving of jobs at plants that are threatened with closing in case of no reconversion.

# 3 Policy instruments incentivising deployment of biofuels

There are several policy instruments available to overcome investment barriers for the deployment of biofuels in general (road transport sector, aviation, etc). Some policy instruments may be less effective and require to be combined with other policy instrument to take effect, depending on the specific context of the countries. Whereas a policy instrument may be effective, the public expenditures required to achieve this might be disproportionate and therefore politically not desirable.

Decision-makers have to deal with selecting an optimal mix of policy instruments, while taking into account a wide range of considerations. They have to identify the different stakeholders associated with each investment barrier, and closely understand the various interests and bases of the barriers.

This chapter identifies and classifies policy instruments for incentivising the deployment of biofuels in general. Finally, this chapter presents an inventory of instruments already applied to support biofuels in the world.

Policy instruments that incentivise biofuels production and use can be grouped in the following categories:

1. Economic instruments
2. Command and control instruments
3. Co-regulation instruments
4. Voluntary and collaborative instruments
5.

Each of these categories of policy instruments can be applied to various stages of the value chain. The four categories include different sub-categories. In most cases, policy instruments of different subtypes and types are combined to form a policy package promoting biofuels production and consumption in a region or a country.

These are also supporting instruments such as communication and diffusion. They basically include information campaigns and marketing actions to increase public awareness of stakeholders to show the necessity of reducing carbon emissions through the use of biofuels. In terms of economic effectiveness, these supporting instruments are less powerful to start or maintain a biofuel market, but they are good for supporting the four categories of instruments described above for changing the public behaviour and reach acceptance of those changes as well.

## 3.1 Economic instruments

Economic instruments are also referred to as price-based instruments or market-based instruments. Economic instruments use market, price, and other economic variables to provide incentives for the production and use of biofuels. These instruments seek to address the market failure of externalities by incorporating the external cost of production or consumption activities.

This is done through direct incentives, subsidies, taxes or charges on processes or products, or by creating rights trading mechanisms (such as biofuel certificates trading or emissions trading mechanisms) . Economic instruments can be implemented in a systematic manner, across an economy, region or across multiple economic sectors

The costs of economic instruments are mainly paid by taxpayers or end-consumers, depending on the instrument. Tax payers pay for direct incentives, subsidies, tax exemptions and tax reliefs for instance. End consumers pay (at least partially) in case of levying specific taxes and charges to the product that is promoted as long as (part of) the cost is passed through.

The application of economic instruments is in general beneficial for starting a market from scratch; however they may become expensive to sustain when the market engages and beneficiaries are reluctant to lose the economic advantages of receiving incentives or benefiting from tax exemptions or discounts.

Economic instruments can be applied to different stages of the biofuel supply chain. A number of examples of economic instruments for incentivising the production and use of biofuels are listed below:

**Production of biomass:**

- Direct incentives: Premiums for energy crops, incentives for sustainable energy crops, support to use waste land;
- Pricing: Regulation of prices for feedstock together with guaranteeing investors and producers a minimum income;
- Funding: R&D for applicability of energy crops and crop yields, demonstration of new crops.

**Production of biofuels:**

- Direct investment and subsides for biofuel production facilities;
- Financing schemes (public loan guarantees) or low-interest rate loans for de-risking the construction of biofuel production facilities;
- Tax exemptions or tax incentives to biofuel producers for reducing the price of biofuel production (proportional to the amount of biofuel produced);
- Funding of R&D for more efficient production and new technologies;
- Tariffs and duties for the trade of biofuels.

**Distribution and supply of biofuels:**

- Tax reduction or exemptions for biofuels;
- Direct investment and incentives for logistics and distribution infrastructure;
- Financing schemes (public loan guarantees) for de-risking the construction of logistics and distribution infrastructure.
- Trading of biofuels certificates (for example RINs in the USA or Biotickets in the Netherlands)

**Final users market:**

- Carbon related taxes or other taxes on conventional fuels;

- Emissions trading systems for a sector (such as commercial aviation);
- Incentives for the purchase of biofuels-compatible vehicles, planes and machinery (or for their conversion);
- Tax incentives for biofuels-compatible vehicles, planes and machinery;
- Funding for R&D and application of high biofuel blends.

## 3.2 Command and control instruments

Command and control instruments are defined as the regulation establishing what is permitted and what is not permitted in a specific industry or activity. The command part establishes the obligations to be complied with, and the control part establishes the sanctions that result from non-compliance. Command and control instruments include direct regulation for the industry development via legislation. As the name implies, the command and control approach consists of a 'command', which sets a standard, a production obligation or consumption mandates (for example the minimum amount of biofuels blended with fossil fuels) and a 'control', which monitors and enforces the standard.

Command and control instruments can be applied to different stages of the biofuel supply chain. They may be linked to established national incorporation targets. Not all command and control instruments have the same effectiveness. Many of them are just accompanying measures to other more relevant instruments

A number of examples of command and control instruments are listed below:

**Production of biomass:**

- Making available or putting quotas on set-aside lands for the production of energy crops and non-food crops destined to the production of biofuels.

**Production of biofuels:**

- Emissions mandates through fuel quality standards. These mandates can be performance-based or technology-based. Performance-based mandates are most commonly used. They stipulate emissions limits for each economic agent (i.e. emissions benchmarks);
- Authorisation quotas for biofuel producers;
- Regulations restraining or increasing the import of biofuels or the feedstock to produce them.

**Distribution and supply of biofuels:**

- Biofuels obligations for a minimum amount of biofuels sold (either blended or pure);
- Specifying product blends that must be available in the market as product alternative offered to users;
- Blending mandates for a certain share of biofuels with fossil fuels. Blending mandates can be related to national biofuels production obligations and are measured over a period of time (usually a calendar year). Mandates can be flexible, for example with the possibility of

waving them under specific circumstances, or making them tradable among obliged parties.

**Final users market:**

- Obligations on vehicles or machinery manufacturers to produce and sell biofuel compatible models;
- Obligations for the procurement of clean vehicles.

## 3.3 Co-regulation instruments

Co-regulation refers to the recognition of industry voluntary initiatives or programs as part of the public regulation. Co-regulation is especially useful when there is a need to regulate economic activities performed across the geographic borders of different countries.

Strengths in public regulation include democratic legitimacy, applicability to all firms within a jurisdiction, and enforceability through national supervisory agencies. Weaknesses include slow development, no applicability outside the national jurisdiction and often high implementation costs for private sector parties. Private initiatives are often flexible, quick and innovative in nature; they may have an international focus and can be applied across national boundaries. Therefore the recognition of industry initiatives as part of the public regulative framework combines the strengths of industry initiatives and public regulation.

Examples of co-regulation instruments for the promotion of biofuels are:

- Governmental recognition of industry agreements setting own “obligations” for the production or consumption of biofuels.
- Governmental recognition of rules for compliance such obligations. These rules may include trading mechanisms for biofuel certificates at national or international level, and can link different sectors (aviation and road transport for example).
- Governmental recognition of industry codes of conduct or industry self-regulation.
- Negotiated support and/or penalties for the compliance of recognised obligations and recognised agreements

The use of voluntary certification systems to proof a mass balance system and sustainability criteria of biofuels targets under the European Renewable Energy Directive (RED) is an example of international co-regulation.

## 3.4 Voluntary initiatives and collaborative instruments

When sufficiently articulated and extended among industry players, voluntary and collaborative instruments may become effective private policy instruments.

The adoption of standards, codes of conduct and self-regulation by the industry, is a form of voluntary instrument (for example the adoption of ISO 14001 standards by several industries in different sectors to reduce environmental impacts). A wide adoption of these voluntary initiatives by the industry can achieve positive results over time. Those initiatives usually have no major issues in being set up internationally. Positive results are probably because the nature of these actions gives facilities incentives to make long-term efforts for better performance. In contrast, under a command-and-control approach, facilities are unlikely to make constant improvement unless regulations are modified and made stricter year after year. However the effectiveness of voluntary instruments must be in all cases considered in relation to regulations.

Voluntary instruments are often classified as "supply-push" (supporting research, development and demonstration of technologies) and "demand-pull" (changing market conditions like voluntary private procurement) instruments.

Voluntary instruments may also happen between the private and public sectors with the so called public –private partnerships (PPP). Voluntary instruments are likely to be most effective when used in synergy with or complementary to other public policy instruments.

A number of examples of voluntary initiatives and collaborative instruments for incentivising the production and use of biofuels are listed below:

**Production of biomass and production of biofuels:**

- Networking, partnerships and contracting between farmers associations and the biofuel sector;
- Agreement for R&D cooperation;
- Harmonisation and adoption of standards;
- Certification and labelling.

**Distribution and supply of biofuels:**

- Voluntary agreements with vehicle or machinery manufacturers;
- Partnerships between vehicle or machinery manufacturers and fuel providers.

**Final users market:**

- Voluntary private procurement.
- Adoption of own targets with respect to usage of biofuels and emissions reduction.

## 3.5 Inventory of existing biofuel policy instruments around the world

Our inventory shows sixty countries around the world have implemented policy instruments within their jurisdictions for promoting the deployment of biofuels, mostly for the road transport sector. The main motivations for promoting the production and consumption of biofuels are:

1. Decarbonising sector activities (mostly the transport sector);
2. Mitigating dependence on fossil fuel availability and price (fuel security);
3. Promotion of local agriculture and creation of jobs, mostly in rural areas.

These countries are grouped in this study in regions to get a better insight in the implemented policy instruments and their impacts:

1. Europe;
2. North America;
3. Central and South America;
4. Asia-Pacific, and
5. Rest of the world.

Note: Countries that are only considering policy instruments or did not fully implement them, are not taken into account in this overview.

### 3.5.1 Europe

The twenty-seven member States of the European Union have been implementing different policy instruments under the common European policy guidelines for the last decade. The impact of implementing policy instruments varies across the European Union. An overview of all policy instruments implemented in Europe is presented in Annex 1.

### 3.5.2 North America

All three North American countries have implemented policy instruments. They all have implemented instruments at federal level, and specific instruments at State or Province level. The USA has experienced the most prolific and effective legislation. Next to federal legislation, forty-five states have implemented additional packages of policy instruments promoting either the production or consumption of biofuels. An overview of all policy instruments implemented in North America is presented in Annex 2.

### 3.5.3 Central and South America

Twelve countries in Central and South America have implemented policy instruments: Argentina, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, Honduras, Jamaica, Panama, Peru and Uruguay. Argentina and Brazil are by far the largest biofuel producers in the region. An overview of all policy instruments implemented in Central and South America is presented in Annex 3.

### 3.5.4 Asia-Pacific

Nine countries in the Asia-Pacific region have implemented policy instruments: Australia, China, Fiji, Indonesia, Japan, Malaysia, the Philippines, South Korea, and Thailand. In recent years Indonesia and Malaysia have been large producers and exporters of biodiesel to the European Union market. An overview of all policy instruments implemented in the Asia-Pacific region is presented in Annex 4.

### 3.5.5 Rest of the world (includes Middle East and Africa)

Additionally, nine other countries have implemented policy instruments: India and Sri Lanka in South Asia, and Ethiopia, Kenya, Malawi, Nigeria, South Africa, Zambia and Zimbabwe in Africa. An overview of all policy instruments implemented in these countries is presented in Annex 5.

# 4 Effects of policy instruments in selected case studies

Several countries have implemented for more than a decade policy instruments for the promotion of biofuels, mainly for the road transport sector. However, not all countries implementing policy instruments have entirely met their targets. This chapter focuses on the effectiveness of policy instruments for the promotion of biofuels for road transport in countries that have achieved significant progress in the production and consumption of biofuels. The effectiveness of policy instruments (or a combination of them) is measured by the relevancy achieved by these countries in meeting their own targets, either as producers or as consumers. This analysis is done focusing on road transport biofuels, since this sector has similarities to that of biojet fuels.

## 4.1 Top global players

Biofuels make a small but growing contribution to fuel use in road transportation worldwide. They provided about 3% of global road transport fuels in 2011. More than 75% of all biofuels is produced in two countries, the USA and Brazil[4]. Ethanol production represents 80% of the world's total biofuel production, whereas biodiesel accounts for 20%. However, biodiesel production has been growing in recent years in contrast to ethanol. The global annual production of ethanol remained stable at around 86 billion litres in 2010 and 2011. In the same period, the global annual production of biodiesel increased from 18.5 billion litres to 21.4 billion litres. This is mainly due to the effects of policy instruments mostly addressed to the promotion of biodiesel in the European Union and in the United States. The world's top fifteen producers of ethanol and biodiesel in 2011 are shown in Table 4.

The largest producers of ethanol in the world are the United States and Brazil, followed at a large distance by China, Canada and France. The US produces ethanol from corn, and Brazil from sugar cane.

The production of biodiesel is more homogeneous among top producing countries. The European Union is the largest producer and consumer of biodiesel, with Germany and France contributing collectively with 52% of the total production within the European Union. The United States, Argentina, Brazil and Indonesia each have an annual production of more than 1 billion litres. Most of the feedstock for biodiesel production is imported, in contrast to ethanol where most of the feedstock is produced indigenously. Argentina and the US are the biggest exporters of feedstock for soybean oil. Indonesia, Malaysia, Thailand and Peru are the most relevant exporters for palm oil.

In 2011, international trade of ethanol accounted for only 3% of the total ethanol produced in the world; in the same year, international trade of biodiesel accounted for 38% of the total world's biodiesel production. International trade figures of biofuels are presented in Table 5 and Table 6.

The most important trade flow for ethanol was between EU Member States (63% of total international trade), followed by trade between Brazil and the United States (13% of total international trade).

[4] REN 21 2012 report

Trade figures for biodiesel are largely different. Trade within EU Member States reached in 2011 fifty 9% of total international trade. Imports from Argentina and Indonesia to the European Union reached in the same year twenty and 15% respectively.

*Table 4: Biofuel production in top 15 countries in 2011. Source REN 21 report*

| Country | Fuel Ethanol | Biodiesel (billion litres) | Total |
|---|---|---|---|
| **United Sates** | 54.2 | 3.2 | 57.4 |
| **Brazil** | 21.0 | 2.7 | 23.7 |
| **Germany** | 0.8 | 3.2 | 3.9 |
| **Argentina** | 0.2 | 2.8 | 3.0 |
| **France** | 1.1 | 1.6 | 2.7 |
| **China** | 2.1 | 0.2 | 2.3 |
| **Canada** | 1.8 | 0.2 | 2.0 |
| **Indonesia** | 0.0 | 1.4 | 1.4 |
| **Spain** | 0.5 | 0.7 | 1.2 |
| **Thailand** | 0.5 | 0.6 | 1.1 |
| **Belgium** | 0.4 | 0.4 | 0.8 |
| **The Netherlands** | 0.3 | 0.4 | 0.7 |
| **Italy** | 0.0 | 0.6 | 0.6 |
| **Colombia** | 0.3 | 0.3 | 0.6 |
| **Austria** | 0.2 | 0.4 | 0.6 |
| **World Total** | 86.1 | 21.4 | 107.0 |
| **EU Total** | 4.3 | 9.2 | 13.5 |

*Table 5: International trade figures for ethanol (million litres). Source: REN 21 report 2012*

| Exporter | Importer | Volume |
|---|---|---|
| **Brazil** | United States | 325 |
| **Canada** | United States | 36 |
| **El Salvador** | United States | 225 |
| **Jamaica** | United States | 109 |
| **Trinidad and Tobago** | United States | 46 |
| **Brazil** | EU-27 | 49 |
| **Egypt** | EU-27 | 28 |
| **Guatemala** | EU-27 | 17 |
| **Pakistan** | EU-27 | 23 |
| **Peru** | EU-27 | 19 |
| **Russia** | EU-27 | 12 |
| **United States** | EU-27 | 18 |
| **EU-27** | EU-27 | 1.572 |

*Table 6: International trade figures for biodiesel (million litres). Source: REN 21 report 2012*

| Exporter | Importer | Volume |
|---|---|---|
| **Argentina** | EU-27 | 1.611 |
| **Canada** | United States | 103 |
| **EU-27** | EU-27 | 4.812 |
| **EU-27** | Norway | 34 |
| **EU-27** | United States | 40 |
| **Indonesia** | EU-27 | 1.225 |
| **Norway** | EU-27 | 96 |
| **United States** | EU-27 | 133 |
| **United States** | Norway | 26 |
| **United States** | Canada | 10 |
| **United States** | Taiwan | 28 |
| **United States** | Israel | 10 |
| **United States** | Malaysia | 8 |
| **United States** | Australia | 6 |
| **United States** | India | 50 |

## 4.2 The United States

### 4.2.1 Legal framework and policy instruments

To accelerate the use of biofuels, the US Congress established the Renewable Fuel Standard (RFS) under the Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007 (EISA) with the aim of encouraging the blending of biofuels into the national fuel supply chain. In 2010, a new version of the standard (RFS2) was established in collaboration with refiners, renewable fuel producers, and many other stakeholders.

The RFS2 is a volumetric standard with the objective to increase biofuel use in the US to 36 billion gallons (136 billion litres) by 2022. It also includes new sustainability criteria for both renewable fuels and for the feedstock used to produce them.

The US Environment Protection Agency (EPA) determines yearly the volume of cellulosic biofuel that will be produced for use in transportation for the following year. Each year, the obligated parties (refiners, importers of gasoline and diesel, and blenders) are required to meet volumetric targets. The RFS2 compliance program is based on the use of unique Renewable Identification Numbers (RINs) assigned to batches of renewable fuel by their producers and importers. RINs are used by obligated parties to demonstrate compliance with the applicable standard. They can be sold and traded within the US.

The RFS2 defines biojet fuels explicitly in its standards and recognises Camelina based biofuel as an RFS2 advanced biofuel.

Additionally to the volumetric mandates, the US has implemented different federal financial incentives that have fixed periods of validity. The impacts of these financial incentives are constantly monitored to decide on their extension and/or modification. A brief description of these tax incentives is given:[5]

1. *Cellulosic biofuel producer tax credit:* A cellulosic biofuel producer that is registered with the US Internal Revenue Service (IRS) may be eligible for a tax incentive in the amount of up to 1.01 US$ per gallon of cellulosic biofuel when produced in the US and:

   a) Sold and used by the purchaser in the purchaser's trade or business to produce a cellulosic biofuel mixture;

   b) Sold and used by the purchaser as a fuel in trade or business;

   c) Sold at retail for use as a motor vehicle fuel; used by the producer in a trade or business to produce a cellulosic biofuel mixture;

   d) Used by the producer as a fuel in trade or business.

   If the cellulosic biofuel also qualifies for alcohol fuel tax credits, the credit amount is reduced to 0.46 US$ per gallon for biofuel that is ethanol and 0.41 US$ per gallon if the biofuel is not ethanol. The incentive is allowed as a credit against the producer's income tax liability. This tax credit expires end 2013.

2. *Special depreciation allowance for cellulosic biofuel plant property:* A taxpayer may take a depreciation deduction of the adjusted basis of a new cellulosic biofuel plant in the year it is put in service. Any portion of the cost financed through tax-exempt bonds is exempted from the depreciation allowance. The credit is available to any enzymatic cellulosic ethanol plant acquired after end of 2006, and placed in service before 2013. The incentive is possibly extended through 2013.

3. *Alternative fuel mixture credit:* The alternative fuel mixture credit is the product of 0.50 US$/gallon and the number of gallons of alternative fuel used by the taxpayer in producing any alternative fuel mixture for sale or use in trade or business of the taxpayer. These credits are scheduled to expire end 2013.

4. *Alternative fuel infrastructure tax credit:* A tax credit is available for the cost of installing alternative fuelling equipment placed into service after 2005. Qualified alternative fuels are natural gas, liquefied petroleum gas, hydrogen, electricity, E85, or diesel fuel blends containing a minimum of 20% biodiesel. Fuelling station owners who install qualified equipment at multiple sites are allowed to use the credit towards each location. Consumers who purchase residential fuelling equipment may also receive this tax credit of up to 1,000 US$. The credit will expire end 2013.

**Policy instruments at State level**

US states are free to implement additional policy instruments applicable to their jurisdiction. Several states have done so; mostly financial incentives, and in a number of cases they have also established product blend mandates. These financial incentives combine incentives for de-risking the investment in new production facilities, tax exemptions, tax discounts to final users, credits and direct incentives for constructing and testing advanced fuel plants.

[5] http://www.ethanolrfa.org/pages/tax-incentives

State instruments may increase the competitiveness of biofuel producers in specific states, and thereby influencing outcomes in other states as well. Annex 6 describes the policy instruments for a selection of eight of the most relevant states in the biofuels industry: California, Illinois, Iowa, Louisiana, Minnesota, Nebraska, South Dakota and Texas.

### 4.2.2 Effects analysis

Flexibility has been an important characteristic of the implementation of policy instruments for the promotion of biofuels in the USA. In most cases, the combination of policy instruments shows a well-designed and effective mix of incentives, mandates, escape clauses, and implementation mechanisms. Volume mandates and federal financial incentives are constantly monitored (usually on an annual basis) and modified to enhance their effectiveness.

Figure 12 shows the evolution of volume mandates as established by the EISA. Mandates are not independent of each other but hierarchical in nature. The US Environmental Protection Agency (EPA) revises the specific mandates each year and has the authority to waive a mandate if it is technically unfeasible or economically not viable for the industry to provide it. This is especially important for the success of the most advanced biofuels that are only at the small-scale experimental stage.

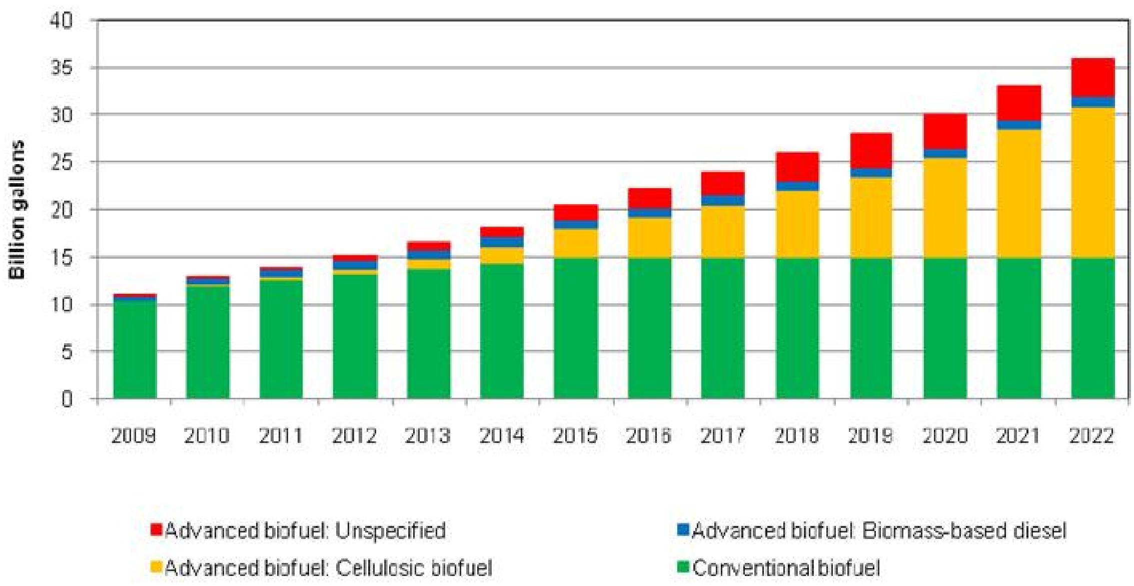



*Figure 12: RFS2 volume by fuels category. Source US EPA (2010)*

Financial incentives for biofuels in the US are specific in their objectives and target group. Because of the different vintages of these incentives, they were created with a specific duration of validity. It is often presumed by the biofuel industry that such incentives will be extended, but this is neither automatic, nor granted. For example, from 1978 through 2004, the federal government provided payers of federal excise taxes on motor fuel with a tax credit for the amount of ethanol blended with gasoline. This was a growing direct subsidy. Due to concerns about the loss of federal revenues for transportation purposes, the tax credit was replaced in 2005 with a federal tax refund to blenders of motor fuel. Then a tax credit for cellulosic ethanol was introduced and the ethanol tax credit was reduced. Still in fiscal year 2009, tax credits for biofuels reduced federal revenues by about 6 billion US$.

The combined effect of incentives and mandates in the US on volumes of biofuel is shown in Figure 13.

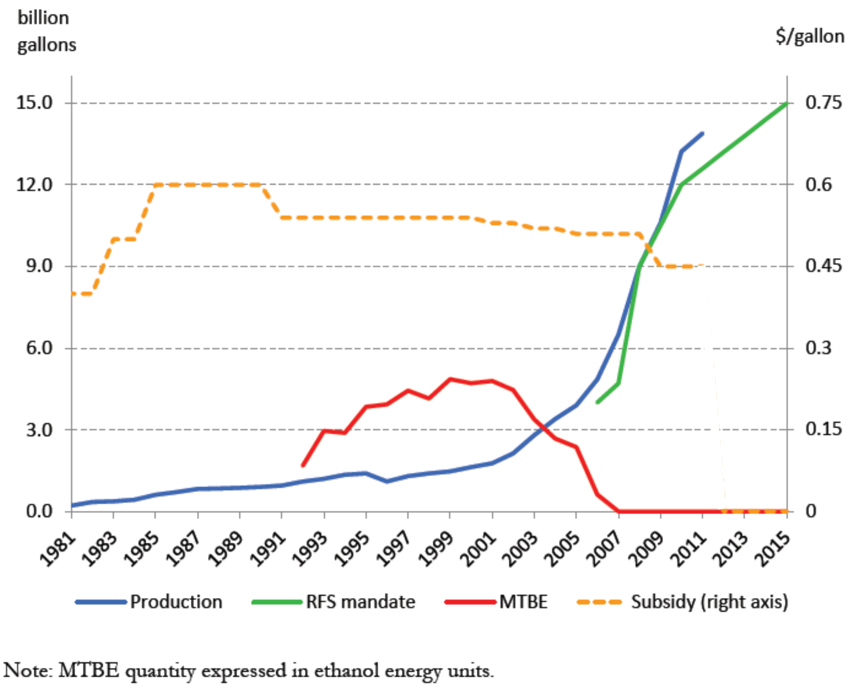



*Figure 13: Evolution of incentives and mandates for ethanol in the US. Source: Moschini (2012)*

This mix of policy instruments has resulted in a more than doubling of consumption, production and installed capacity of ethanol since 2006 in almost a perfect match (see Figure 14). The United States does not import ethanol and exports just a fraction of its production.

For the case of biodiesel, consumption was constant until 2010 when it more than tripled in one year. Production has grown along with consumption. Installed capacity stopped growing in 2009, since when it stayed just about constant (see Figure 15).

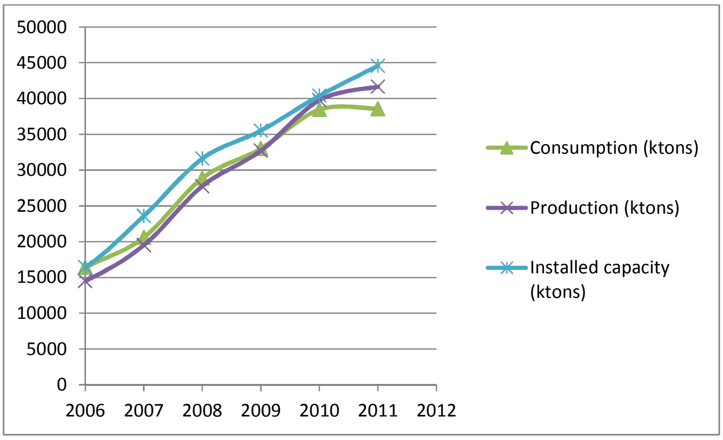



*Figure 14: Ethanol evolution in the USA (2006-2011). Source: EIA and Alternatives Fuel Data Center*

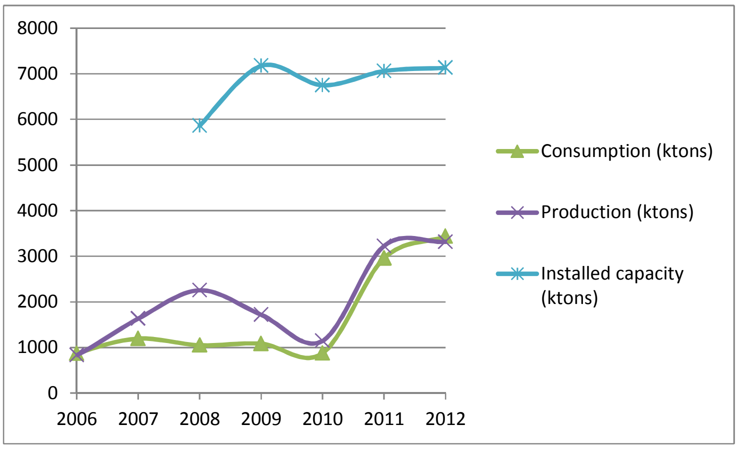



*Figure 15: Biodiesel evolution in the USA (2006-2011). Source: EIA and Alternatives Fuel Data Center*

Numerous studies have simulated how the American market would behave under differing market conditions. When petroleum prices are relatively high, mandates (when combined with the right tax credits) are not binding and have little impact on the market outcomes. In this case, prices of petroleum, ethanol, and corn are closely linked and the blender's tax credit increases demand for biofuels, which translates into higher prices for biofuel and the feedstock from which it is produced. When petroleum prices are low and mandates are binding, the mandate is critical to the quantity of transactions, and prices of petroleum and the feedstock are not so closely linked. In fact, the mandates have seldom been binding except from Fall of 2008 to the Spring of 2009 when petroleum prices were low.

For the more advanced biofuels, the current mix of conventional fuel prices, biofuel production costs, tax credits, and mandates, will make the quantity of biofuels produced fall short of the mandated amounts. In the future, the scheduled increase in mandated volumes would require biofuels to be produced in amounts that are probably beyond what the market would produce even if the effects of the tax credits were included.

## 4.3 The European Union

### 4.3.1 Legal framework and policy instruments in place

Four European Directives are relevant for the promotion of biofuels in transport within the European Union:

- The 2003 Biofuels Directive [Directive EC 2003/30/EC] sets an indicative target of 2% of biofuels to be used in the transport sector by 2005 and of 5.75% to be reached by 18 May 2010;
- The 2003 Energy Taxation Directive [Directive 2003/96/EC] allows Member States to reduce or exempt excise duties on biofuels;
- The 2009 Renewable Energy Directive [Directive 2009/28/EC] repeals the 2003 Biofuel Directive and sets a mandatory target for 10 % renewables in the transport sector;
- The 2009 Fuel Quality Directive [Directive 2009/30/EC] sets a mandatory 6% decarbonisation target for the suppliers of transport fuels.

The Biofuels Directive of 2003 supported a growth of biofuels production and consumption in the European Union. The Renewable Energy Directive (RED) of 2009 shapes the European market for biofuels until 2020 by adding sustainability requirements to all biofuels computed to meet the EU target of 2020. Under the current EU policy framework, Member States have to meet a 10% energy target from renewable sources (such as biofuels) in the transport sector by 2020.

The support for bioenergy in the European Union was also incorporated into the Common Agricultural Policy (CAP) in 1992, e.g., by introducing in 2004 an energy-crop premium of EUR45/ha on a maximum of 2.0 million ha of set-aside land. With the 'Health Check' reform of 2007, the energy-crop premium and the compulsory set-aside were abolished from 2009 onward. The CAP is currently being revised.

The support for biofuel consumption in the EU Member States is often a combination of a blending mandate with tax exemptions. Those combined are the two most common instruments implemented in the EU Member States. In few instances, only one of these two instruments is used (see Table 7).

Biojet fuels are not explicitly considered in the RED, but not explicitly excluded either. In other words this means that if biojet fuel is not included in Member States' regulation, there is no means to get it accounted. The Netherlands is the first EU country introducing recently the possibility of voluntary registration (so called opt-in) for biojet fuel. This option enables biofuel suppliers to use their biojet fuel activities (except biofuel for road transport, biogas and electricity from renewable source) for meeting their renewable targets, as long as the biojet fuel market remains a niche market. Once registered, the supplier has to meet the blending target first before oversupply can be used for tradable biotickets. Dutch biotickets are tradable biofuel rights among companies, used to comply with Dutch biofuel mandates. Biotickets are not attached to the physical biofuel consignments. The Bioticket mechanism hereof is similar to tradable emission rights. Those who produce or blend additional biofuel – in addition to the obligatory amount – can sell this excess to those who have difficulty producing or blending the obliged amount.

*Table 7: Summary type of instruments in EU MS. Source: Ecofys report "Financing renewable energy in the EU)*

| Member State | Biofuels Quota Obligation | Intermediate Target (2010) | Tax Exemption | Other Support |
|---|---|---|---|---|
| **AT** | Yes | 5,75%[6] | Yes[7] | - |
| **BE** | No | 5,75%[8] | Yes[9] | - |
| **BG** | Yes | 5,75% | No | - |
| **CY** | Yes | 2% (biofuels);<br>2,5% (transport) | Yes | - |
| **CZ** | Yes | 3,5% (ethanol);<br>4% (diesel)[10] | Yes[11] | |

[6] 2009 target. http://ec.europa.eu/energy/renewables/biofuels/doc/member_states_reports_directive_2003_30_ec_2009.zip

[7] Bioethanol 442 (normal: 475) €/1000litres with a least 44 litres of biofuel/1000 litres; Biodiesel 347 (normal: 375) €/1000litres with a least 44 litres of biofuel/1000 litres; Bioethanol 0 (normal: 475) €/1000litres 100 % biofuel; Biodiesel 0 ((normal: 375) €/1000litres 100 % biofuel; Bioethanol 0 ((normal: 475) €/1000litres With a bioethanol content of at least 65% and at most 75% by volume from 1 October to 31 March (autumn and winter) and of at least 75% and at most 85% by volume from 1 April to 30 September (spring and summer)

[8] Biodiesel: 380,000 litres. Bio-ethanol: 250,000 litres

[9] Tax levels: Diesel: 0.33 €/litre; B5: 0.31 €/litre; PPO: 0 €/litre; Gasoline 0.59 €/litre; ETBE15: 0.55 €/litre

[10] 2009 target

[11] Only for B31

| Member State | Biofuels Quota Obligation | Intermediate Target (2010) | Tax Exemption | Other Support |
|---|---|---|---|---|
| **DE** | Yes[12] | 5,75% | Yes[13] | Yes[14] |
| **DK** | Yes | 0,75%[15] | Yes[16] | Yes[17] |
| **EE** | No | - | Yes | - |
| **ES** | Yes | 5,83% | Yes | - |
| **FI** | Yes | 4% | No | Yes[18] |
| **FR** | Yes | 7% | Yes[19] | - |
| **GR** | No | 5,75% | Yes | - |
| **HU** | No | 5,75% | Yes[20] | Yes[21] |
| **IE** | Yes[22] | 4% | Yes | Yes[23] |
| **IT** | No | 5,75% | Yes[24] | - |
| **LT** | Yes | 5,75% | Yes | Yes[25] |
| **LU** | Yes | 5,75%[26] | Yes[27] | - |
| **LV** | Yes[28] | 5,9% (ethanol); 5,8% (diesel) | Yes | Yes[29] |
| **MT** | No | 5,75% | Yes | - |
| **NL** | Yes | 4% | No | Yes[30] |
| **PL** | Yes | 5,75% | Yes | Yes[31] |
| **PT** | Yes[32] | 5,75% | Yes | - |
| **RO** | Yes | 4% | Yes | - |
| **SE** | No[33] | 10% | Yes | Yes[34] |
| **SI** | Yes | 3%[35] | Yes | - |

[12] 6.25% overall biofuel quota, based on energy content

[13] Ruled out by 2013/2015. E5/ETBE are equally taxed as gasoline. Tax level 2010: Diesel: 0.47 €/litre; B100: 0.27 €/litre; PPO: 0.26 €/litre

[14] BTL fuel projects support in 2008 was 10 € million

[15] 5.75% target put forward to 2012

[16] Exemption on CO2 tax

[17] 200 million DKK is available for 2nd generation biofuel demonstration projects in the period 2006-2010

[18] In spring 2007, Tekes – the technology and innovation development centre – launched BioRefine – New biomass products technology programme. The programme began in 2007 and will run until 2012.

[19] Tax on biofuels increases annually, in 2012, it will be equal to excise on gasoline and diesel

[20] 8.3 HUF/litre tax deduction

[21] Support programmes for biofuel factories

[22] From 2010

[23] Additional: National Energy Crop Premium

[24] Tax levels: Diesel: 0.41 €/litre; Biodiesel: 0.29 €/litre; Gasoline: 0.56 €/litre; Bioethanol: 0.29 €/litre

[25] Pursuant to the Regulations for financing the development of the production of biofuels for transport, LTL 26.6 million (EUR 7.7 million) was appropriated for the development of biofuel production from the national budget, and 118 580 tonnes of rapeseed (crop area of 59 290 ha) and 78 300 tonnes of cereal grain (crop area of 26 181 ha) were purchased for biofuel production in 2008

[26] Indicative Target set by the European Biofuels Directive from 2003

[27] No tax exemption for blended fuel but a pollution tax (1.200 EUR/1000 litres) for not reaching the target value of 2% in 2007. Tax exemption of 100% for pure biofuel (B100/E100) consumed on the Luxembourg territory

[28] Introduced at the end of 2009

[29] Reduced permit costs for warehouse keepers and traders

[30] Besides the tax incentives, towards the end of 2006 the Dutch cabinet earmarked grants totalling sixty million EUR for projects in the field of innovative biofuels that yield a significant reduction in CO2 emissions. This scheme has been extended to run until 2010. Companies that intend to invest in projects focusing on innovative or improved production of biofuels for transport and will incur extra costs for reducing CO2 emissions may qualify for grants. Besides investment projects, the programme also supports projects for applications or uses that reduce CO2 emissions in transport. 2006-2010

[31] Several research (PLN 2.78 million in 2008) and development (PLN 13.435 million, in 2008) projects are supported

[32] Quota for FAME in diesel

[33] Only for larger filling stations

[34] The development of second-generation biofuels will be supported and SEK 875 million will be earmarked between 2009 and 2011 for the commercialisation of new energy technology, including biofuel demonstration plants

| Member State | Biofuels Quota Obligation | Intermediate Target (2010) | Tax Exemption | Other Support |
|---|---|---|---|---|
| **SK** | Yes | 5,75% | Yes | - |
| **UK** | Yes | 3,5%[36] | Yes[37] | Yes[38] |

Apart from the general market measures, several EU Member States have implemented other support measures to specific sectors, such as:

1. Additional measures for farmers other than set aside land or energy crop payments in Belgium, Greece, Ireland, Lithuania, and Poland (direct input subsidy for fertilizers, feed, energy, water, transportation, etc.);
2. Additional measures for the biofuel industry in Cyprus, Czech Republic, Latvia, Lithuania, and Poland in order to reduce the infrastructure costs, e.g., investments in renewable fuel plants;
3. Measures for biofuels distribution in the United Kingdom;
4. Measures for purchase and maintenance of cars, that can use larger blends of biofuels, in Austria, Belgium, Cyprus, Denmark, Estonia, Ireland, Malta, Poland, and Sweden.

The European Union and its Member States have continued to foster research and development activities via various programs. Special focus has been on projects concerning second-generation biofuels. Total funding was estimated to be at least EUR 63 million and EUR 68 million in 2007 and 2008, respectively. Although substantial, this number is relatively small compared to the estimated support of EUR 2.8 billion in 2008 through exemptions for fuel excise tax (GSI, 2012).

**Expected policy changes**

In October 2012, the European Commission has proposed to amend the Renewable Energy Directive (RED) and the Fuel Quality Directive (FQD) in relation to sustainable biofuels and bioliquids.

The general objective of the proposed amendments is to promote advanced biofuels that will help achieve substantial emission reductions and which do not directly compete with food production and are more sustainable at the same time. The specific objectives of the proposal are fourfold:

- Cap the contribution from conventional biofuels made from food crops to 5% while keeping the national 10% renewable energy target in the transport sector by 2020;
- Improve the GHG performance of biofuels by raising the GHG savings required to biofuels produced in new installations to 60% (as of 1 July 2014). This means that production of biofuels from all food crops will in principle not be allowed in new installations;
- Encourage a greater market penetration of advanced biofuels by allowing multiple-counting of such fuels towards national targets;
- Improve the reporting of GHG emissions with the reporting of the estimated indirect land use change (ILUC) emissions of biofuels.

The proposal intends to give a strong message to the biofuel industry to move towards non-food crop based biofuels. The proposal also stresses that existing investments should be protected until

[35] Obligation for distributers are set at 5% (energy content) in 2010

[36] Target for 2009/2010.

[37] In the form of a duty incentive

[38] Refuelling Infrastructure Grant Programme

2020 and does not take a position on the actual need for financial support to biofuels before 2020. However, the Commission is of the view that in the period after 2020 food-crop based biofuels should no longer be subsidised if they do not result in substantial GHG savings (including emissions from ILUC). This amendment will result in a strong support for advanced biofuels that are produced sustainably. The European Council and the European Parliament will both have to approve these amendments. The process started in early 2013 and will probably be concluded in 2014. Until then, uncertainty remains about the content of the proposal. From then, only six years remain to achieve the targets for advanced biofuels, which is limited time considering the innovations needed to commercialize its technologies.

**The EU Emissions Trading Scheme (EU-ETS) for Aviation**

The European Commission (EC) adopted in 2005 a Communication entitled "Reducing the Climate Change Impact of Aviation"[39]. The goal of this Communication was to start a discussion on the internalisation of the environmental costs of aviation within the EU-ETS. The need to support R&D focusing on the "greening" of air transport was stressed, together with the mitigation potential of the use of biojet fuels. The improvement in air traffic management was mentioned as option to increase air traffic efficiency and at the same time decrease aviation's overall fuel consumption. The wider application of energy taxation to fuel for commercial aviation was also discussed as option to internalise aviation's environmental costs and reduce GHG emissions. In this Communication, the EC concluded that the combined effect of these measures alone would not be sufficient to offset the growth in air traffic emissions. While there is a clear roadmap to attaining aircraft fuel efficiencies and air traffic management improvements, biojet fuels pricing remains a significant barrier. Therefore, the integration of the aviation within the EU-ETS, set up in 2003[40], was considered as the most cost-efficient and environmentally effective option for controlling and reducing GHG emissions from the aviation industry.

The Commission established the legal framework for this integration through Directive 2008/101/EC after assessments of various policy options[41]. All flights arriving and departing from EEA airports (27 EU MS, Norway, Iceland and Lichtenstein) are covered by the EU-ETS until their first stop[42]. Table 8 presents the key design elements of the integration of the aviation sector within the EU-ETS.

In order to reduce emissions under the ETS, airlines can also use biojet fuels, and count these towards achieving their reduction targets. The biomass fraction and hence the emissions, are determined using fuel purchase records. Airlines must keep track of all biojet fuel purchased and include this in their Annual Emissions Reports. Sustainable biofuels will have zero-rating – meaning that these biofuels will be considered to have zero emissions. The sustainability of biofuels is determined under the EU RED, concerning the sustainability requirements for the production of biomass and biofuels. Thus, only sustainable biofuels can be counted towards targets at a zero-rating.

[39] COM (2005) 459 final. "Reducing the Climate Change Impact of Aviation".

[40] Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for GHG allowance trading within the Community and amending Council Directive 96/61/EC

[41] Directive 2008/101/EC of the European Parliament and of the Council of 19 November 2008 amending Directive 2003/87/EC so as to include aviation activities in the scheme for GHG allowance trading within the Community.

[42] Small aircrafts (under 5.7 tonnes maximum take-off mass), state, military, rescue, emergency, visual flight rules and training flights, and commercial air transport operators with less than 2 flights per day or emitting less than 10 000 tonnes of CO2 per year are exempted (EEA. 2012).

*Table 8 EU-ETS and Aviation – Quick facts. Source: EEA. 2012. "Greenhouse gas emission trends and projections in Europe 2012 – Tracking progress towards Kyoto and 2020 targets"; and IETA. 2012. "EU-ETS and Aviation"*

| **EU-ETS and Aviation: Quick facts** | |
|---|---|
| **The cap** | Cap (% of the baseline):<br>2012: 97%<br>2013-2020: 95%<br>Sizes the total quantity of allowances allocated to the aviation sector |
| **The baseline** | Is based on annual average historic emissions from 2004 to 2006, namely: 221.4 Mt CO2 for all participating countries[43]. |
| **The benchmark** | Is used to allocate the free of charge allowances to the operators;<br>Is calculated by dividing the total cap by the sum of tonne-km data provided by the operators in 2010;<br>The benchmark is set at:<br>0.6797 allowances/1000 tonne-km in 2012;<br>0.6422 allowances/1000 tonne-km in 2013-2020. |
| **Free allocation (predominant method of allocation)** | The amount of free allowances for a certain operator is calculated by multiplying the benchmark with the 2010 tonne-km data of the operator;<br>The operators will receive for free:<br>• 85% of the calculated allowances in 2012<br>• 82% in 2013-2020 |
| **Auctioning** | 15% of the remaining allowances will be sold by auction. |
| **Special reserve** | From 2013 onwards, the remaining 3% of the cap will be set aside in a special reserve for:<br>• New entrant operators performing aviation activity after the monitoring year;<br>• Existing operators that increase tonne km by an average of more than 18% annually between the monitoring year and the second calendar year of the period. |
| **Use of stationary allowances** | Aircraft operators may use aviation allowances and stationary allowances while stationary installations are not allowed to use aviation allowances for compliance. |
| **Offset use** | Airline operators can additionally use credits from flexible mechanisms<br>In 2012: up to 15% of their verified emissions;<br>2013-2020: the final quantity is to be determined but it will not be below 1.5% of verified emissions. |

The EU-ETS has ran internationally into fierce resistance, especially in the US and China. In parallel to these developments at EU level, the International Civil Aviation Organisation (ICAO) therefore aims to develop a global agreement to tackle aviation's growing GHG emissions. In the perspective of waiting an ICAO proposition for a market-based instrument, the EU adopted on 24 April 2013 a Decision[44] (the so-called "Stopping the clock" Decision) until September 2013, to exclude international flights – operating to and from the EU – temporarily from the EU-ETS. The legislation continues to apply to all flights within and between the 30 EEA countries, plus Switzerland and the new EU Member State Croatia. The EC made clear that the following key

[43] Commission Decision 2011/149/EU of 7 March 2011 on historical aviation emissions pursuant to article 3c(4) of Directive 2003/87/EC of the European Parliament and of the Council establishing a scheme for GHG allowance trading within the Community.

[44] Decision No 337/2013/EU of the European Parliament and of the Council of 24 April 2013 derogating temporarily from Directive 2003/87/EC establishing a scheme for GHG allowance trading within the Community.

elements[45] should be included in ICAO's proposition. If not, the EU-ETS would be re-established and apply to external flights:

- It must deliver aviation emission reductions at least as big as those within the EU-ETS (including aviation in the EU-ETS is forecast to save around 176 million tonnes of $CO_2$ emissions by 2015[46]);
- It must be non-discriminatory for all airlines;
- It must contain targets and measures for ICAO member countries.

Currently, the EC expects that ICAO will agree on an immediate and meaningful applicable framework with national and regional market-based mechanisms and a realistic timetable for a global market-based mechanism, as well as an ambitious set of technological and operational measures.[47]

### 4.3.2 Effects analysis

Despite the extended use of blending mandates within the European Union (EU), production of biofuels varies greatly among Member States. This is partly explained by the large imports of biodiesel or feedstock from other world regions, and the notion that free trade and short distances within Europe encourage intra EU trading. About 30% of ethanol and 52% of biodiesel consumed by EU Member States are imported from other Member States. To prevent this, some countries (Belgium, France, Italy, Ireland, Portugal, and Spain) apply a quota mechanism where the amount of biofuels benefiting from the support is shared amongst different suppliers through calls for tender. This means that the right to supply biofuels is allocated through licenses to either domestic or European firms. This mechanism allows national governments to specify the amount of supplied biofuels each year.

The scale of the impacts of mandates depends on different factors such as whether it is accompanied by tax exemptions in the respective Member State, and whether competition from imports is allowed. Contrary to the well-structured and monitored financial incentives strategy in the USA, different approaches to tax reductions are used in the EU Member States in which biofuels blending is mandatory: Some countries provide full tax exemption for biofuels, others only partial or none.

Overall though, consumption, production and installed capacity in the European Union have been growing consistently for many years. However, most countries did not reach the 2005 and 2010 general targets (see Table 7), with exception from Germany and Sweden. Figure 16 shows the development of ethanol during the period 2006-2012, and Figure 17 shows this for biodiesel.

Ethanol shows relatively constant trends for both consumption and production in the European Union. However installed capacity increased at a higher rate from 2006 to 2010, creating an overcapacity. The European Union hardly exports any ethanol beyond the Member States. Biodiesel experienced the same trend but to a larger extent. Production capacity quadrupled between 2006 and 2010 whereas the consumption only grew with a factor of 2.5 in the same period. Production of biodiesel has been lagging behind consumption since 2007; illustrating an increasing competition with biodiesel imported from other regions as Argentina or Malaysia. These

[45] http://ec.europa.eu/clima/policies/transport/aviation/index_en.htm
[46] http://ec.europa.eu/clima/policies/transport/aviation/index_en.htm
[47] http://greenaironline.com/news.php?viewStory=1681

graphics show that the mix of blending mandates with non-homogeneous, well-structured financial incentives were effective only in promoting the construction of new biofuel production facilities. They were, however, not effective enough in making they produce because of the relatively high costs compared to importing countries.

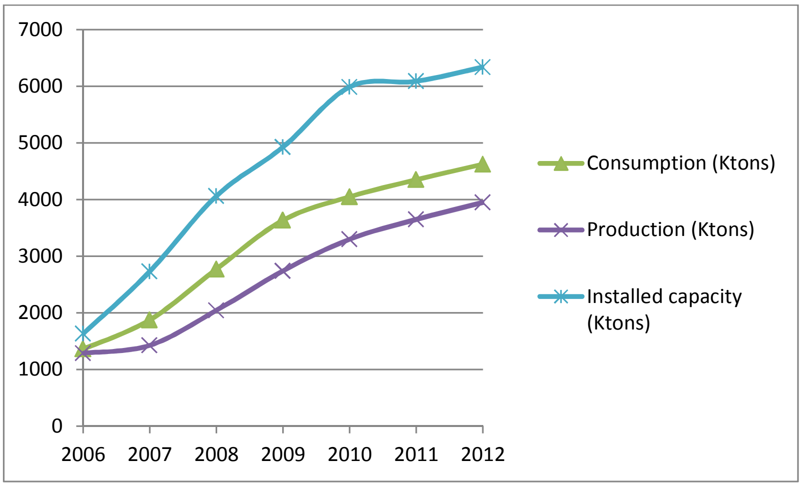



*Figure 16: Ethanol evolution in the EU (2006-2012). Source: Eurostat–GAIN reports*

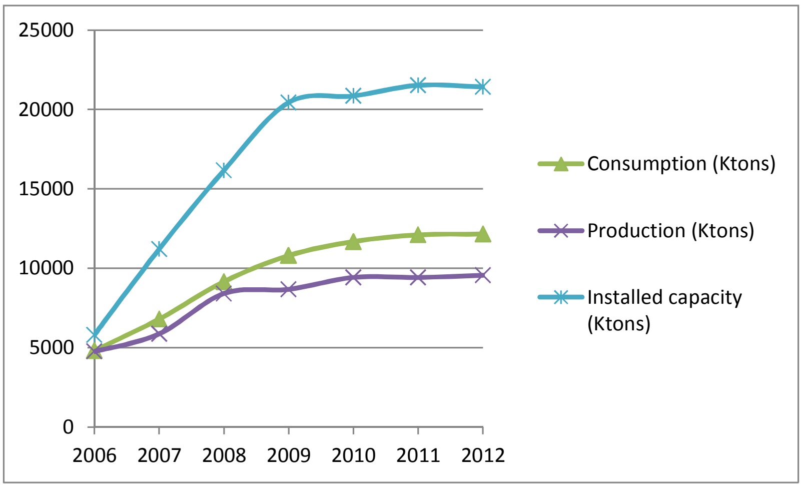



*Figure 17: Biodiesel evolution in the EU (2006-2012). Source: Eurostat–GAIN reports*

Tax payments of EU consumers for the mandated use of biofuels can be roughly estimated at EUR 13 to 16 billion per year over 2010-2011 (representing about 4.5% of EU road fuel use). About EUR 2 to 3 billion worth of biodiesel and approximately EUR 0.5 billion worth of ethanol were purchased from outside the European Union. While the rest of biofuels were produced in the EU, much of the feedstock was imported. Benefits of the economic development of this sector therefore only partially come back to the European taxpayer.

The proportions between imported and nationally produced biofuels vary considerably among EU-27 countries. For instance, in Spain the share of biodiesel imported from Argentina and Indonesia was estimated as 89% of domestic consumption in 2011 (APPA Biocarburantes, 2012).

Further along the value chain, the EU biodiesel industry purchased around EUR 3.5 to 4.5 billion worth of crop feedstock from EU farmers: approximately 80 to 90% of this value was paid for rapeseed and the rest for sunflower seeds, soybeans and some other indigenous feedstock. The biodiesel industry also uses recycled vegetable oil and tallow as feedstock. At the same time, the EU biodiesel industry also imported about EUR 3 to 4 billion worth of feedstock such as palm oil, soybean oils, and oilseeds.

Thus, due to the purchasing of foreign biofuels and feedstock only about a half, if not less, of the value of biofuel sales in the EU market went to the EU farmers growing feedstock crops as it is shown in *Figure 18* where biofuel related cash flows are explored, together with the effect of the EU biofuel policies on EU farmers.

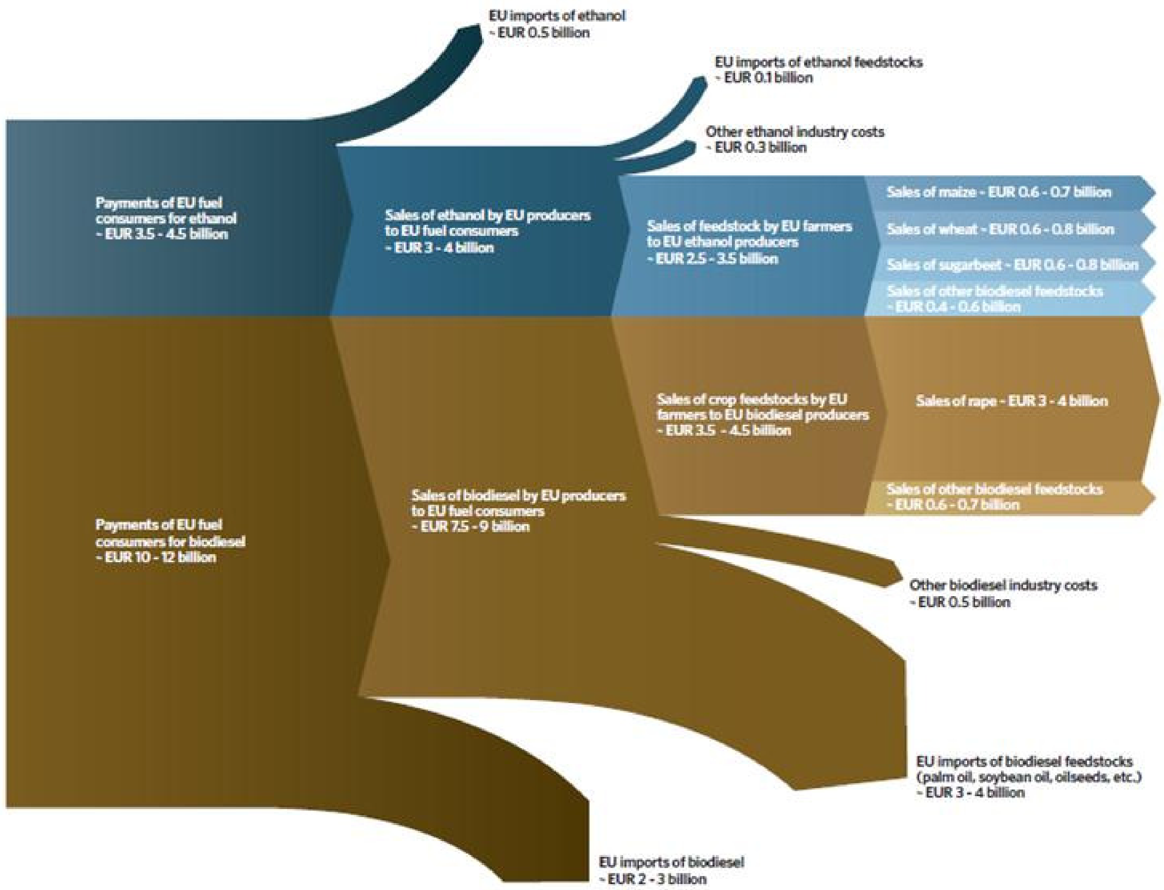



Figure 18 *Biofuel related cash flows in the EU. Source: GSI (2013)*

## 4.4 France

### 4.4.1 Policy instruments

A combination of two types of policy instruments have been implemented in France throughout the time: tax exemptions, and mandatory blending requirements. The current combination in place is:

- Blending mandates for ethanol and biodiesel. The quota of biofuels to be blended within conventional fuels is defined for each fuel type. Companies are obliged to pay a higher tax rate on polluting activities, in case they do not meet the quota;
- Tax reduction for E85 (blending) is set at 17.29 EUR/hl; other biofuels at 14 or 8 Euro/hl;
- Partial tax exemption of the Domestic Consumption Tax (TIC) for biodiesel and ethanol, and full exemption for pure vegetable oils used as fuel in agricultural and fishing. Exemption only applies to biofuels produced by units approved after a call for tenders published in the Official Journal of the European Union;
- Further tax exemptions scheduled for 2013 are 14 EUR/hl for ETBE; 14 EUR/hl for ethanol; 8 EUR/hl for biodiesel; 14 EUR/hl for EEHV; 8 EUR/hl for EMHA/EMHU; and 8 EUR/hl for biodiesel (synth.).

### 4.4.2 Effects analysis

France established the 5.75% market share for biofuels for 2008. This was gradually increased to 7% for 2010, and to 10% for 2015. The target for 2009 was set at 6.25%, and real consumption reached 6.04% (6.27% biodiesel and 5.24% bioethanol). E10 blends (SP95-E10) have been gradually distributed and sold in France from 2009 onwards. E85 is also sold on the French market. Concerning biodiesel, B7 is on the market since 2009. Currently France has approved B30 blending for captive fleets and the B30 standard for municipal vehicle fleets.

Production quotas are set according to the market shares to be reached. For biodiesel this started with 417.000 tonnes for 2005, increased annually to 2.728.000 tonnes in 2009. For ethanol, these quotas rose from 561.000 tonnes in 2007 to 1.091.000 tonnes in 2009.

Blending mandates are combined with tax exemptions in France. Tax exemptions enable the compensation for the extra manufacturing costs of biofuels compared to fossil fuels. It only applies to biofuels produced by units having been approved after a call for tenders published in the Official Journal of the European Union. This exemption amounted to 500 million EUR for 2007, 720 million EUR for 2008 and 521 million EUR for 2009. The amounts are adjusted each year in the Finance Law to take into account the development of economic conditions. The 2009 Finance Law therefore sets the unit amounts (EUR/hl) of the tax exemption until 2011, with a progressive decrease in the tax exemption, with a view to an eventual reform following the recasting to come from Directive 2003/96/EC on energy taxation.

Further tax exemptions that are scheduled through 2013 are 14 EUR/hl for ETBE; 14 EUR/hl for ethanol; 8 EUR/hl for biodiesel, 14 EUR/hl for EEHV, 8 EUR/hl for EMHA/EMHU, and 8 EUR/hl for biodiesel (synth.).

This mix of policy instruments resulted in a consumption increase of ethanol of 30% in 2011. Production of ethanol followed the consumption growth. Installed capacity is relatively excessive as it almost twice as high as the actual production (see Figure 19).

For biodiesel, consumption quadrupled from 2006 until 2009. Installed capacity has grown at the pace needed in this period. Consumption and production of biodiesel has stabilised since then (see Figure 20).

In the case of France, the mix of mandates and tax incentives for the promotion of biodiesel resulted in an effective combination to incentivise its production and consumption.

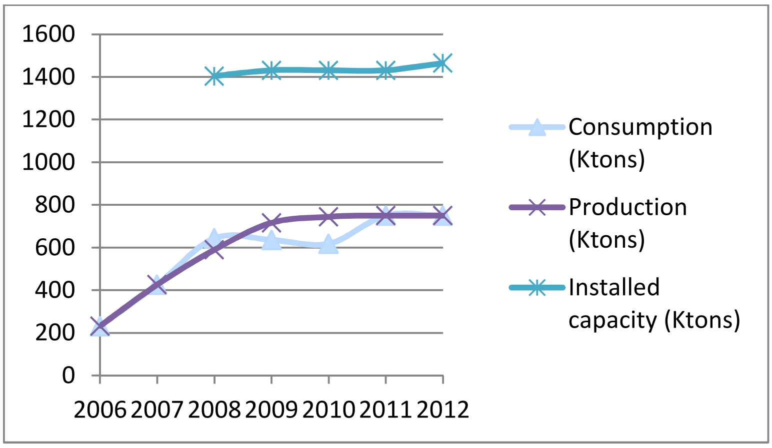



*Figure 19: Ethanol evolution in France (2006-2012). Source: Eurostat–GAIN report*

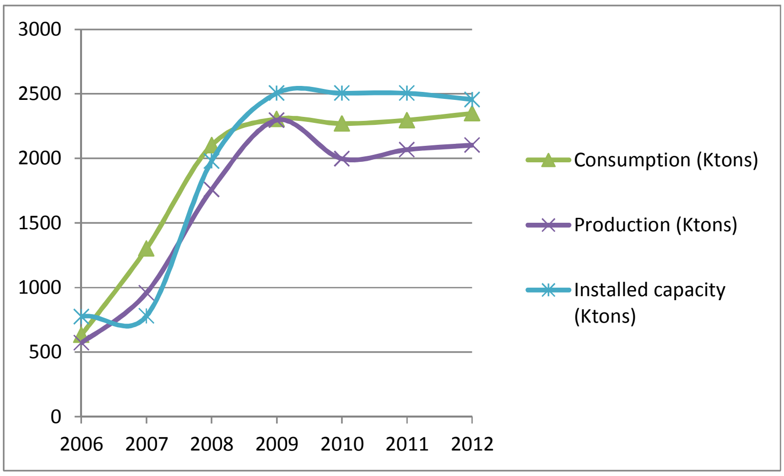



*Figure 20: Biodiesel evolution in France (2006-2012). Source: Eurostat–GAIN report*

## 4.5 Germany

### 4.5.1 Policy instruments

Different combinations of three types of policy instrument have been implemented in Germany throughout the time: tax exemptions, incentives to activities, and mandatory blending requirements. They are analysed in the following paragraphs. Currently the policy instruments in place are:

- Hybrid quota system with blending mandates for biodiesel and ethanol;
- Quota obligation (quota is allocated in terms of energy). Support is mainly established by the blending mandate. The mechanism obliges companies to ensure that biofuels contribute to a certain percentage of the company's total annual sale of fuels (petrol, gas or diesel) as set out in the Biofuel Quota Act. Fuel suppliers may assign this obligation to other companies. The biofuel quota will be preplaced by a greenhouse gas reduction quota in 2015;

- Standard excise taxes on fuel, applied to all biofuels (in blended or pure form) that are used to meet the quota, except for second-generation biofuels. The fuel duty for petrol and diesel amounts to EUR 65.45 cent per litre and EUR 47.04 cent per litre, respectively (Energy Tax Act §2);
- Full tax exemption to second-generation biofuels (BtL, lignocellulosic ethanol), biogas and ethanol (in the form of E85) until 2015;
- Tax relief for pure biofuels only when they are not used to meet the quota. Since 2010 the reduced excise tax rates for pure biodiesel (B100) and vegetable oil are set at EUR 18.60 cents per litre and EUR 18.50 cents per litre, respectively;
- Greenhouse gas reduction quota will be introduced in 2015. Accordingly, the allowed share of greenhouse gases discharged from diesel and gasoline is being reduced in form of a quota, meaning that the usage of biofuel is only indirectly stimulated. By 2015, emissions have to be reduced by 3%, by 4.5% from 2017 on and by 7% from 2020 onwards.

Other financial incentives in Germany are incentives for R&D activities and agricultural subsidies[48].

- Incentives for R&D activities: Germany's government grants funds for research and development (R&D) supporting the biofuels sector through the Agency for Renewable Resources (FNR). Since the launch of the Renewable Resources aid scheme up to June 2010, around EUR 50 million has been provided for 90 biofuel R&D projects.
- German R&D support has gradually shifted towards the promotion of biojet fuels, providing incentives for its deployment at e.g. Lufthansa. The German and United States governments have signed an agreement in September 2012 to cooperate on further development of alternative aviation fuels, while strengthening the relationship between the Commercial Aviation Alternative Fuels Initiative (CAAFI) and its German equivalent AIREG[49].
- Indirect subsidy to feedstock producers through the Single Payment Scheme: Biofuel feedstock production benefits from agricultural subsidies under the Single Payment Scheme (SPS). Payments to farmers under the SPS are independent from production and thus do not incentivize the cultivation of feedstock for biofuel production.

### 4.5.2 Effects analysis

Germany is Europe's leading biodiesel producer. In the initial phase of government support to biofuels, Germany granted extensive tax exemptions for biofuels in order to stimulate market growth. Due to the substantial fiscal support provided to the pure biodiesel market (B100), the industry's production base expanded significantly. Government support for biofuels led to rising costs to the government's budget. In 2006 the fiscal costs resulting from the tax exemptions for biofuel and heating oil made from biomass peaked at EUR 2,144 million (see Figure 21).

[48] Biofuels - At what cost? Mandating ethanol and biodiesel consumption in Germany, 2012
[49] http://www.greenaironline.com/news.php?viewStory=1590

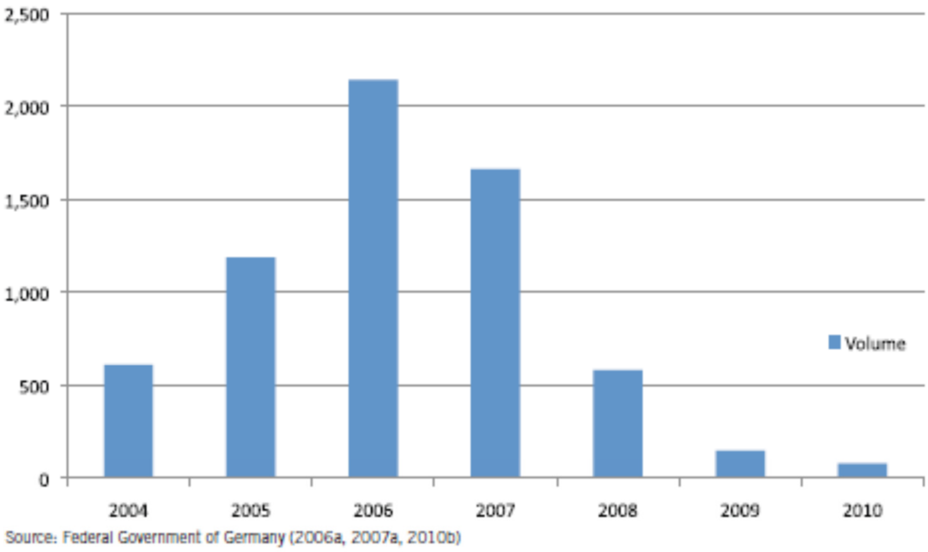



*Figure 21: Tax exemptions in Germany. Source: Federal Government of Germany*

In response to this, Germany currently employs a hybrid quota system: it grants a tax relief for pure biofuels if they are not used to meet the quota. The biofuels used to fulfil the quotas are levied with the statutory tax rate except second-generation biofuels, which are tax-exempt.

As a result, there are currently lower direct fiscal costs associated with the German government's biofuel support policies, because Germany employs a mix of policies to stimulate the biofuels market. The shift away from supporting the biofuels industry through the use of tax incentives and the adoption of blending mandates had a negative impact on the markets for 100% biodiesel fuel and vegetable oil. It resulted in a temporary overall decrease of biodiesel consumption.

All these changes in the mix of policy instruments have had important impacts in the biofuel industry. Since 2008, no more significant investments have been made for ethanol production. Production of ethanol consequently also stopped growing since 2009. Consumption of ethanol surpassed the production capacity in 2009. Hence imports of ethanol increased to cover the gap between production and consumption (see Figure 22).

In the case of biodiesel, blending mandates have been increasing yearly since 2007, but overall consumption has slightly decreased since 2007. This is explained because of the switch from pure biodiesel consumption to mainly blend fuels consumption. Despite policy changes, installed capacity increased strongly between 2006 and 2008, though this excess capacity was not yet needed (see Figure 23).

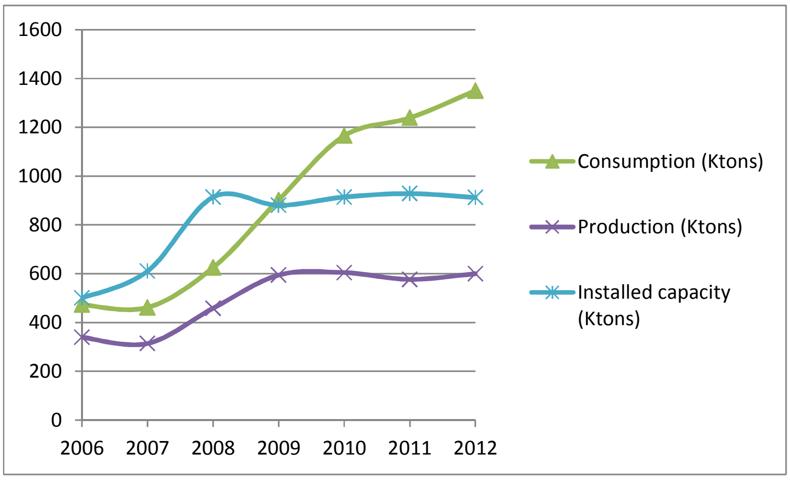



*Figure 22: Ethanol evolution in Germany (2006-2012). Source: Eurostat–GAIN report*

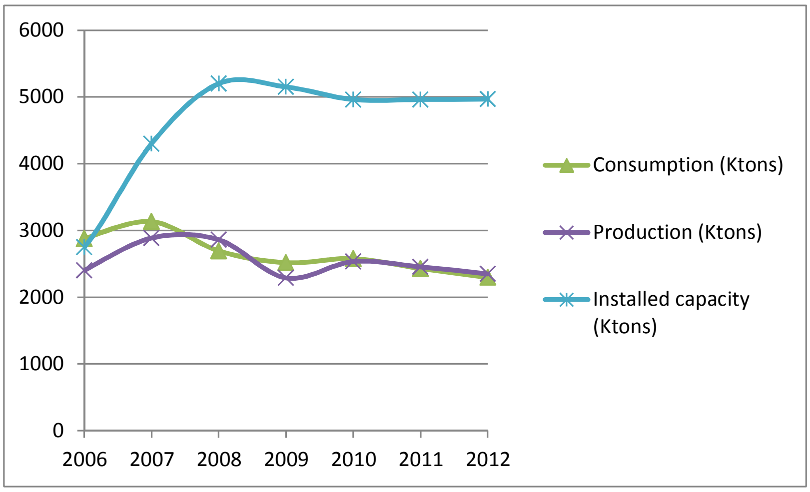



*Figure 23: Biodiesel evolution in Germany (2006-2012). Source: Eurostat–GAIN report*

The additional biofuel production costs of biofuels in 2020 are estimated to be between EUR 1,374 million and EUR 2,153 million. These costs are being shifted almost completely to the private sector through the blending mandates. Given the inelasticity of demand, at least in the short term, it appears likely that higher costs of biofuels will be passed on to consumers.

## 4.6 Argentina

### 4.6.1 Policy instruments

The policy instruments in place in Argentina are:

- Product blend mandates (E5 and B7);
- Biofuel producers for the domestic market benefit from the choice of reimbursement of VAT or accelerated depreciation on capital investments;

- The export tax on biodiesel was raised this year to 32% from 20% to make it equal to the export tax on soybean oil export tax. A required internal reference price for biodiesel was also adjusted to US$4,405.30 pesos/ton (approx. US$ 958 per ton), a 15% drop from the previous mandate[50];
- The government guarantees that the biofuel producer's output will be entirely purchased over the course of the Biofuel Law's term, which is 15 years. Biofuels governed by this promotional regime will be exempt from three taxes on fossil fuels.

### 4.6.2 Effects analysis

Argentina ranks today as the world's third largest producer of biodiesel. It is also the largest soy oil exporter and the largest soy producer overall, to be used for various end-uses as food, feed or fuel.

A mix of policy instruments to increase production of the soybean fields, and with that also increase the production of biodiesel have been implemented as of 2006 and 2008 (for ethanol), primarily covering fiscal incentives, export taxes and product blend mandates. This resulted in an increase of both installed capacity and production as of these policy implementation periods. Fiscal incentives include tax exemptions from taxes applied to fossil fuels. For domestic production additional incentives include tax breaks and a choice between anticipated reimbursements of the value added tax or accelerated depreciation on capital investment. Under the Biofuels Law, as of 2010, increasing blending mandates have been set in place, starting with B5 and E5 in 2010, while B5 was increased to a B7 mandate within a few months. Most production of biodiesel is currently still for export (close to 60%).

Figure 24 shows the development of ethanol in Argentina during the period 2009-2012. Although the ethanol industry in Argentina is still small, it has grown rapidly from zero to 200 ktonnes/year. Production capacity has also grown accordingly with the growth of demand, showing that the mix of policy instruments was effective to start up a market. Figure 25presents the development of biodiesel since 2006 until 2012. A new industry was constructed from scratch to make Argentina the world's third largest producer of biodiesel in only half a decade. Most production of biodiesel is currently still for export (close to 60%) mainly to the European Union. In this case, also the mix of policy instruments was effective to create another export market for locally produced soybean oil in the form of biodiesel.

[50] GAIN report on Argentina's biodiesel tax increase and temporary soybean import policy, 2012

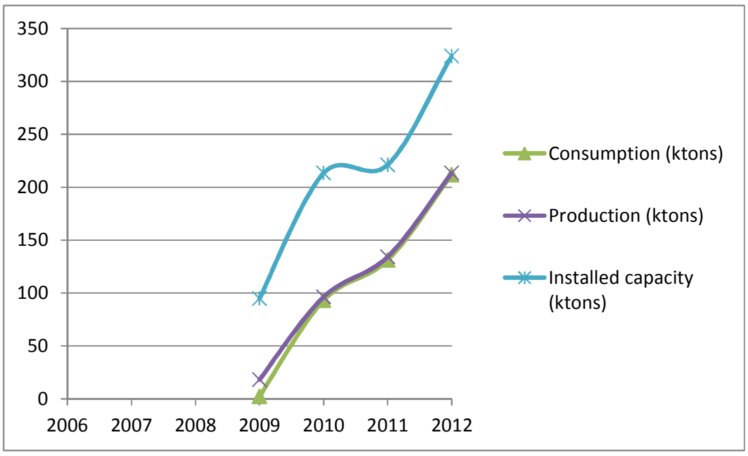



*Figure 24: Ethanol evolution in Argentina (2009-2012). Source: GAIN report*

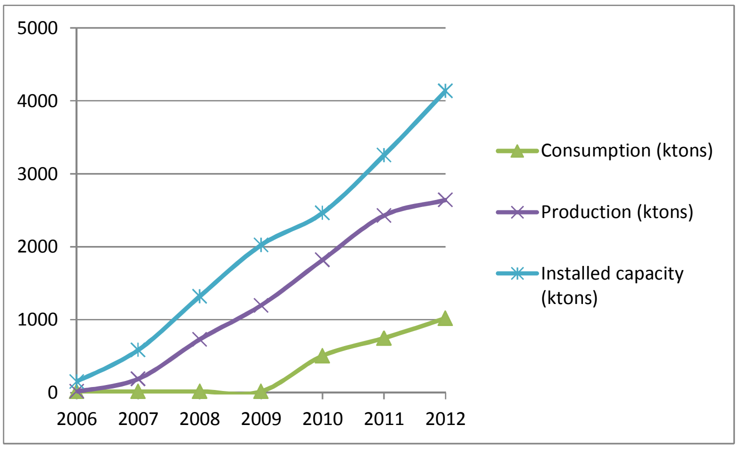



*Figure 25: Biodiesel evolution in Argentina (2006-2012). Source: GAIN report*

## 4.7 Brazil

### 4.7.1 Policy instruments

The policy instruments in place in Brazil are:

- Brazil has implemented a product blend mandates for several decades. In the case of ethanol, Brazil reduced its mandates from E24 (24% blend ethanol in gasoline) to E18–E20, partly in response to poor sugarcane yields in recent years. Biodiesel blend has been set at B5 (5% blend biodiesel in diesel);
- Mandates have been implemented for biofuels in public transport and taxis (plan until 2017);
- Preference to flex-fuel vehicles in municipal vehicle fleet purchases;
- Large subsidy program for the ethanol sector to support its expansion. Also finance incentives were introduced, aimed at increasing sugarcane yields;
- Tax incentives for ethanol and biodiesel were introduced, on production and consumption;
- Different government programs were initiated to implement pilot projects to fuel city buses fleets with a blend of diesel with new or advanced biodiesel.

### 4.7.2 Effects analysis

Brazil has a long history of supporting ethanol for transportation. This began in 1975 as a consequence of the first oil crisis, when the Alcohol Program was launched. This program stimulated the production of sugarcane and the use of the resulting ethanol in motor vehicles. From this time on, government policies have covered both the supply side of installed capacity (through credits for production and investment as well as funding infrastructure development) and ethanol production (with price controls and production quotas), and the demand side (with mandatory blending targets). The success of combining these instruments has been illustrated by the relatively constant and high levels of installed capacity, and a relatively equal and constant level of production and consumption. Subsequently, most of the produced biofuel is consumed domestically.

Since the 1990s, the Brazilian government and Brazil's National Economic and Social Development Bank (BNDES) provide incentives to stimulate the development of the ethanol industry. This includes short-term loans to farmers, with a value of US$ 277 million in 2010, under the programs NPR (Rural Promissory Note), DR (Rural Duplicate Note), and CPR (Rural Product Note).

Government support to the supply side of the ethanol industry further extended as of 2000. This started with the financial incentives of subsidized credits (subsidized loan rates of 8.75%) to sugarcane producers using degraded pastureland and credit programs (combining support from both government and private investors) to increase ethanol production. Credit available to sugarcane had reached nearly US$3.1 billion by 2010; 47% to operating capital, 16% to marketing, and 36% to investments[51].

On the demand side, the government has been implementing increasing blending mandates, starting with 11 % in 1976 to 20% and 25% by 2010, to create a guaranteed domestic market for the produced fuel ethanol. As of 2001 ethanol consumers have been exempted from paying the CIDE tax. These policy instruments were later supplemented by financial incentives stimulating the growth of ethanol-consuming vehicles.

Figure 26 shows the development of ethanol in Brazil during the period 2008-2012. As expected, consumption, production and installed capacity do not change much, as this is already a very stable industry in Brazil.

[51] http://www.ers.USDA.gov/media/126865/bio02.pdf

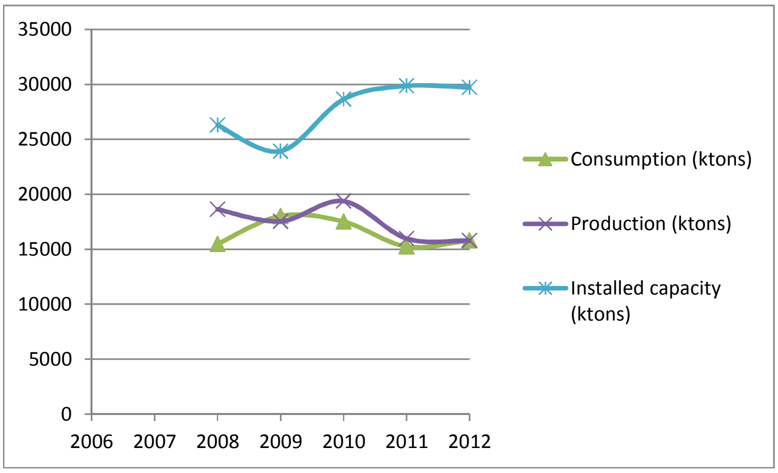



*Figure 26: Ethanol evolution in Brazil (2008-2012). Source: GAIN report*

On the other hand, the biodiesel industry in Brazil is rather new and started from zero consumption and production in 2006. The development of the biodiesel industry in Brazil took off through the implementation of the Brazilian Biodiesel Production and Use Program (2004). This program has been developed and implemented as an overall integrated approach, and hence covers both the supply and demand side of the industry, to be developed simultaneously. The program includes a production mandate for biodiesel's vegetable oils (Social Fuel Seal Mandates, from 15 % in the North and Central-West regions to 30% in the North-East, South and South-East regions), tax incentives for biodiesel producers (tax exemptions and tax obligation reductions from 32 to 68 %) and increasing blending mandates (from B2 in 2005 to B5 by 2010).

A special financing program from BNDES has been supporting the biodiesel industry in addition to the fiscal incentives and blending mandates, inducing a rapid growth. This concerns the Financial and Investment Support Program for Biodiesel, offering 80% to 90% financing for various projects, from cultivation of vegetable oils to commercialization of by-products from biodiesel's production process.

Brazil is now the fourth largest producer of biodiesel in the world. Installed capacity has increased significantly and amounts to about 3 times the country's actual production. Figure 27 presents the development of biodiesel between 2006 and 2012.

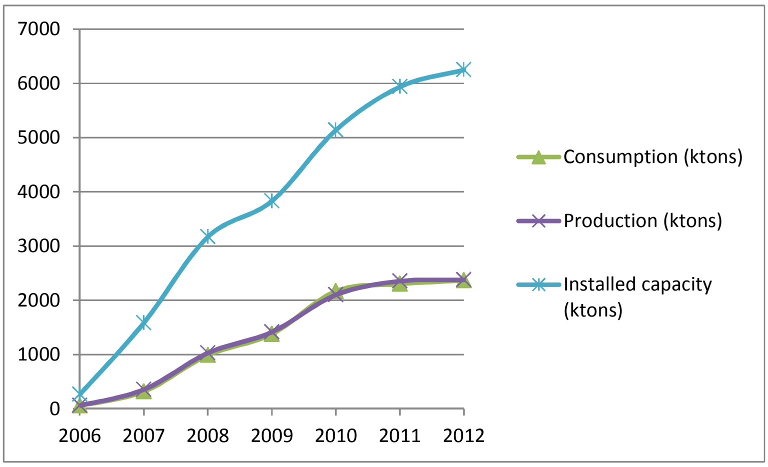



*Figure 27: Biodiesel evolution in Brazil (2006-2012). Source: GAIN report*

## 4.8 Additional case studies

See Annex 8 for Canada China, Indonesia, the BENELUX region, Italy, Spain and the United Kingdom

## 4.9 Findings and conclusions

There are basically three different approaches towards incentivising the production and consumption of biofuels: The US, the EU and the Brazilian approach.

The US approach combines volume targets on four different types of biofuels, with very specific financial incentives that are regulated at federal level. These financial incentives have fixed (usually annual) periods of validity, which is key for the monitoring and evaluation of their results prior to their extension. Their extension is neither automatic, nor granted. On top of this, states are allowed to give extra incentives that help the competitiveness of their industry (creating additional competitive advantages among states). On the other hand, volume mandates are revised every year, and under specific criteria, they can be waived. This creates the necessary flexibility in an industry that still needs support from policy instruments to grow.

The EU approach combines blending mandates mainly on fuel suppliers in most of the EU Member States, with financial incentives (mostly tax exemptions). Financial incentives are given at Member State level and not at EU level, which results in a large variety of situations across the EU. These financial incentives tend to be general and not specific as they are in the US. Blending mandates in the EU are usually more rigid and there are no established mechanisms to waive them if rationally valid circumstances arise.

The Brazil approach is basically the development of an internal market with not much interaction with other biofuel markets and the reconversion of the strong sugar cane industry into an ethanol industry.

The US and the EU policy frameworks are the most relevant for the research of policy instruments that can be implemented for the promotion of biojet fuels. Annex 9 presents a full description of the main differences between both approaches. In the next paragraphs, an analysis of these differences is presented.

### 4.9.1 Differences in blending vs. volumetric mandates

Compared to the US, EU biofuels markets have greater certainty for planning and undertaking investments, which clearly favours the mandatory over indicative targets. Moreover, setting a single target for all biofuel types gives the market flexibility to choose a cost-effective way of one appropriate technology, while sectorial targets (as in the United States) can—in theory—create the long-term confidence for inducing new investments in a broad range of biofuel technologies, including biojet fuels technologies for instance.

The fact that the United States chose volumetric targets and the European Union chose percentage targets in part reflects the political economy of the biofuels policy in those regions. By setting volumetric mandates, the United States reduces uncertainty faced by biofuels producers and farmers. In the European Union, setting a target in terms of percentages addresses the commitment of the sector in meeting the overall Kyoto limits. However, setting the targets in terms of GHG emissions themselves would increase the effectiveness of policy in this respect.

### 4.9.2 Effectiveness of EU vs. US financial incentives

Incentives to the EU biofuels sector are significant and insufficiently targeted to support specific objectives. If incentive measures are to be used then they should be differentiated in terms of their policy objectives. For example, if their objective is GHG savings, then they should be for biofuels which can actually deliver against the stated policy objective as opposed to a blanket support mechanism available across technologies and parts of the production and consumption cycle. Contrary, US biofuels target more specific beneficiaries and there is a much closer monitoring and market assessment of the results of these incentives.

### 4.9.3 Differences in regulation hierarchy

The US-wide approach to biofuels policy would not be possible in the confederate-type governance of the European Union unless Member States agreed to turn over authority and funding to the centralized governance of the Commission, as was done with the CAP and Regional Policy. Of course, granting such supranational authority was in exchange for substantial budgetary resources to support the policies. The current decentralized approach of the European Union has the advantage of allowing countries to find the most effective means to achieve the targets, which may differ country by country. In the United States, it is the RIN market that allows production and distribution to move to the most cost-effective facilities and regions.

### 4.9.4 Differences in incentives for second generation biofuels

The EU approach of providing higher credits for second generation biofuels provides an incentive for the advanced technology development. The United States had such a credit, giving a 2.5 times credit to second generation technology in RFS1, but it was converted to the quantitative categories in the RFS2. The EU approach is more flexible in that the volume of second generation biofuels is related to their competitiveness with respect to other biofuels. The US approach, in theory, provides more certainty by setting a mandated volume, but this mandate can be (and has been) waived depending on the technology available and this undermines the advantages that this provides.

An interesting aspect of the EU approach is that if a successful cellulosic biofuel (which is double-counted under RED) does emerge, this will probably reduce the volume of biofuels used. This is because of the double counting mechanism, thereby undermining the advantages of setting percentage targets in reaching GHG goals. Double counting is not exempt of other relevant problems. Multiple cases of fraud have already been detected around the implementation of double counting in the European Union, especially related to imported feedstock for the production of eligible biofuels. The threat of fraud increases with the value at stake. In this sense, multiple counting with factors of 3 or 4, as recently proposed, represents a substantial risk for fraud.

In general, the current combination of policy instruments in the EU leans towards conventional biofuels. –

### 4.9.5 Effective combinations of policy instruments

From the various country analyses, we conclude that the most effective approach towards the development of a stable biofuels industry and market has been the complementary implementation of policy instruments pushing both production and demand. These initiatives ought to be complemented with incentives for infrastructure development. Policy instruments for supply and demand, as well as those for infrastructure development, have mutual benefits towards each other. The development of infrastructure creates ways to have effective exchange of production and consumption within a region or a country, while the simultaneous boost of production and consumption provides incentives for infrastructure development and investments herein.

# 5 Applicability of instruments to the aviation industry

The measured impacts of the different available instruments to stimulate biofuels in the road transport sector provide good insight in their feasibility and effectiveness in the aviation sector. However, there is substantial variation in the needs, opportunities, and constraints faced by the aviation sector, and differences between the different regions and countries of the world. The international dimension of the aviation sector calls in many cases also for international agreements. In this respect, the role of the aviation industry initiatives is of special relevance to achieve such agreements.

Additional criteria must be considered for the selection of policy instruments applicable to the promotion of the production and consumption of biojet fuels:

1. Feasibility of implementation in target countries;
2. Suitability of policy instruments to choices of biomass feedstock and conversion processes that works best for the aviation sector.
3. Feasibility for international regulation and cross country implementation
4. Impacts on marginal costs of biojet fuels

## 5.1 Feasibility of implementation in target countries

It is important to realize that one size does not fit all. Even within similar economic regions, there is a substantial variation in the capacity to implement policy instruments across countries and regions.

Geographically, there are already some target countries for the implementation of policy instruments to incentivize the production and blending of biojet fuels. Those countries are relevant respect to the production of jet fuels and the management of its logistic chain. Other target countries are the ones in which feedstock can be produced at competitive cost; those countries are more difficult to identify though.

Annex 7 provides information about the most relevant spots in the world's jet fuel supply chain. The most relevant countries in the logistic chain of jet fuels are:

1. North America: United States, Canada;
2. Europe: The European Union, and especially the United Kingdom, the Netherlands, Germany, France and Spain;
3. Asia- Pacific: Australia, China, Russia, South Korea, Japan, Singapore, Thailand;
4. South America: Brazil;
5. Middle East, Africa, rest of the world: United Arab Emirates, , India, Egypt and South Africa.

From this list, high-income regions/countries such as the United States, Canada, the mentioned EU countries, Australia and Japan are more suitable for the implementation of economic instruments than the rest of countries. Tax payers from high-income regions/countries have more possibilities to subsidize activities that will result into climate benefits. These countries usually have well-staffed and well-equipped regulatory agencies, as well as strong judicial response systems. All these capacities offer stronger guarantees to make implemented policy instruments successful. These countries also have experience in carbon trading mechanisms and other market-based-mechanisms for trading emissions.

A different situation may occur in the rest of the relevant countries, mostly emerging economies. Emerging economies in most cases approach the climate challenges differently. Their business drivers and policy interests focus on a fast international market expansion rather than the solving of the climate challenges in itself. Therefore the willingness to allocate economic resources for promoting the production of biojet fuels in these countries may be limited.

In the less developed countries the gap in availability of financial resources is even larger. Not only economic instruments, but also the command and control type of instruments (such as mandates) face difficulties in these countries, as most of them would tend to increase the price of the final product. Price increments in less developed economies have strong impacts in their already small markets. On top of this, inspection and enforcement resources may not be sufficient. Policy instruments in these countries may be effective though, if an international market for their biojet fuel is granted

All these aspects are highly relevant when selecting or designing economic instruments suitable for these regions..

## 5.2 Suitability with respects to the choice of feedstock and technology options

The biojet fuel industry is still characterized by many uncertainties in terms of development of technologies, costs and availability of feedstock. This, combined with the international character of the industry, requires a flexibility of (combination of) policy instruments in time and in place.

Therefore, a stepwise introduction of (a combination of) policy instruments and incentives is required. Designing policy implementation must pinpoint sufficient moments over time to allow for adjustments.

For the aviation sector, the objective of all instruments should be in line with the possibilities and expectations in terms of availability of feedstock, capacity, logistics and infrastructure. Over- or under-capacity of plants or infrastructure should be avoided.

Given the risks involved in the biojet fuel sector, long-term objectives and policies are required. Short-term, unstable policies will create uncertainty in the market.

Experiences in the road transport sector (e.g. USA) show that timely adjustments of incentive instruments have a positive impact on the success of their combined implementation. In order to do so, adequate monitoring is required. An example of the mix- and time-sequence of policy instruments is shown in Figure 28.

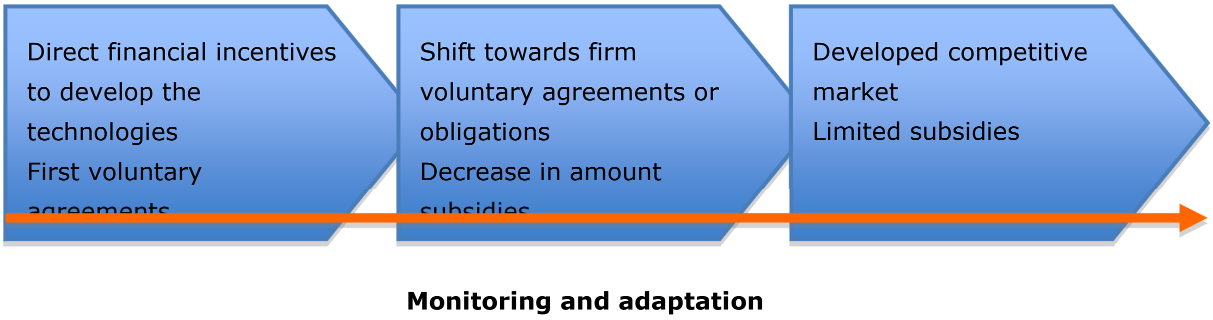



*Figure 28: Mix and time-sequence of policy instruments for incentivising the production and use of biojet fuels*

Experiences in the road transport sector show that most countries start with the introduction of economic instruments (incentives and tax exemptions) to help bringing technologies to a mature stage. Follows a phase in which collaborative instruments are combined creating a market need and controlling the risk of market access by guaranteeing a market: first voluntary agreements and partnerships for the consumption of the product are usually made. Generally, and to make the whole economically viable, other economic instruments and financial incentives are introduced and maintained until up-scaling of the technologies and market development make the industry competitive by its own, or with limited incentives. In the final phase, neither firm agreements nor mandates, nor other economic incentives, remain necessary. The risk of any combination of instruments is that they may develop a market that is not economically sustainable in the end. Policies must make clear what the maximum amount of money needed is, in the form of economic instruments to create an economically viable market and for how long those instruments will remain in the market.

The rationale behind this can be explained with Figure 29:

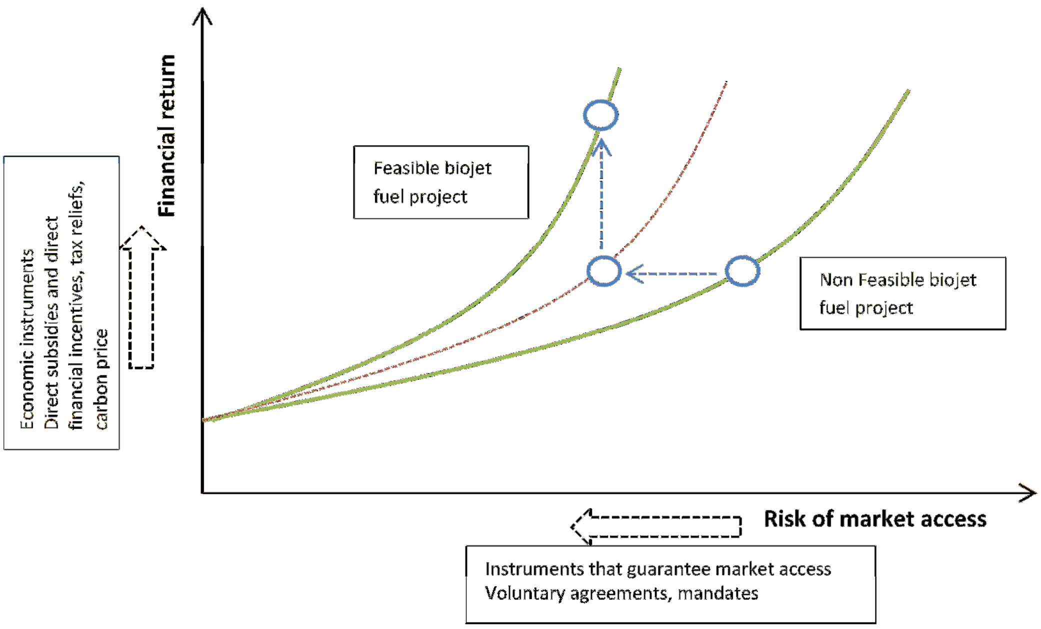



*Figure 29: Rationale of the application of policy instruments to convert non-feasible projects into feasible ones. Source: UNDP (2013)*

## 5.3 Feasibility for international regulation

Experiences in the road transport sector (e.g. in the European Union) show that international policy agreements do not get transposed in national legislation simultaneously. The example can be found in the pace of implementation of European policies for the promotion of biofuels across Member States of the EU. There is always a period of transition that can last years before all agreed instruments are introduced and developed within national legislations. This transition period has to be limited and its enforcement clearly communicated.

The development of the biojet fuel sector cannot be seen separately from on-going policy developments in related sectors (agriculture, forestry, bio-based economy, and the road transport sector). Preferably, the introduction of instruments strengthens the related sectors internationally as well and do not have a weakening or even distorting effect on competing markets.

Administrative barriers should be avoided with the development of new policy instruments. Internationally agreed technical and sustainability standards are important in this respect.

### 5.3.1 Economic instruments

Economic instruments, such as incentives or guaranteed loans, are granted by national governments to specific sectors or companies operating within their jurisdiction. Economic instruments usually target the development of the production chain or certain parts of it. It is important that economic instruments applied to the aviation sector avoid international incoherence. The application of economic instruments must take into account that the production of biojet fuels may be in itself restricted to geographical limitations that do not correspond to the availability or willingness to allocate economic incentives.

**Financial incentives for feedstock development**

Various feedstock (for example waste, Camelina, Jatropha, Algae, woody biomass) meet the requirements to produce the physical and chemical characteristics of biojet fuels. The characteristics of the aviation sector set certain conditions on the feedstock sourcing:

1. Feedstock should be available in a large and sustainable scale, preferably close to the production facility. For this reason, a multi-feedstock strategy makes sense and is necessary for economic and environmental reasons;
2. The suitability of crops for biojet fuel producing countries depends on their climate and land suitability. For example, Jatropha is suitable for tropical regions while Camelina grows in semi-tropical and colder regions. Beside, farming practices should be taken into consideration. For example, Jatropha has been promoted as a smallholder crop. Given the volumes needed for producing biojet fuels, it is questionable whether such an approach is at the end feasible and economically desirable for the biojet fuel industry;
3. Given the volume and cost reductions needed for the production of biojet fuels, an industrial approach will be needed;
4. From the perspective of sustainability, the aviation sector intends to avoid as much as possible competition with food. This results into a preference of non-food crops that can be used for advanced biojet fuels.

Limited dependence on exports and the availability of domestic feedstock production is needed to ensure a reliable supply for biojet fuel production in (expected) important biojet fuel consuming countries and airport hubs.

Consequently, incentives targeted at the development of feedstock production and related infrastructure should be targeted at those regions where:

- Feedstock can be, in a mixture, produced on a large, sustainable scale;
- Production facilities are located near to where large quantities of biojet fuel are (expected) to be blended.

**Financial incentives on production capacity development**

The availability of domestic production capacity to ensure a more reliable fuel supply is especially needed in the important biojet fuel consuming countries. Currently, there is not a single biorefinery in Germany that is suitable for the production of biojet fuels for instance.

As part of a national strategy, countries could actively support the transition from pilot plants to industrial production, and the conversion of strategically located first-generation biofuels plants to biojet fuel plants (see chapter 2.7.3).

**Trading systems**

An alternative economic instrument is the development of trading systems for emissions or for biojet fuel rights. These trading systems may incentivise sustainable biojet fuel development. Any trading system implemented in the aviation sector should show the pluralities between different world regions, and the design of international mechanisms will in the end be needed.

For the success of economic instruments in general, national governments should formulate an intra-sectorial vision of their world region, synergizing multiple objectives from various sectors.

In short, economic instruments should:

- Search for international approaches that safeguard a level playing field in the aviation sector;
- Promote the biojet fuel sector in various steps in the supply chain, meeting their specific needs;
- Look for synergies with the road transport sector and the bio-based economy (e.g. bio-refineries, bio-based hubs, ports, etc.).

### 5.3.2 Command and control instruments

Obligations and mandates have become the preferred policy instrument used by governments to support the biofuels industry for road transport. Generally, setting a mandate or obligation—and, thus reducing the risk of market access by creating a fixed market share—for a product usually puts an upward pressure on its price, which is often transferred to the final users. The scale of this impact depends on different factors such as whether the mandate is accompanied by financial support, and whether competition from imports is allowed. Mandates can differ though on what agent of the supply chain they target, and what the rules for their application are.

Command and control instruments are however not easily suitable for international regulation. They are generally implemented at a country level and developed to meet a specific country’s internal market characteristics, and country’s policy objectives.

When mandates or any sort of obligation are implemented, the further trading of biofuels across country borders requires careful registration and monitoring, otherwise a door is left open to fraud. These control measures are usually needed because compliance obligation is enforced through penalties. This complexity is well phrased in the Dutch legislation (the first legislation in the EU accepting biojet fuels to fulfil their national mandates): "The international rules governing the determination of the national GHG and the trans-boundary nature of aviation have as result that the reduction of GHG in the airline do not contribute to the achievement of the relevant national objectives"[52].

Airlines operate across international borders which complicates very much the feasibility and the design of national obligations of any sort. Non-negotiated obligations between airlines and countries would result in airlines being regulated under different type of mandates. This will potentially severely affect the level playing field allowing for international competition within the aviation sector.

In order to make feasible any type of command and control instrument at international level for the aviation sector, there is a need for international negotiations and agreements regarding their design and the accompanying policy instruments. In this aspect, voluntary industry initiatives in the aviation sector should be the preferred way to arrive to such agreements.

In short, obligations should:

- Be flexible (slow increase in percentages) and tradable between different countries to meet the international scope;
- Be generally defined with restricted government control (leave strategic decisions to the market);
- Be temporarily waived when certain key conditions (e.g. technological advancement, lack in capacity) are not met (comparable to what the RFS program does in the US).

### 5.3.3 Co-regulation instruments

While co-regulation builds upon the combined strengths of public regulation and industry initiatives, it also requires extensive negotiations and finding agreement between conflicting interests from all participating stakeholders and governments. Co-regulation may result in a very lengthy international process.

Lack of clarity and guidance during the implementation of co-regulation may also end up in some weak combinations of industry initiatives with lenient national regulation. These weak combinations may result in failure or even potentially fraud in achieving co-regulation goals. Contradictory demands by different governments when giving too much freedom for implementing co-regulation may increase implementation costs. Furthermore, if the dynamics of industry initiatives are not fully understood by governments, then co-regulation may be wrongly used in a way that endangers its neutrality and credibility (e.g. for protectionist purposes).

Success of co-regulation instruments require an organised approach from the industry, and the firm political will of countries involved. It is better when this political will is translated into steering from a supra-national public body (such as ICAO).

[52] Resolution of 26 November 2012 to change of the Decision Renewable Energy for transport and the Decision air pollution fuels

### 5.3.4 Voluntary and collaborative instruments

Voluntary agreements among airlines for the consumption of biojet fuels, and collaborative agreements between producers and consumers are not exempt of difficulties. While they basically just require the free will and agreement of its participants, they can also be negatively affected by the lack of harmonisation of systems required for international trade. Voluntary and collaborative instruments require the use of internationally harmonised standards and systems. Global aviation relies on harmonised standards and specifications. Those standards exist for jet fuel technical specifications, but not yet for sustainability issues at an international level. Different countries and different regions have different (or simply do not have) sustainability requirements for biofuels. The current co-existence of different sustainability standards for example is a bottleneck for collaborative instruments to take place at large scale and between partners from different world regions. In order to encourage multi participants, voluntary, and collaborative instruments, there is a need to adopt international standards for sustainability issues, either private standards, or in the format of international conventions or treaties.

In short, voluntary and collaborative instruments should:

- Provide a long-term strategic vision and be based on international agreements;
- Align strategies between feedstock producers, biofuel producers and oil companies to promote the biojet fuel sector within a region or country;
- Cooperate between competitive sectors to strengthen innovations and promote coherence in regional development (e.g. thinking on bio-based hubs) instead of competition;
- Harmonize requirements (sustainability requirements for example) for competitive end-uses, this to avoid unnecessary administrative burden. International coherence in reporting and standardization requirements is key to avoid operational burden;
- Search synergies with possible green procurement policies established by national governments.

## 5.4 Impacts on marginal costs of biojet fuels

With the tough international competition among airlines today and with fuel costs already making up for roughly 30% of total costs, there is no expectation of a global economic driver for alternative aviation fuels. More favourable and competitive cost structures are therefore crucial. The ENER Biofuels Flight Path (2011) indicates that, from a direct cost perspective it can be expected that all biojet fuels, capable of meeting aviation fuel quality standards, will be significantly more expensive than fossil jet fuel for the aviation industry until at least 2020 if no financial incentives occur.

Key to improving the economics of biojet fuels is to significantly reduce its unit production costs. With regard to expected cost developments, substantial differences of the cost structure of HEFA and F-T have to be considered. Production costs of F-T fuels are still characterised by high uncertainties. Production costs of HEFA strongly depend on the feedstock prices for oily biomass (see Figure 30).

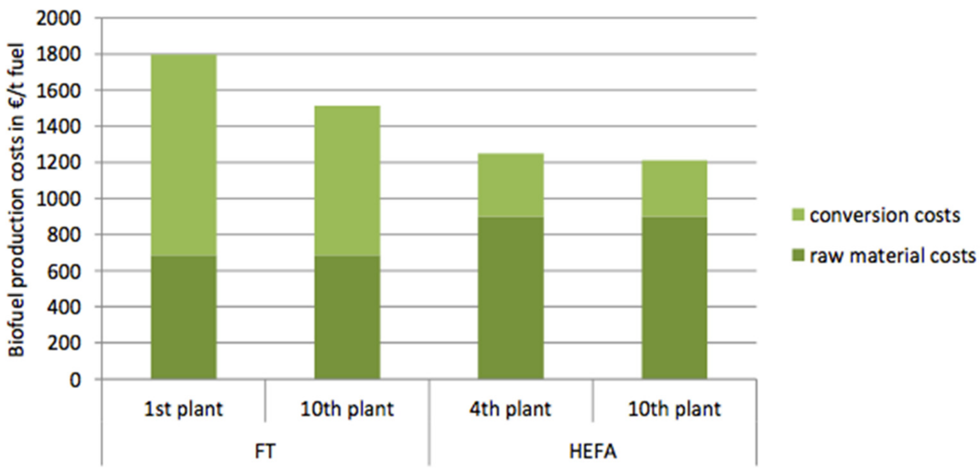



*Figure 30: Development of conversion costs for different biojet fuel pathways. Source: Figure from IEA Bioenergy Task 40 (DBFZ, 2012, Lange 2008, Maniatis, 2011).*

Incentives shall target specific parts of the biojet fuel production chain, most likely targeting the constructions of plants, R&D or commercialization of technologies. This may incentivize certain developments.

This process of technical commercialization can be related to the Fuel Readiness Level Table (see Table 9) as developed by CAAFI.

*Table 9: Fuel Readiness Level Table*

| FRL scale | Description | Toll gate |
|---|---|---|
| 1 | Basic principles observed and reported | Feedstock/process principles identified. |
| 2 | Technology concept formulated | Feedstock/complete process identified. |
| 3 | Proof of concept | Lab scale fuel sample produced; energy balance analysis executed. |
| 4 | Preliminary technical evaluation | System performance and integration studies. |
| 5 | Process validation | Sequential scaling from laboratory to pilot plant. |
| 6 | Full-scale technical evaluation | Fuel properties verified in engine testing. |
| 7 | Fuel approval | Fuel class/type listed in international fuel standards. |
| 8 | Commercialisation validated | Business model validated for production. Airline/military purchase agreements. Facility-specific GHG assessment conducted. |
| 9 | Production capability established | Full-scale plant operational. |

All stages would require an economic incentive in the form of grants or R&D to biofuel producers. The objective of the incentive can be different depending on the phase of commercialization: The first stages may have a larger focus on R&D while financial support for construction of plants may be of more importance in the later stage. In all stages, support will still be needed to compensate for the higher cost of the final product. This would be temporarily and on a regressive basis after stage 9.

Other type of economic incentives is the trading of biojet fuel certificates. These certificates may also contribute with reducing the cost of production of biojet fuels.

There is a limited choice of feedstock for the production of biojet fuels. One of the current barriers for a wider use of biojet fuels is the high feedstock cost. Market prices for agricultural commodities are expected to remain high. There may exist a cost reduction potential for non-commercial crops over time (in comparison to the current situation), though this is also uncertain because those crops will become commercial when their market reaches some momentum.

Competing demands together with the limited availability of land is likely to result in rising feedstock costs for biojet fuels. Reducing the unit production costs of biojet fuels will depend to a large extent on improvements in the productivity of feedstock, the extraction of oil or sugars from those crops, and the conversion into fuel.

Feedstock prices are expected to have the following relation with policy instruments:

- The introduction of an obligation and/or mandate in a country or region will increase the demand for biojet fuels. This will also create a rising demand on its feedstock base, and consequently increase its price. Export quotas of these feedstock may go down accordingly, and this may affect international trade;
- Related sustainability requirements may limit the availability of land and/or feedstock that can be used. The increased demand itself will also affect the land availability for feedstock production, and hence competition and prices;
- Economic instruments aiming at reducing the price of feedstock must be carefully implemented and monitored, as those incentives may very well end up subsidizing other agricultural activities or even other competitive uses of the feedstock.

Economic instruments can create the required scaling and learning of the sector to lower down conversion costs. However, the structural impact of economic instruments on the cost structure of biojet fuel is expected to be limited if they are only addressed to the conversion phase. Feedstock costs shall also be kept low (for crops that are currently non-commercial crops), or reduced when they become agricultural commodities with a demand and other competing uses.

# PART 2: EVALUATION OF OPTIONS

# 6 Policy options for the aviation sector and impacts on relevant stakeholders

The objective of this chapter is to assess the policy options to move towards the cost-competitive, global deployment of large quantities of biojet fuel. Cost-competitive means in this context that biojet fuel is competitive with fossil fuel. 'Large quantities' is defined in our study as evolving globally towards a blending percentage of 3% by 2030. This is a conservative pathway. Sensitivity analyses of the impacts of more ambitious pathways are described in chapter 8.

The objective can be reached through different ways:

- Making feedstock available at a large, economic and sustainable scale;
- Reaching the stage of commercial maturity for second generation technologies contributes to the ramp up of number of biojet fuel plants;
- Improving the cost-competitiveness of biojet fuel production by accelerating the technology learning curve;
- Engaging an international growing market for biojet fuels either through voluntary commitments or obligations.

Policy instruments are needed in order to achieve this objective and solve the underlying bottlenecks. Experiences in the road transport sector show that each country seeks its own combination of instruments depending on the target, the maturity of the sector and other country specific conditions.

This chapter will first discuss the suitability of selected policy options to contribute to the cost-competitive deployment of large quantities of biojet fuel. It will then discuss the impacts of these policy options on the different involved stakeholders.

## 6.1 Selected policy options

The policy options are combination of instruments selected for this study. Selected policy options are shown in Table 10. These options are selected based on the following criteria:

- Each option has a main policy instrument , upon which the option builds (example: mandate as main instrument with economic incentives as supporting instruments);
- The options are realistic (based on discussions with IATA, experiences in the biofuels sector and trends in the aviation sector);
- The options cover the range of more extreme combinations to demonstrate the impacts when biojet fuels are supported substantially;
- Impacts for stakeholders are analysed per option.

*Table 10: Policy instruments combination options*

| Option 1: Price driven (Economic instruments driven) |
|---|
| **Main instrument: Direct economic support to reduce the price of biojet fuels**<br>• Financial support for R&D, production capacity and infrastructure build up<br>• Economic incentives for the reduction of feedstock price<br>• Targets are set individually or by voluntarily joining incentives from within the aviation sector;<br>• Governmental targets are not legally binding;<br>• |
| **Option 2: Obligation driven (Command and control instruments driven)** |
| **Main instrument: Blending mandate**<br>• There is a governmental obligation for the blending of biojet fuels;<br>• Targets are set at country level;<br>• Financial support for R&D and production capacity build up exists but at lower levels than option 1<br>• No economic incentives to reduce feedstock price are considered. |
| **Option 3: Co-regulation driven** |
| **Main instrument: International industry initiative to set blending targets and rules for accomplishment at supranational level, translated into national regulation.**<br>• There is a general agreement at supranational level in the aviation sector, embedded in a resolution by ICAO;<br>• This resolution is adopted by all or a majority of countries into their own legislations;<br>• When not sufficient, additional economic instruments can be complementary in some scenarios**.** |
| **Option 4: Voluntary driven** |
| **Main instrument: Voluntary agreements are set by the aviation sector itself**<br>• There is no obligation or target set by either governments or the industry;<br>• Companies choose individually to incorporate biojet fuels;<br>• Economic support (through economic instruments) is zero;<br>• This option is 'Business as usual' |

## 6.2 Stakeholders groups and impacts

In this study, we make a distinction between the following stakeholder groups:

- Airlines (especially airlines operating international flights);
- Oil companies;
- Dedicated feedstock producers, biojet fuel producers, exporters and distributors;
- Airports;
- Stakeholders from other biofuels chains (road transport sector);
- Others (such as governments); Governments are not direct stakeholders in the biojet fuel value chain. Their role involves shaping policies, and indirectly influencing market conditions, in their own country and abroad (for example direct incentives in a country can dry up the market of other countries which decide to only export).

The description of impacts focuses on the following issues:

1. Costs: Economic impacts on stakeholders can be both negative and positive. Introducing incentives can relieve investment costs for biojet fuel producers, but can be costly for

national governments and subsequently for tax payers. Overall costs involved to achieve the objective are discussed in chapter 8;

2. Competitiveness: The introduction of policy instruments can impact the competitiveness and level playing field of airlines using biojet fuels;
3. Operational burden; Additional administration, man-hours and capacities required in relation to benefits of achieving the targets;
4. Responsibility: Depending on how instruments are designed, responsibilities may rest at different stakeholders in the value chain.

## 6.3 Option 1: Price driven

Direct economic support to lower the price of biojet fuels down to competitive prices is the main driver in option 1. This option assumes that national governments are willing to subsidise sufficiently to realize the ambition to enable biojet fuels to compete with fossil fuels. Large government support results into fast learning curves for technologies.

The available individual support instruments under this category are explained in chapter 3. Table 11 below shows:

- In how far these individual instruments contribute to the global deployment of cost-effective biojet fuels by solving the underlying issues;
- Their possible applicability in time (short or long term) in different world region;
- Their applicability at country or project level, and if international cooperation is required.

Economic instruments can solve different issues. All have their strengths and weaknesses. In practice, a combination of these instruments is used to stimulate a sector, for example a combination of financial support for R&D activities, direct incentives to the price of feedstock, and the inclusion in a carbon market or in a biojet fuel tradable certificate market.

Most of economic instruments are introduced either on a project or on a country level. Direct project support has the advantage of being tailor-made; impacts at this level are however generally limited to the end use of the specific project.

Experiences from the road transport sector show that economic support instruments are often used when starting up a sector, especially in the short to medium term. Governments mainly carry with the cost burden of these instruments. The downside of most economic support instruments is that they are usually limited by the overall country budget. They can disappear at any time, which does not provide a sound basis for the steady development of biojet fuels.

*Table 11: Indication of suitability and applicability (in time and regions) of individual instruments that are categorized under policy option 1*

| Indicative:<br>O = to certain extent<br>OO = most likely<br>- = risk to be counter effective | Premiums energy crops | Price regulation income farmers | R&D energy crops, yields | Subsidies production facilities | De-risking investment production facilities | R&D conversion technologies | Tariffs and import duties fuels | Subsidies logistics and infrastructure | De-risking investment infrastructure |
|---|---|---|---|---|---|---|---|---|---|
| **Solving the bottlenecks** | | | | | | | | | |
| Biomass production | | | | | | | | | |
| Lowers feedstock production costs | OO | O | OO | | | | | | |
| Stimulates yield increases | | | OO | | | | | | |
| Reduces input costs | O | | O | | | | | | |
| Unlocks feedstock availability | O | O | OO | | | | | | |
| Logistics | | | | | | | | | |
| Lowers feedstock transportation costs | | | | | | | | OO | OO |
| Improvement in logistics feedstock | | | | | | | | OO | OO |
| Conversion | | | | | | | | | |
| Reduces technology conversion costs | | | | O | O | OO | | | |
| Technology learning | | | | O | OO | OO | | | |
| End-use | | | | | | | | | |
| Contributes to competitiveness biojet fuel | O | | O | O | O | O | O | O | O |
| Certainty in (growing) demand | | | | | | | | | |
| Stimulates a level playing field | | | | | | | | | |
| **Likely period of introduction** | | | | | | | | | |
| ***Indicative*** | O | Short to mid term | | | OO | Mid to long term | | | |
| World | | | | | | | | | |
| Europe | O | O | O | O | O | O | O | O | O |
| US | O | O | O | O | O | O | O | O | O |
| Asia | O | O | O | O | O | O | OO | O | O |
| Africa | O | O | O | O | O | O | OO | O | O |
| Latin America | O | O | O | O | O | O | OO | O | O |
| Introduction on country level | O | O | O | O | O | O | O | O | O |
| Introduction on project level | | | O | O | O | O | | O | O |
| International cooperation required | | | | | | | | | |

In option 1, the main economic support instruments are the financial support to R&D activities along the supply chain, production capacity and infrastructure build up, and economic incentives specifically addressed to the reduction of feedstock price.

The use of biojet fuels by the aviation sector in this option is foreseen to take place first in those regions where they become economically attractive. It will depend on the level of economic support but even more on other economic drivers as fossil fuel prices, carbon prices or competition with the road transport sector (and feedstock) if this approach is successful. How much economic support is needed to become cost-competitive under this option is further discussed in chapter 8.

In this option, targets for the use of biojet fuels are set individually by airlines, or by voluntarily joining incentives from within the aviation sector. This option also considers that governmental targets are not legally binding.

### 6.3.1 Impacts on stakeholders

Under this section, the impacts of the policy option 1 are discussed.

**Airlines**

Table 11 shows that most of the economic instruments provide an incentive for lowering production costs of biojet fuels in various parts in the supply chain. Airlines may therefore feel incentivised to purchase biojet fuels when biojet fuel price is competitive compared to that of fossil jet fuel and carbon. Not only the amount of economic support is of importance, but other economic drivers (such as carbon price or oil price) will largely determine the choice to deploy biojet fuels – and the extent of this deployment. Airlines operating in jet fuel importing countries may choose to use biojet fuels as a strategic measure against their exposure to volatile oil prices.

Airlines will have to adapt their strategies towards limitations and fluctuations and limitations in national budgets allocated to the economic support of biojet fuels. When incentives are stopped, most airlines will switch back to fossil fuels as long as oil prices are lower than biojet fuels.

**Oil companies**

There is an increasing interest in oil companies to develop technologies and production capacity of biofuels in general; however their core business is fossil fuels. . For oil companies, it is of more importance that the blended biojet fuel meets the required technical specifications (ASTM certification included) to avoid contamination of their end product.

While strong economic support in this option helps to reduce biojet fuel production costs, still the final sale price will be largely determined by the jet fuel price (and the fluctuations of the fossil fuel price). Oil companies will adapt their refinery and blending capacities in reaction to the demand and supply of the market, therefore the impacts on oil companies is relatively limited.

**Feedstock producers, biojet fuel producers, exporters and distributors**

Under this option, biojet fuel is produced only where the right economic support for reducing its price exists. This is a situation that will exist until production costs get competitive with no help from economic support given by governments. Feedstock producers and biojet fuel producers would strongly benefit from direct incentives to R&D, demonstration plants, business planning, plant construction and from other grants aimed at the improvement of logistics and infrastructure. Technical innovation and commercialization would mainly occur in those world regions that already have developed experience in producing biojet fuels, and that are in general more willing to put in place policy instruments (including economic incentives) for the promotion of biofuels (e.g. US or Europe). This could also be the case for countries that have the most favourable conditions for the production of cheap feedstock and with an adequate industrial and logistic development (e.g. Brazil)..

Feedstock producers are not selling exclusively to biojet fuel producers. Wood residues for example can also be used for electricity generation, second-generation biofuels for the road transport sector, or for the wood sector itself. Vegetable oils (such as Camelina or Jatropha) have growing markets in the food and chemistry related industries as well. Used cooking oil has become a globally traded good already. Feedstock prices and their competitiveness will therefore largely depend on demand and (competing) markets developments.

Experiences from the road transport sector show that economic instruments provide uncertainty in the long term for this stakeholder group, especially when they occur in combination with fluctuations in oil and carbon price . Sustained high oil prices will stimulate the production and consumption of biojet fuels, but fluctuating oil prices and not guaranteed economic support puts in a high level of risk any long term investment.

**Airports**

Airports are the distribution points of fuels to the aviation sector. As the biojet fuel is a drop-in fuel, only limited or no infrastructural changes will be needed at airports to handle biojet fuel blends.

Some airports may consider the delivery of biojet fuel blends as a competitive advantage compared to other airports. For example, Amsterdam Airport Schiphol is aiming to become the world's first bioport by 2017. By setting such an ambitious target, Schiphol hopes to stimulate the use of sustainable jet fuel[53] by the airlines operating there.

**Stakeholders from other biofuels chains (road transport sector)**

Stakeholders in the biofuel chain for the road transport sector partly coincide with the biojet fuel supply chain. Logistics, trading and storage may be partly combined – particularly in the beginning of the chain. Targets for biofuels use are set in multiple countries (see chapters 3 and 4). Some countries like the US include targets for advanced biofuels. These advance biofuels may include conversion options that are of interest for the biojet fuels industry. However the experience shows that countries are struggling to meet the specific targets for those advanced. Key reasons are the limited production capacity of plants with advanced technologies and the high feedstock prices

Under option 1, the road transport sector may benefit from the economic support and research developments provided to biojet fuels deployment; this is especially relevant as the road transport sector in Europe and the US are in transition towards the use of second generation biofuels (current revisions of the European Renewable Energy Directive and targets for the RFS2 in the USA). Financial support for R&D innovations and other types of economic support can benefit multiple sectors, when designed accordingly.

Possible economic opportunities and synergies for biojet fuels and second-generation biofuels for the road transport sector are:

- With the upcoming changes in the European Renewable Energy Directive (RED), there will be the need for a strategic roadmap with incentives to stimulate advanced biofuels technologies such as FT or HVO/HEFA. This support may benefit the biojet fuels sector (e.g. when a ratio of HVO output is reserved for biojet fuels);

[53] Source: http://www.iamsterdam.com/Schiphol%20plans%20to%20be%20first%20bioport

- Currently, capacity of conventional biofuels plants is not fully used in Europe. Parts of the assets of these plants can possibly be used for advanced HVO plants, benefiting both the road transport and the aviation sectors. The production ratio of biojet fuel and other biofuels in a HVO plant is largely influenced by demand. Based on interviews with industry experts, a cost reduction of 20% may be realisable under certain conditions (see chapter 2).

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- Availability and prices of feedstock: the market decides on price and end-use. Financial support and other policies could influence availability and prices (for example land allocation or cascading policies);

The experience in the road transport sector shows that competition between local and imported biofuels may distort markets that are already receiving a large amount of economic support (for R&D and infrastructure for example). It is therefore of key importance that the development of an economically incentivised market for biojet fuels goes gradually and hand in hand with its production and capacity development – aligned with other markets at national and international levels.

**Others (governments)**

The role for governments is to implement economic support and to monitor its effectiveness. Large deployment of economic support is mainly seen in countries with strong economies such as Germany in Europe and the US. These incentives often involve a combination of economic instruments such as economic or financial support for R&D activities and for the building of the first commercial plants. In the case of the road transport sector, tax reliefs are widely used as an economic instrument for the quicker deployment of biofuels.

The experience in the road transport sector also shows that competition between local and imported biofuels may distort markets that are already receiving a large amount of government economic support (for R&D and infrastructure for example). It is important that governments implement effective monitoring of the economically incentivised markets. This is needed to assure that deployment of biojet fuels happens gradually, hand in hand with their production capacity development, and aligned with development of other markets at national and international levels.

The research done in 2010 by the Intelligence Energy Europe (IEE) in the framework of the ELOBIO project showed that significant financial support via an initial investment subsidy (>50%) coupled with partial tax breaks, soft loans and multiple counting, can enable high shares of second-generation biofuels in the market by 2020 and 2030 (see Figure 31). This forecast assumes that second-generation biofuels become cost competitive in 2020 after substantial incentives have been provided.

To achieve competitiveness the ELOBIO project assumes that technology risk is shared between the public and private sector; commercialization of these technologies will require an approach where industry and governments cooperate around R&D and demonstration towards commercialization. In detail, initial economic support (subsidy) is given to realise the investment needed in R&D and first commercial plants. This is later combined with double counting of the produced biofuel towards the renewable transport fuels mandate is assumed to be an effective way of increasing the share of second generation biofuels. The subsidy is discontinued two years after the first market introduction of second generation biofuels, while double-counting is stopped in

2020. An important limitation of this project though, is that the scenario analysis assesses the agronomic feasibility of feedstock for second generation biofuels, but does not apply cost criteria to judge their economic viability, nor does it give specific consideration to possible other uses of biomass. Currently it is known that competition for feedstock is an important factor in the establishment of prices of feedstock and must not be overlooked.

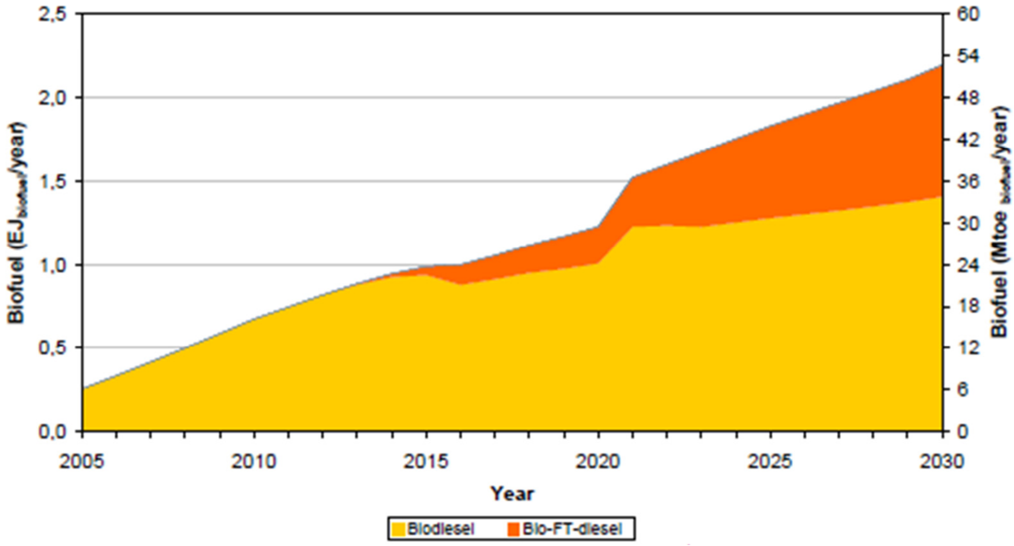



*Figure 31: EU Biofuel mix using double counting of second generation biofuels until 2020 and a 70% investment subsidy in the pre-commercial phase. Source: ELOBIO project*

Economic instruments are often used to stimulate a young, still developing sector to move towards maturity. Economic supports generally lowers when this phase is reached. Experiences from the road transport sector show that government only have limited budgets to support biofuels, especially during times of economic crisis.

## 6.4 Option 2: Obligation driven

In option 2, governments use blending mandate as main command and control instrument for the promotion of biojet fuels. Table 12 shows in how far the blending mandate and other individual 'command and control' instruments (see also chapter 3) contribute to the global deployment of cost-effective biojet fuels by solving underlying issues and their possible applicability in time (short or long term) and in different world regions.

*Table 12: Indication of suitability and applicability (in time and regions) of individual instruments that are categorized under policy option 2*

| Indicative:<br>O = to certain extent<br>OO = most likely<br>- = risk to be countereffective | Quotas set-aside land | Emission mandates fuel quality standards | Authorisation quotas biojet fuel producers | Regulations restraining/increasing imports biojet fuels | Biojet fuel mandate for minimum sold | Specifying product blends that must be available in market | Blending mandate for % share of biojet fuel (all transport sectors) | Blending mandate for % share of biojet fuel (for aviation sector only) |
|---|---|---|---|---|---|---|---|---|
| **Solving the bottlenecks** | | | | | | | | |
| Biomass production | | | | | | | | |
| Lowers feedstock production costs | O | | | | | | | |
| Stimulates yield increases | | | | | | | | |
| Reduces input costs | O | | | | | | | |
| Unlocks feedstock availability | OO | | | | | | | |
| Logistics | | | | | | | | |
| Lowers feedstock transportation costs | | | | | | | | |
| Improvement in logistics feedstock | | | | | | | | |
| Conversion | | | | | | | | |
| Reduces technology conversion costs | | | | | | | | |
| Technology learning | | O | | | | | | |
| End-use | | | | | | | | |
| Contributes to competitiveness biojet fuel | | O | | | O | O | O | O |
| Certainty in (growing) demand | | O | O | O | O | OO | OO | OO |
| Stimulates a level playing field | | | | - | | O | | - |
| **Likely period of introduction** | | | | | | | | |
| ***Indicative*** | O | Short to mid term | | | OO | Mid to long term | | |
| World | | | | | | | | |
| Europe | O | O | OO | O | O | O | O | OO |
| US | O | O | OO | O | O | O | O | OO |
| Asia | O | O | OO | OO | OO | O | OO | OO |
| Africa | O | O | OO | OO | OO | O | OO | OO |
| Latin America | O | O | OO | OO | OO | O | OO | OO |
| Introduction on country level | O | O | O | O | O | O | O | O |
| Introduction on project level | | | | | | | | |
| International cooperation required | | O | | O | | O | O | O |

Table 12 also shows the different types of mandates that can be introduced individually or in combination. Generally speaking, four different characteristics can be distinguished: sector, value chain, time and space:

- Sector: a mandate can be designed for the biojet fuel sector specifically or for the transport sector fuels in general;
- Value chain: Mandates can be put at different stages of the supply chain. Based on experiences from the road transport biofuel supply chain, obligations are most likely to be set on the last ling of the supply chain, having most control in the chain. These are the airlines and the fuel suppliers to the aviation sector;
- Time: mandates can be introduced gradually over time and their conditions can be temporarily waived (when conditions are not met);
- Space: A mandate can be introduced in a restricted geographical area or in a wider region covering multiple countries.

The design of the mandate clearly determines the impacts and effectiveness of the instrument in solving the underlying issues. Potentially, an adverse impact from a mandate would be that it stifles innovation. If biojet fuel developers mobilize their resources towards the currently cheapest production route, they may neglect the needed R&D activities towards more promising technologies for the future. This could lead to the scaling-up of structurally flawed options that would never be cost competitive with conventional jet fuel. It is actually required the careful selection of technology pathways (and feedstock) that have potential to be commercially viable in the medium to longer term (IATA, 2011).

Table 12 also shows that the introduction of a mandate mainly contributes to creating demand and on the longer term cost reductions through up-scaling. Mandates have limited influence on solving the bottlenecks at the beginning of the supply chain though. Mandates need to be combined with economic support measures from governments for starting up a market (see option 1). This economic support must focus on R&D and the construction of the first commercial plants, which are needed to meet targets.

Based on Table 12, the impact of stakeholders will focus on three types of mandates:

- Option 2a: A biojet fuel blending mandate is set for oil companies or refineries - combined with an additional mix of economic instruments;
- Option 2b: A blending mandate is set for airlines –combined with an additional mix of economic instruments;
- Option 2c: a mandate on all transport fuels together; biojet fuels count towards the overall target. For example in the US, biojet fuel now qualifies under the RFS to generate RINs that can be traded on the open market, though jet fuel itself is exempt from RINs obligations. The economic value assigned to the renewable content of the jet fuel can help the producer of that fuel to close the price gap with traditional jet fuel; volume obligations are adjusted over time (Platts, 2013).

Chapters 7 and 8 will discuss in more detail which blending mandate is needed over time to come to the global, large-scale deployment of cost-effective biojet fuels.

## 6.4.1 Impacts on stakeholders

Under this section, the impacts of the policy option 2 are discussed.

**Airlines**

Option 2a: A biojet fuel mandate for oil companies (fuel supplier)

Airlines are likely to select the provider that can supply the cheapest aviation fuel (including biojet fuel), herewith putting pressure on the suppliers to keep price down.

Option 2b: A biojet fuel blending mandate for airlines

Under this option, airlines are obliged to purchase a certain amount of blended biojet fuels, risking a penalty in case of non-compliance. Given the international dynamics of the aviation sector, it may be difficult to establish which airline faces the mandate and related jurisdiction.

A restricted introduction of a country mandate may result in an uneven level playing field. This is confirmed by a recent study from NERA (2012). As Table 13 shows, the competitive disadvantage of airlines (case of the UK) increases when the mandate is more restricted in space. A limited introduction of a mandate also poses the risk that airlines circumvent a mandate in a country by intensifying the use of airports in those countries that do not have a mandate introduced. This form of "leakage" can be averted if a mandate is introduced in a wider region, using the similar requirements.

*Table 13: Incremental costs for airlines in the UK (BA=British Airways) due to mandates applied in different world regions. Source: NERA, 2012*

| Policy: | UK-only Fuel Mandate | | | EU-only Fuel Mandate | | Global Fuel Mandate |
|---|---|---|---|---|---|---|
| **Traffic at Risk** | **Domestic** | **Intra-EU** | **All flights** | **Intra-EU** | **All flights** | **All flights** |
| Point-to-point | | | | | | |
| *Intra-UK* | All | All | All | All | All | All |
| *UK-EU* | - | All [1,2] | All [1,2] | All | All | All |
| *UK-non-EU* | - | - | All [1,2] | Some EU carriers | All [1,2] | All |
| Hub / Indirect | | | | | | |
| *UK-EU* | - | BA, others | BA, others | All | All | All |
| *EU-EU* | - | BA | BA | All | All | All |
| *non-EU-EU* | - | BA | BA | BA, others | All [1,2] | All |
| *non-EU-non-EU* | - | - | BA | - | BA, others | All |

**Notes:** *1. Subject to mandate being enforceable on foreign-flagged carriers under Chicago Convention, etc.*
*2. Carriers offering* *indirect* *routes to compete with BA's point-to-point services would acquire a competitive advantage, although they would also face the mandate costs (to a lesser extent).*

- \- Policy is not relevant for route category
- No impact or positive impact on BA
- Some competitive disadvantage to BA
- Significant competitive disadvantage to BA
- Greatest competitive disadvantage to BA

Mandates make possible to artificially create a market volume and demand. The uncertainties in biojet fuel availability (uncertainties in logistics, feedstock prices, capacity, and technologies) ask for a slow and gradual introduction of mandates. The lessons learned from the road transport sector are that mandates are more effective after the early stages of sector development when certain scaling and learning effects are already realised, otherwise they can actually have a detrimental impact on the final cost of the fuel. Therefore, gradually increasing targets over time is crucial to avoid market distortions.

A blending mandate required at all fuelling point, may also lead to local price spikes driven by difference in availability of biojet fuels in different markets.

The introduction of mandates may also result into additional operation burden. International coherence in sustainability and reporting (see policy option 4) can partly reduce these additional costs.

Option 2c: A blending mandate for all transport fuels

The introduction of a mandate for all transport fuels – including biojet fuels - allows obliged parties to use biojet fuels in order to meet the overall target. Compared to the previous two options, the burden is not placed on the aviation sector alone but carried by other transport sectors as well. This allows for more flexibility and cooperation within the jurisdiction(s) where the mandate is placed.

**Oil companies**

Option 2a: A biojet fuel blending mandate for oil companies (fuel suppliers)

Option 2 is comparable to the instruments taken in most countries to promote biofuels for the road transport sector, as is the case in the UK or in Spain. In this situation, oil companies are obliged to bring a certain volume or percentage of biojet fuel on the market. They are the responsible parties to proof compliance, also of sustainability, risking a penalty for non-compliance.

As a result of this option:

- All fuel suppliers subject to an obligation will need to offer an amount of blended biojet fuel per year within the jurisdiction affected by the mandate. This means in practice that the blended biojet fuel is stored over various facilities. Some airplanes will use biojet fuel from wood residues, others from Camelina, others from waste;
- As biojet fuel is a drop-in fuel, this will most likely result into one price for (blended) jet fuel irrespective of the costs of the individual batches of biojet fuels. Jet fuel prices will therefore vary slightly within the jurisdiction affected by the mandate, although the fluctuations of the fossil fuel price will remain the dominant factor for establishing this price;
- There may be price distortion between jet fuel suppliers when neighbouring countries do not have a country mandate. The potential risks for leakage and an uneven level playing field (as explained under airlines) can be averted when a mandate is introduced to a wider geographical region.

The biojet fuel industry is still a very young and innovative industry. Challenges exist in terms of technical limitations, available capacities and other uncertainties. Clearly, setting a mandate requires some flexibility to meet these possible constraints. Same as under the RFS, requirements set by mandates could temporarily be waived when certain conditions are not met. This can for example be a mismatch in demand and supply. Another possibility is to look at mechanisms that offer more flexibility with respect to the location where the mandate is fulfilled (different jurisdictions for example). This is discussed in more detail in policy option 3.

Option 2b: A mandate for airlines

In this option, airlines are obliged to use a certain percentage of biojet fuel per year. When providing a blended biojet fuel, oil companies will need to meet and follow the sourcing and quality requirements, as stipulated by the mandate. In this situation, oil companies basically have the choice to blend biojet fuel into their jet fuel or not; and this will depend on the economics and demand in the market.

Option 2c: A blending mandate for all transport fuels

In case of an overall mandate, refiners and other obligated parties can meet their obligation based on their own business strategy. The large advantage of this option is that obligated parties can choose how to meet their obligation and biojet fuels is one more option. The experiences in the US(Platts, 2013) show that refiners meet their targets by blending road transport biofuels, by buying RINs, by exporting products or by altering their production of fuels that are not subject to a direct obligation of RINs (such as jet fuel).

The disadvantage for biojet fuel deployment is that many refiners have switched their production from regular diesel for road transport to conventional jet fuel to avoid the RINs obligation requirements. This increased production of conventional jet fuel could lower prices increasing the cost gap with biojet fuel making it even more economically uncompetitive.

**Feedstock producers, biojet fuel producers, exporters and distributors**

With the introduction of a specific biojet fuel blending mandate at the end of the value chain, biojet fuel producers will see an increased and guaranteed market for biojet fuels; the size and certainty depends on the design of the mandate. A more stable market allows biojet fuel producers to make the move from limited case-by-case biojet fuel production towards "business as usual" production. This allows reducing manufacturing costs of proven technologies. Competition – or synergies - exists when this demand goes hand in hand with demand for biofuels for the road transport sector (second generation biofuels for instance). Considering this, exclusive agreements throughout the chain will be needed to ensure supply, preferably in a regional approach (see also option 4). A mandate that allows the inclusion of biojet fuels in an overall renewable fuels mandate will certainly also create additional demand, although the amount is much more uncertain and determined by the competition with biofuels for other sectors different than aviation.

The strong involvement of the government under this option opens the possibility for the introduction of a government quota allocation system for biojet fuel producers. Similar allocation systems exist in the UK or in Spain for biofuels for the road transport. Under this system, biofuels production quotas are allocated between producer companies. Competent authorities decide on the quota allocation for a longer period of time considering environmental, security of supply, production capacity, economic and financial viability criteria.

Under policy option 2, economic agents in the supply chain (from feedstock production to fuel supply) will need to meet the sustainability and reporting requirements set up in the mandates. This brings additional administrative burden with associated costs to them. Obviously, these requirements should be harmonized as much as possible between jurisdictions affected by mandates to avoid unnecessary extra administrative burden for international operators.

**Airports**

As the biojet fuel is a drop-in fuel, zero to limited infrastructural changes will be needed at airports to support the deployment of biojet fuels in the aviation sector. Airports can choose to adopt a supporting role– especially in countries where biojet fuels is highly supported by governments and/or participating airlines (see also option 1).

**Stakeholders from other biofuels chains (road transport sector)**

The introduction of mandates for biojet fuels, combined with sustainability requirements, will have its impact on stakeholders in other transport sectors as well, especially in the road transport sector:

- A specific mandate for biojet fuels will create extra demand for feedstock processing and trading capacity in countries with already existing policies for other biofuels. Given the infancy of the biojet fuels sector (compared to biofuels for road transport), it is neither likely nor desired that a mandate will be introduced in countries without any implemented policy for biofuels;
- The additional option to consider biojet fuels under an overall renewable transport fuels mandate (option 2c) allows stakeholders from other transport sectors to include biojet fuels in their strategy towards fulfilling their obligation. The extra demand for feedstock processing and trading is therefore largely determined by the total demand in biomass feedstock and the mutual competition between biojet fuels and biofuels for other sectors, mainly road transport.

Parts of the production steps in the biojet fuel and other biofuels chains coincide, especially early in the chain. Consequently, stakeholders will need to comply with technical and sustainability requirements from different sectors. However, the biojet fuel market seems to be more restrictive as it is moving towards higher sustainability criteria than biofuels for road transport at the moment. Obviously, these restrictions can be averted when criteria become more harmonized between sectors. Ideally, a trader would be able to sell its feedstock to a producer of biojet fuel or to a producer of biofuels for road transport. One of the obvious requirements would be that existing certification systems broaden their scope to include biojet fuels.

**Others (governments)**

Governments have the capacity to align sectorial objectives and targets (road transport, aviation, etc.). This includes aligning capacity and demand, creating synergies, promoting innovation and bringing various interests together. It is the responsibility of the government to embed this in a long-term renewable energy strategy that includes the deployment of biojet fuels, translated to intermediary targets.

In this option, governments have an important role in pushing the deployment of biojet fuels through the setting of a mandate. This can be embedded in an overall renewable energy target. In the US, the RFS allows for the (further) inclusion of biojet fuels, whereas in Europe it is in principle also covered by the Renewable Energy Directive (which does not explicitly exclude biojet fuels). EU targets are defined for 2020. The preferred renewable energy mix is still to be discussed for after 2020; this could for example include a switch to electric vehicles, which will enlarge the spectrum of resources for road transport (e.g. wind, solar) and reduce pressure on biomass resources for other end-uses such as biojet fuels. The advantage of embedding biojet fuels in a renewable energy strategy is that governments have the possibility to steer developments and categories in an integrated approach.

Governments also have to enforce compliance, monitor developments and establish national plans. The level of control of a mandate is key for governments. The international dimension of the aviation sector makes this a complicating factor. The introduction of a mandate will also add some costs to the government, though these costs are small compared to the costs to be assumed by airlines and end users, and also small to the necessary economic support needed to make biojet fuels competitive under policy option 1. Costs for governments under option 2 are basically those required for building up additional capacity for consultation and development of policies. It is recommendable to strive for a lean framework largely driven by the market to avoid the costs of administrative or bureaucratic burden.

Stimulating the biojet fuel sector with mandates can bring a country in a front role position in the deployment and use of biojet fuels. When applied gradually, and properly incentivised with the right economic support measures, tt can create economic development and reduced dependency on the volatility of crude oil prices. The latter is especially of key importance for jet fuel importing countries (e.g. Australia, Japan), where aviation plays a key role in the economy. On the other hand, governments must be aware that the large-scale deployment of biojet fuels will bring its own price fluctuations and, once they are traded as commodities, crude oil and biomass prices will be likely coupled together.

Under this policy option, governments should be careful not to create additional distortions in the market, which may hamper the international competitiveness of their aviation sector. Stronger reliance on imports of biojet fuels or its feedstock may negatively impact the position of a country and enlarge dependence on other countries. This pleads for the development of domestic biojet fuel capacities, especially in key consuming countries.

## 6.5 Option 3: Co-regulation and carbon trading

Option 3 is based on the combination of two main policy instruments: co-regulation and a trading component, as economic instrument:

- 'Co-regulation' refers to the combination of voluntary industry initiatives with public regulation. Co-regulation is especially useful when there is a need to regulate economic activities performed outside the geographic borders of a country, as is the case in the aviation sector. It builds upon the combined strengths of public regulation and industry initiatives (see also chapter 3).
- The trading component refers to an international agreement on setting an agreed mechanism on biojet fuels trading in the aviation sector itself. This mechanism is set through a worldwide international agreement within the aviation sector itself and, if considered interesting, it can be related to the avoided emissions achieved, contributing to the overall emission reduction goals of the aviation sector.

The concept of co-regulation and the available individual support instruments under this category are explained in more detail in chapter 3. Co-regulation would allow airlines to work themselves on an ambitious targets setting and on designing the rules of the mechanism established for their compliance. This mechanism may include the specific provisions for setting targets, revising, waving and trading them, as well as monitoring their compliance. Under a co-regulation process, these agreements may be recognised by a supranational organisation like ICAO, and adopted by member countries within their own regulation systems. An international trading mechanism for trading biojet fuels "certificates" to fulfil compliance could potentially make the targets much more flexible to comply with. Table 14 shows in how far these individual instruments contribute to the global deployment of cost-effective biojet fuels by solving the underlying issues and their possible applicability in time (short or long term) and in different world regions.

*Table 14: Indication of suitability and applicability (in time and regions) of individual instruments that are categorized under policy option 3*

| Indicative:<br>O = to certain extent<br>OO = most likely<br>- = risk to be countereffective | Co-regulation | Self-regulation | Industry rules | Codes of Conduct | Public Private Partnerships | [redacted] | International trading system for a sector: biojet fuel certificates |
|---|---|---|---|---|---|---|---|
| **Solving the bottlenecks** | | | | | | | |
| <u>Biomass production</u> | | | | | | | |
| Lowers feedstock production costs | | | | | O | | |
| Stimulates yield increases | | | | | O | | |
| Reduces input costs | | | | | | | |
| Unlocks feedstock availability | | | | | O | | |
| <u>Logistics</u> | | | | | | | |
| Lowers feedstock transportation costs | | | | | | | |
| Improvement in logistics feedstock | | | | | O | | |
| <u>Conversion</u> | | | | | | | |
| Reduces technology conversion costs | | | | | O | | |
| Technology learning | | | OO | OO | | | |
| <u>End-use</u> | | | | | | | |
| Contributes to competitiveness biojet fuel | O | | | | O | | OO |
| Certainty in (growing) demand | O | O | O | | | | OO |
| Stimulates a level playing field | OO | OO | OO | | | | OO |

**Geographical applicability and likely period of introduction**

***Indicative*** O Short to mid term OO Mid to long term

| | Co-regulation | Self-regulation | Industry rules | Codes of Conduct | Public Private Partnerships | [redacted] | International trading system for a sector: biojet fuel certificates |
|---|---|---|---|---|---|---|---|
| World | OO | | | | | | OO |
| Europe | O | O | O | O | O | | OO |
| US | O | O | O | O | O | | OO |
| Asia | OO | O | O | O | O | | OO |
| Africa | OO | O | O | O | O | | OO |
| Latin America | OO | O | O | O | O | | OO |
| Introduction on country level | O | | | | O | | O |
| Introduction on project level | | O | O | O | O | | |
| International cooperation required | O | O | O | O | O | | O |

The combination of co-regulation and trading especially contributes to creating demand while ensuring an international level playing field in the aviation sector. Individual instruments, as code of conduct or PPPs, can be tailor-made for solving bottlenecks in various parts of the value chain.

Unlike option 2, the targets in option 3 are defined on international level by the aviation sector itself; this allows for a more flexible approach. The ambition level and rules of implementation is a process of negotiation with the different associations and its members.

Table 14 also shows that the design and agreement of a co-regulation process and of an international trading mechanism needs time. Policy option 3 can be seen as an ideal long-term solution; subsequent to or in conjunction with other options.

The key elements in policy option 3 are:

- An overall worldwide agreement forms the basis of this option; the ambition level of this agreement in terms of volume of biojet fuels and rules for its implementation highly influences the effectiveness of this option;
- The ambition level could be aligned with the objectives from industry associations, especially the ambitions of IATA for a carbon-neutral growth path after 2020;
- The industry associations would propose and negotiate these agreements with ICAO (UN International Civil Aviation Organisation), an intergovernmental organisation, in which IATA has an observer seat;
- ICAO would prepare a worldwide resolution, and recommend its adoption to ICAO's member states;
- This Resolution is adopted and further transposed into national legislations;

Cooperation forms a strong basis of this option, through the establishment of international platforms and multi-stakeholder initiatives. Additional support, including direct economic support, from national governments is complementary in to support the ambitions of the aviation sector and solve existing bottlenecks is complementary in this option.

Over time, the trading mechanism can possibly be linked to other already existing trading mechanism as the RFS in the US.

There are, however, various crucial factors for the success and effectiveness of this option:

- The ability to develop a robust, long-term framework;
- Reaching an international procedure and resolution is crucial in this option where the aviation sector seeks to take the responsibility of the implementation;
- The status of the agreement (in terms of legality, recognition by countries) and in terms of enforcement and compliance;
- The capacity of the responsible organization or authority to translate an overall international target to real implementation (level of credibility);
- The influence of price dynamics in fossil fuels and carbon prices.

Considering this, a solid international framework will not be reached easily and it may take time for its negotiation.

### 6.5.1 Impacts on stakeholders

Under this section, the impacts of policy option 3 are discussed.

**Airlines**

Coping with the international dimension of the airlines requires a flexible and more general approach compared to the road transport sector. Option 2 showed the time and geographical issues related to the implementation of national mandates. Co-regulation offers a more flexible approach, as it leaves the strategic implementation choices to the airlines themselves, assuming they can agree to one.

The trading mechanism opens the option for airlines to buy biojet fuels themselves or make use of trading biojet fuel certificates instead, based on their own possibilities. Airlines can use the biojet fuel in selected flights to their best strategy and in those countries where the blend is available.

International cooperation forms the basis of this option. The aviation sector can make use of already existing international cooperation initiatives to further explore the potential use of the co-regulation instruments such as:

- The European Biofuels Flight Path 2020 in Europe, combined with other multi-stakeholder initiatives as ITAKA and BRIDGE;
- The SUSTAF initiative and working group to develop a road map on the deployment of biojet fuels and sustainability on world level (with regional working groups);
- Already existing government cooperation, e.g. between the US and Germany.

The framework of international cooperation can also be used to standardize reporting and other requirements to avoid extra operational burden. This will also include an extension in registration and administrative operations of trading biojet fuel certificates.

**Oil companies**

This option allows for flexible production and supply of biojet fuels. Oil companies are more flexible in choosing where the biojet fuel is blended and stored and where it is not. These strategic business choices are based on demand and supply. This option requires agreements with airlines to identify supply hubs.

**Feedstock producers, biojet fuel producers, exporters and distributors**

Option 3 gives more certainty in market demand due to implemented co-regulation agreements. This allows for commercial choices to be made and most competitive technological pathways could be selected. Consequently, prioritization and development in terms of selection of feedstock, technologies and demand would be based on regional approaches – in cooperation with relevant stakeholders. On the less positive side, uncertainty would exist as to the level of direct economic support as this will differ from country to country.

Economic support should preferably be focused on improvements in regional value chains international cooperation.

**Airports**

Airports are interested in reducing their emissions to get the highest level of ACI Airport Carbon Accreditation (carbon neutral with paid offsets). Aircraft landing-take-off cycle fuel use counts towards airport goals. The Airports Council International (ACI) participates actively in roundtable discussions to align their own emission reduction efforts with the ambitions of the aviation sector and this could be further explored for the international agreements that form the basis of co-regulation.

**Stakeholders from other biofuels chains (road transport sector)**

The implementation of international co-regulation for the deployment of biojet fuels will have impacts on the road transport sector.

A closed trading mechanism for biojet fuel certificates (only within the aviation sector) will result in similar competition with the road transport sector as described in Policy Option 2 "Obligation driven".

The energy use in the road transport sector is roughly 10 times bigger than the energy use in aviation. A trading mechanism that considers exchange with other existing trading mechanisms (such as RINs) would increase the dynamics between the two sectors. The price interaction between both sectors will be closely interlinked. . Biofuel producers will pursue to maximize the margin they can make with second generation biofuels for road transport, as well as with biojet fuels. Many second generation conversion processes yield several fractions of fuels simultaneously, including biodiesel and biojet fuel. Trading mechanisms that allows exchange should encourage producers to produce as well biojet fuels in an adequate ratio for fulfilling the market demand at competitive costs.

In contrast to a country mandate, the focus of biojet fuel deployment under policy option 3 will be those countries where participating airlines have the highest interest due to their capacity and potential. Although this will most likely align with the most relevant biofuel producing countries, it may also create opportunities to stimulate capacity in countries that do not have an existing biofuels policy yet. This can create interesting opportunities in cooperation for the biofuels sector in general while using the other instruments considered in this option (e.g. PPPs). The international context of this option provides a good forum to harmonize sustainability and technical standards for both sectors as well.

**Others (governments)**

In this option, governments have different roles. They are strongly involved in international organisations (as ICAO) and are responsible to transpose their resolutions into national legislation. The design of a trading mechanism and its rules are key to avoid leakage effects, double counting and administrative burden. Governments may also take the role of monitoring compliance by fuel suppliers and airlines with co-regulation provisions at a country level

Governments can also participate with the development of public-private partnerships. It is essential that the technology risks are shared between the public and private sector. Experiences from the road transport sector show that it will otherwise be difficult to find private capital willing to invest in second-generation biofuels in the scale needed for engaging a market for biojet fuels. Governments can also decide to implement supportive policies, in addition to the existing framework, or propose rules for the interaction of trading mechanisms for biofuels certificates.

## 6.6 Option 4: Voluntary driven

This option illustrates a business as usual case. Under this option, the deployment of biojet fuels is fully voluntary driven. The industry itself can agree to commit to increase the use of biojet fuel over time. Effectively, this would result in a continuation of the current situation where an increasing number of airlines develop projects in strong cooperation with biojet fuel suppliers to increase the overall percentage of biojet fuel over time. An advantage of this approach is that biojet fuels will only be used where it is serves a commercial purpose and is most likely very cost effective. A good example of this is the project of Air France-KLM that recently introduced regular flights between Amsterdam and New York with a blend of biojet fuels, produced by SkyNRG. There is no industry or government mandate. Companies choose individually for incorporating biojet fuels. Economic incentives from governments are either zero or limited.

Table 15 shows the individual instruments that can be introduced under this option, orY combinations of them. They are explained in more detail in chapter 3.

*Table 15: Indication of suitability and applicability (in time and regions) of individual instruments that are categorized under policy option 4*

| Indicative:<br>O = to certain extent<br>OO = most likely<br>- = risk to be countereffective | Networking | Partnerships | Contracting between partners | R&D cooperation agreements | Harmonization standards | Certification and labelling | Voluntary agreements maufacturers and providers | Voluntary private procurement |
|---|---|---|---|---|---|---|---|---|
| **Solving the bottlenecks** | | | | | | | | |
| | | | | | | | | |
| Biomass production | | | | | | | | |
| Lowers feedstock production costs | | | O | | | | | |
| Stimulates yield increases | | | | O | | | | |
| Reduces input costs | | | | | | | | |
| Unlocks feedstock availability | O | O | | | | | | |
| Logistics | | | | | | | | |
| Lowers feedstock transportation costs | | | O | | | O | | |
| Improvement in logistics feedstock | O | O | | | O | | O | |
| Conversion | | | | | | | | |
| Reduces technology conversion costs | | | | O | | | O | |
| Technology learning | O | O | | | | | | |
| End-use | | | | | | | | |
| Contributes to competitiveness biojet fuel | | | | | | | O | |
| Certainty in (growing) demand | | | | | | | | O |
| Stimulates a level playing field | O | O | | | O | O | | |
| | | | | | | | | |
| **Likely period of introduction** | | | | | | | | |
| ***Indicative*** | O | Short to mid term | | | OO | Mid to long term | | |
| World | | | | | | | | |
| Europe | O | O | O | O | O | O | O | O |
| US | O | O | O | O | O | O | O | O |
| Asia | O | O | O | O | O | O | O | O |
| Africa | O | O | O | O | O | O | O | O |
| Latin America | O | O | O | O | O | O | O | O |
| | | | | | | | | |
| Introduction on country level | O | O | | O | O | O | | |
| Introduction on project level | O | O | O | O | O | O | O | O |
| International cooperation required | O | O | O | O | O | O | O | O |

### 6.6.1 Impacts on stakeholders

Under this section, the impacts of the policy option 4 are discussed.

**Airlines**

In this option, the deployment of biojet fuels for airlines is fully voluntary driven. The possible motivations to use biojet fuels are:

- Individual CSR policies and niche demand on specific routes (for example the KLM flights between New York and Amsterdam);
- Fossil fuel dependency in jet fuel importing countries (for the long term);
- Changes in economics between the jet fuel – biojet fuel – carbon prices, although an effective carbon trading system is not in place. Substantial price increases in fossil fuels or carbon price may motivate airlines to switch to biojet fuels in the long term, without any economic support or agreement.

In this option, airlines themselves can develop specific programs to create demand. An example is the Dutch KLM Corporate Program (a form of voluntary procurement) where 14 large companies have committed themselves to fly 'green'. SkyNRG has the ambition to extend this program to other world regions as well.

In this option, the desired cost reductions in the production costs of biojet fuels will only be realised once a substantial volume is reached, which is not very likely in this option.

Cooperation programs, partnerships and further harmonization in standards and certification can contribute to creating a level playing field in the market and making joint efforts most effective.

**Oil companies**

Due to the expected small demand in biojet fuels, fuel suppliers have limited interest for this market: their core market is fossil fuels and there is no reason to deviate from it. Consequently, a limited number of oil companies may offer blended biojet fuels to airlines, creating a niche market with production costs and sales prices remaining very high .

**Feedstock producers, biojet fuel producers, exporters and distributors**

Responsibilities of this stakeholder group will remain restricted to meeting their individual clients' requirements. Production processes for biomass feedstock and conversion remain costly. Prospects for the required technological innovations are limited and highly dependent on innovations made in the biofuels for the road transport sector. Biojet fuel production is a niche market and remains largely limited to small-scale production and individual, ad-hoc projects. Partnerships, networking and cooperation between stakeholders can join forces to make progress in technology and innovation. This is, however, most likely not sufficient to make the next step towards international commercialization and use of the biojet fuels. .

**Airports**

Deployment of biojet fuels takes place on limited scale through individual, scattered initiatives. Airports continue functioning as they do now and the topic has little or no attention in the international discussion.

**Stakeholders from other biofuels chains (road transport sector)**

Initiatives for the deployment of biojet fuels are voluntary and scattered. At the same time, there is an existing mandate with economic support for the biofuels used in the road transport sector, therefore synergies with the aviation sector are not used. There is neither competition nor substantial demand for biojet fuels. The biojet fuel market is considered a niche market with high costs and sales prices.

**Others (governments)**

There is no role, or just a very limited one, for national governments in this option. There is neither a mandate nor any economic support for the deployment of the biojet fuel sector. Mandates and economic support exist for biofuels produced for the road transport sector. Some innovations may indirectly influence the development of biojet fuels.

## 6.7 Summary of findings

- Stakeholders in the biojet fuel value chain are dependent of each other. The impacts of a policy option – both negative and positive – are interrelated and cannot be seen separately. The majority of the stakeholders participate in multiple economic sectors. External drivers and competition with other sectors can largely influence the success or failure of the biojet fuel sector and any policy strategy should take these external drivers into consideration.
- There is no single policy instrument that solves all the underlying issues to come to the global, large-scale deployment of cost-effective biojet fuels alone. Solving these issues together requires the design of a framework that includes different types of instruments;
- Instruments under policy option 1 (price driven) and policy option 4 (voluntary driven) can be introduced on the short- to mid-term. The introduction of instruments under policy option 2 (obligation driven) and policy option 3 (co-regulation) generally needs more time: these instruments are applicable when the sector is more mature and some form of international agreement is reached;
- Instruments that can be introduced at project level can be introduced in the short to midterm; they can be tailor made and made specific for solving issues in regional value chains;
- Policy option 3, co-regulation, needs more time for development. On the longer term though, this policy option would be more robust and stable than the rest of options.
- The stability of the market is more at risk under option 1 as political changes or national budget reasons can stop implemented economic incentives with little or no prior notice.

Table 16 presents the key findings on the impacts on stakeholders for each policy option. The results show that there is no optimum solution for all stakeholder groups: every option has its own advantages and disadvantages. The overall relative power and cost burden of the four policy options to reach the objective is further discussed in chapter 8.

*Table 16: Summary of impacts on stakeholders under four different policy options*

| Stake-holders | Option 1: Price driven | Option 2: Obligation driven | Option 3: Co-regulation and trading | Option 4: Voluntarily driven |
|---|---|---|---|---|
| **General** | • Can push markets (price decrease, volume increase) especially in 1st phase of deployment | • Creates volume although costs may remain high – at least on short to mid term<br>• Possibilities for up-scaling; | • Allows flexibility aviation sector geographically and in time<br>• Trading system<br>• Focus on reduction carbon emissions;<br>• Strong international angle | • Business as usual with no incentive for biojet fuel deployment;<br>• Limited to individual project initiatives |
| **Cost carrier** | • Governments mainly | • For all sub options the final consumers (passengers). Additionally:<br>• 2a: Oil companies<br>• 2b: Aviation sector<br>• 2c: Renewable energy sector<br>• Direct economic support from government | • Aviation sector and final consumers (passengers)<br>• Direct economic support from government | • Cost (limited) is carried by the aviation sector and final consumers (passengers) |
| **Airlines** | • Economic driven<br>• Supports innovation<br>• Long term uncertainty in deployment | • 2a: Mainly price driven<br>• 2b: strictness limits flexibility geographically<br>• Risk for uneven level playing field;<br>• Implementation questionable<br>• Flexibility in time: temporarily waiving mandate when criteria not met<br>• 2c: allows sharing burden with renewable energy sector | • Airlines are flexible in time and geographically to implement target<br>• Strategic implementation choices left to the airlines<br>• International agreements are needed<br>• International approach and coherence required<br>• Success dependent on credibility, level of involvement and effectiveness system | • Deployment fully voluntarily driven and remains costly unless fossil fuel / carbon prices change substantially<br>• Ad-hoc initiatives; no up-scaling |
| **Oil companies** | • Adjustment to demand – supply | • 2a: Strictness limits flexibility in space;<br>• Risk for uneven level playing field<br>• 2b: Follows demand and technical / sustainability requirements<br>• Flexibility in time: temporarily waiving mandate when criteria not met<br>• 2c: integration | • Allows for flexibility in supply;<br>• Requires international agreements | • Limited number of oil companies supply biojet fuels based on mutual interest |

| | | | | |
|---|---|---|---|---|
| | | with renewable energy sector (most commercially attractive option) | | |
| **Feedstock producers, biojet producers, traders** | • Economic support results into innovation<br>• Meeting demand clients priority<br>• Long-term uncertainty<br>• Competition from other sector in price dynamics | • Guaranteed demand, especially coming from stronger economies (US, Europe);<br>• Long term scaling effects (and cost reductions) expected); | • Innovations and commitments are cross-boundary (regional value chain approach);<br>• International agreement ensures demand<br>• Prioritization based on commercial development pathways (where, how) and level of support | • Responsibilities limited to client needs;<br>• Production and conversion remains costly;<br>• Innovations dependent from biofuels sector |
| **Airports** | • Limited | • Limited | • Limited<br>• Possible stronger role involvement ACI | • Business as usual |
| **Stakeholders from other biofuels chains (road transport sector)** | • Benefit from support biojet fuels<br>• Possibilities for synergies and cooperation | • Opportunities in synergies and cooperation (demand, aligning innovations);<br>• Risk for competition in feedstock and overlapping processes | • Opportunities in countries with no existing biofuels policy framework;<br>• International framework may contribute to harmonization in biofuels sector;<br>• Interaction price, market dynamics (when trading mechanisms are linked) | • No competition or substantial demand from the biojet fuel sector.<br>• This is considered a niche market |
| **Others (governments)** | • Strong economic support<br>• No control over realisation | • Strong control is required.<br>• Economic support expected.<br>• Limitations in implementation (when mandate is at airlines especially) | • General Framework setting<br>• Supporting and facilitating role;<br>• Monitoring role;<br>• Requires recognition of international agreement by countries;<br>• Strong international cooperation required | No role and supporting role through creating awareness with the public and by willingness to pay premium for tickets. |
| **Relative power to drive prices down along time** | High | Medium. Requires economic incentives before this option can be implemented | Medium. More flexible approach is possible Requires economic incentives before this option can be implemented. | Low |

# 7 Model based approach for biojet fuel prices trends

An Excel model has been developed for the specific use of this study. The model delivers the quantitative backbone for the development, support and dialogue with policy makers for the appropriate combination of biojet fuel support policy instruments applied at a global level.

## 7.1 Model characteristics and limitations

The model consists of four modules:

1. Assumptions module (dataset)
2. Demand air travel module
3. Supply biofuels module
4. Demand biofuels module

Figure 32 shows the interaction between the four sub-modules. Each sub-module is described in more detail below.

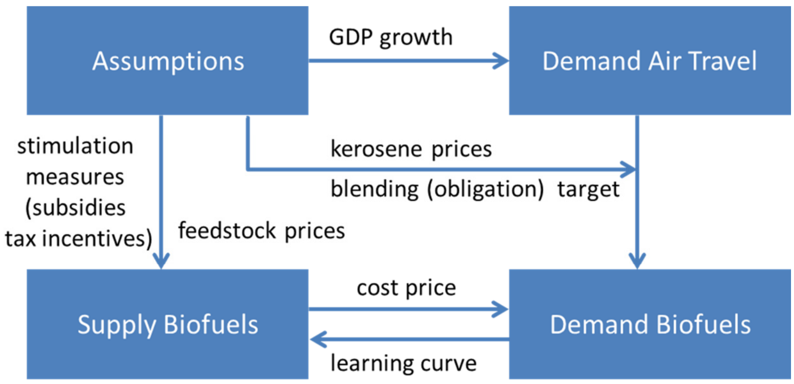



*Figure 32: Schematic overview of the model.*

### 7.1.1 Assumptions module

The assumptions module consists of a dataset of price scenarios for:

- Brent oil
- Jet fuel
- Carbon, and
- Potential feedstock resources for biofuels.

In addition, the database consists of various potential policy measures for stimulating blending of biojet fuel with jet fuel, including incentives for feedstock, technology and infrastructure, implementation of blending obligations, etc.

The assumptions module also includes a list of $CO_2$ emission factors determining the amount of $CO_2$ emitted per unit of fuel, airplane efficiencies, and other relevant parameters.

The scenarios are generally based on the IEA world energy outlook 2012 scenarios and are further specified by including assumptions and air travel demand forecasts as presented by IATA.

Specifically on biojet fuels, the dataset assumes learning curves on conversion and feedstock production for a variety of biojet fuels, which will impact overall fuel costs.

### 7.1.2 Demand air travel module

The demand air travel module determines the demand for air travel over time. The module includes five regions, i.e. Europe, Asia, North America, South America and Sub-Saharan Africa. Consequently, the module will determine the air travel demand for the following routes:

- Intra N. America
- Intra Europe
- Intra Asia
- Intra S. America
- Intra Sub-Saharan Africa
- Trans-Atlantic
- Trans-Pacific
- Europe-Asia

The demand for air travel is based on scenarios from the Forecasting and Economic Support Group (FESG) of CAEP. Figure 33 presents the schematic overview of this module. Scenarios for air travel demand are taken from IATA and converted into demand for jet fuel using expected efficiency improvements over time.

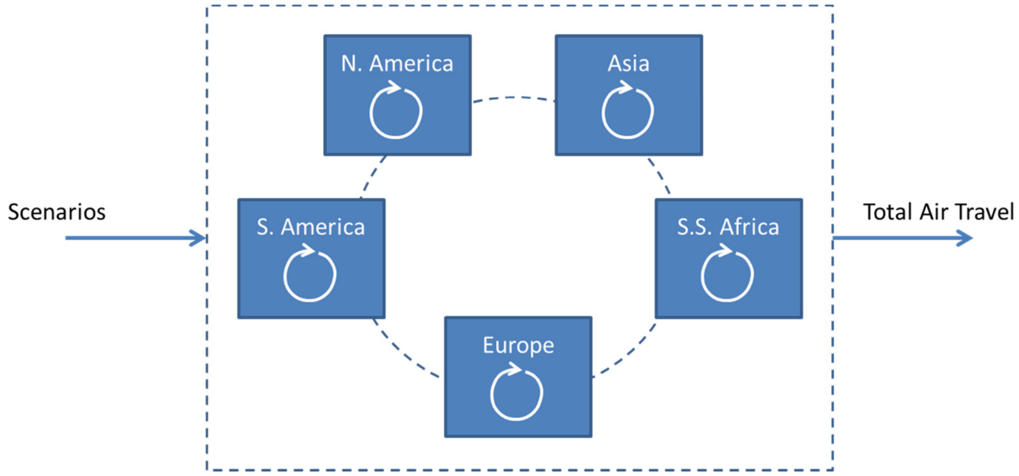



*Figure 33: Schematic overview of Demand Air Travel module*

### 7.1.3 Biofuel supply module

The biofuel supply module determines the expected future cost curves of biojet fuels based on a selection of technologies and feedstock (see also chapter 2.1 and 2.2). Cost calculations are performed for the following technology-feedstock combinations:

- HVO /HEFA
  - Jatropha
  - Camelina
  - Algae
- F-T (Fischer-Tropsch)
  - Straw or woody biomass

- ATJ (Alcohol to Jet)
    - Alcohol

The main factors determining the cost price of biojet fuel are the market price for the feedstock and the investment costs. Further the model contains assumptions for other costs such as transport. The investment costs for a technology are assumed to reduce when more installations are installed for operation. Learning curves have been developed resembling including a maximum learning factor in time and a maximum potential cost reduction. Figure 34 presents the schematic overview of this module.

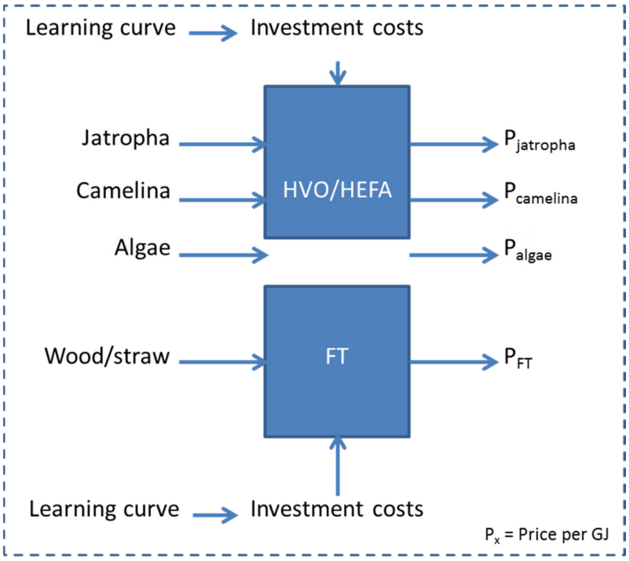



*Figure 34: Schematic overview of Supply Biofuel module.*

### 7.1.4 Biojet fuel demand module

This module calculates the demand for biojet fuel based on the expected overall demand for aviation and the instruments applied to stimulate biojet fuel use. The calculation of demand for biojet fuel depends on the way its use is stimulated. In case of an obligatory blending percentage, the key output will be the impact on the fuel price, and the demand for biojet fuel will solely depend on the development of air travel. When the use of biojet fuels is stimulated through other (i.e. economic incentives) instruments the biojet fuel price becomes an input and not an output. In this case, the key output of the model will be the delta between the cost price of biojet fuel and the fossil jet fuel price (including the costs of carbon, if any). In theory, the switch level should result in a binary decision whether to use a (blend with) biojet fuels or just fossil jet fuel. However, in practice, biojet fuels will only penetrate the market gradually when it becomes profitable, which is reflected by the model by introducing a market penetration rate. This market penetration rate can be limited by a maximum number of new biojet fuel production plants coming online each year.

Hence the output (and thus input) of the demand biojet fuel module depends on the selected policy measure. An overview of the Biojet fuel demand module is given in Figure 35.

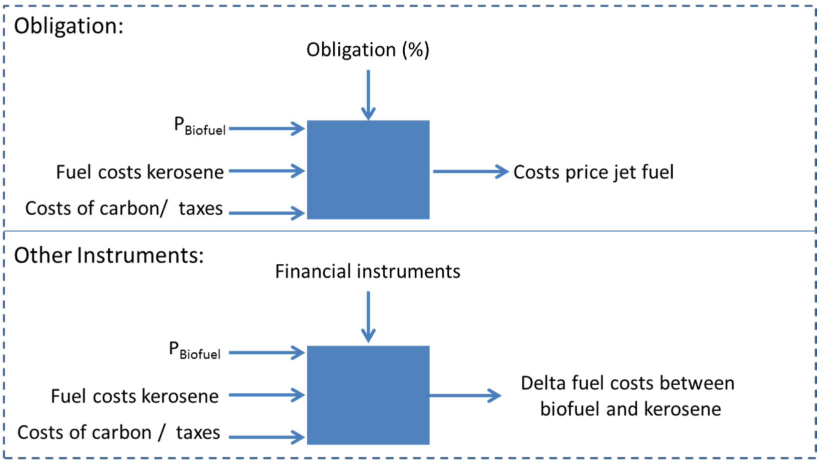



*Figure 35: Schematic overview of Biojet fuel demand module*

**Technology assumptions (e.g. efficiency, efficiency impact of biojet fuels)**

In order to assess the total demand for jet fuel and the specific demand for biojet fuel, the FESG forecasts are used. The model uses the total historical fuel consumption per year and the total ton kilometres to calculate the average fuel efficiency as the total historical fuel consumption. The model assumes no efficiency loss as a result of biojet fuel usage, as drop-in fuels are assumed to be technologically similar to fossil fuels.

## 7.2 Selection and description of scenarios

Scenarios are used to explore economic calculations over time. Scenarios provide story lines in time and should therefore not be considered as fixed predictions into the future. The scenarios used in this model apply to oil, jet fuel and carbon prices over a time frame of 30 years. The scenarios provide input on possible future prices of some of the key parameters, such as jet fuel and carbon prices.

The current markets scenario (Market forwards) and three IEA scenarios have been selected as the most relevant and are developed further.

### 7.2.1 Market forwards scenario

The Market forwards scenario is entirely based on current market prices and forward markets as far as possible (in practice to 2020). Numbers beyond 2020 are extrapolated from the forward curves. The scenario assumes relatively low carbon and oil prices where demand growth can be met by exploiting unconventional gas and oil reserves and further growth of coal production. The Market forwards scenario is not based or linked to any of the four IEA World Energy Outlook 2012 scenarios.

### 7.2.2 IEA scenarios

The IEA published in its world energy outlook 2012 four scenarios: Current policies, new policies, 450 and efficient world scenario. The first three IEA scenarios have been selected for this study Table 17 summarizes these selected IEA scenarios.

The Current policies scenario anticipates no new policies with only moderate higher carbon prices and substantially higher oil prices as a result. The New policies scenario still anticipates a strong demand for oil resulting in an expected oil price of 125 US$ per barrel in 2035 and a carbon price of 45 US$ per tonne in 2035. This scenario is seen as the central scenario by the IEA. The 450 scenario is the most extreme and results in relatively low oil prices of around 100 US$ per barrel in 2035 as a result of lower demand, and high carbon prices of 120 US$ per tonne in 2035

*Table 17: Three IEA selected policy scenarios*

| | **Current policies scenario** | **New policies scenario** | **450 scenario** |
|---|---|---|---|
| **Definitions** | Government Policies that have been enacted or adopted by mid-2012 continue unchanged. | Existing policies are maintained and recently announced commitments and plans, including those yet to be formally adopted are implemented in a cautious manner. | Policies are adopted that put the world on a pathway that is consistent with having around a 50 % chance of limiting the global increase in average temperature to 2°C in the long term, compared with pre-industrial levels. |
| **Objectives** | To provide a baseline that shows how energy markets would evolve if underlying trends in energy demand and supply are not changed. | To provide a benchmark to assess the potential achievements (and limitations) of recent developments in energy and climate policy. | To demonstrate a plausible path to achieve the climate target. |

### 7.2.3 Forecast for oil, jet fuel, and carbon prices

The bases of the calculations are the scenarios for oil, jet fuel and carbon prices. Figure 36 shows the global crude oil prices for the IEA and Market forwards scenarios. Jet fuel prices are calculated based on historical correlations between oil and jet fuel prices (see Figure 37). The jet fuel price is highest over time under the Current policies scenario and lowest under the Market forwards scenario. All prices are in 2011 US$.

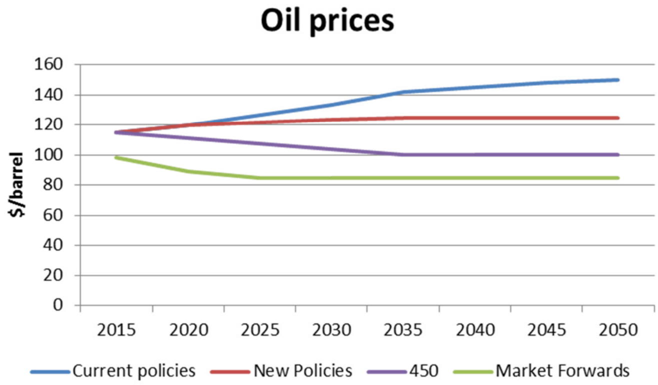



*Figure 36 Oil price scenarios*

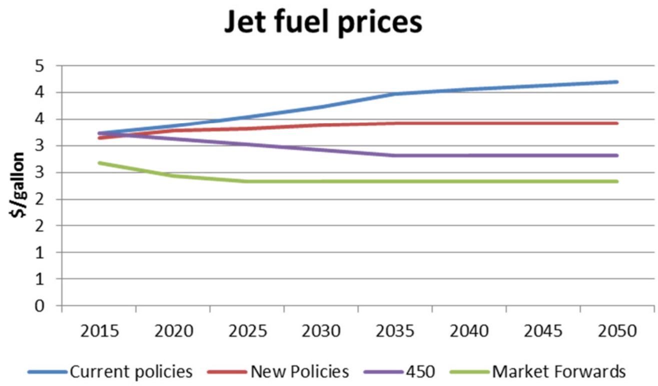



*Figure 37 Jet fuel prices*

Different scenarios for carbon prices exist for different regions. Figure 38 is the assessment made of the global trend of carbon prices under different scenarios. The market forwards scenario is an extrapolation of current ETS prices into the future. The carbon price will become highest under the '450' scenario.

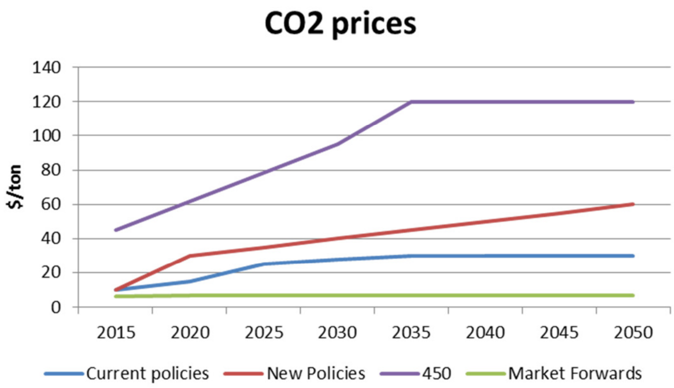



*Figure 38 Global carbon prices in US$/ton*

## 7.3 Technology learning curves and feedstock prices

Important assumptions for the estimation of the trend for biojet fuel prices are linked to the technologies learning curves and to the feedstock prices

### 7.3.1 Learning curves

The learning curves are used to provide an estimate of the maximum amount that can be saved on the conversion costs for biojet fuels (as a fraction between 0 and 1) and the investments needed to achieve those savings, given as the number of plants (horizontal axis). Figure 39 provides the current learning curves implemented in the model. Parameters that determine the rate at which cost savings can be reached, and the minimum and maximum savings, can be changed in the model according to expectations. In general it is assumed that a higher blending will trigger more investments in plants, which in turn will deliver cost savings at a faster pace. Further it is assumed that FT has a higher cost reduction potential than HVO and ATJ. F-T is at an earlier stage of development and if implemented on a large scale, the technology is very promising.

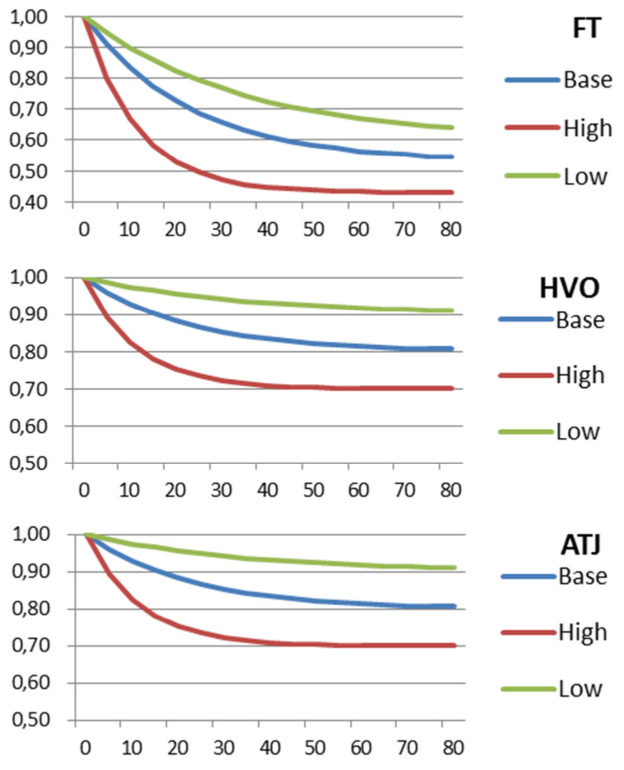



*Figure 39 Learning curves for three different technologies*

### 7.3.2 Feedstock prices

Camelina, Jatropha, Algae, wood residues and straw, and alcohol are used as potential feedstock for the selected technologies. Camelina and Jatropha are assumed to correlate strongly with fluctuations in oil prices. The base scenario for feedstock price is correlated to the new policies scenario. Sensitivities are calculated with the base scenario and not correlated to other oil price scenarios (see Figure 40).

It is unclear if correlations of the feedstock prices in the future with oil prices will be similar as in the past. It is possible that oil prices will be lower because of lower demand (and high carbon prices), whereas feedstock prices for biojet fuels will actually be higher because in that scenario demand for biojet fuels will be much higher.

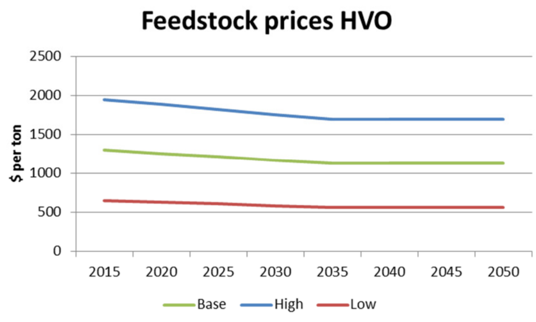



*Figure 40 Feedstock prices of Camelina and Jatropha*

Wood residues and straw follow their own forecasts (which are based on literature and interviews), uncorrelated to oil. Future prices are expected to increase as growing demand for a variety of end-uses will push prices up (see Figure 41).

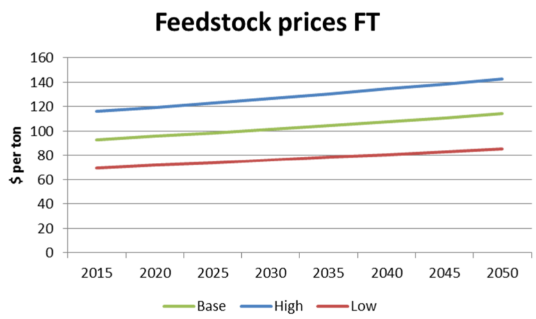



*Figure 41 feedstock prices of wood residues and straw*

Feedstock prices for algae are probably the most speculative because algae oil has many other more valuable uses in more expensive industries and its use for energy purposes is still in a very early phase and therefore highly unpredictable. Current prices are extremely high but the industry expects significant improvements in the production technology of algae in the next decades (see Figure 42).

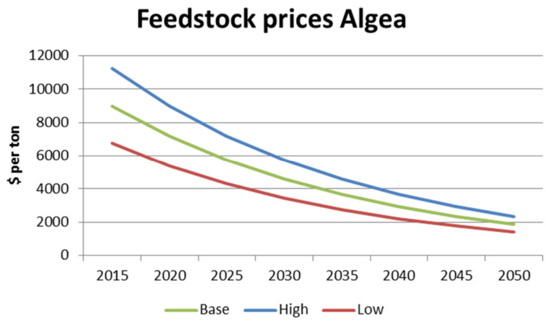



*Figure 42 feedstock prices of algae*

Basically alcohol (Figure 43) behaves similar to vegetable oils: both are traded internationally as a commodity. Both prices have in the last years strongly correlated to fossil fuel price variations, and it is foreseen that this trend remains. The base scenario is correlated to the new policies scenario. Sensitivities are around the base scenario and not correlated to other oil price scenarios, similar as for Camelina and Jatropha. It is unclear if correlations in the future will be similar as in the past. It is possible that oil prices will be lower because of lower demand (and high carbon prices), where feedstock prices for biofuels will actually be higher because in that scenario demand for biofuels will be much higher.

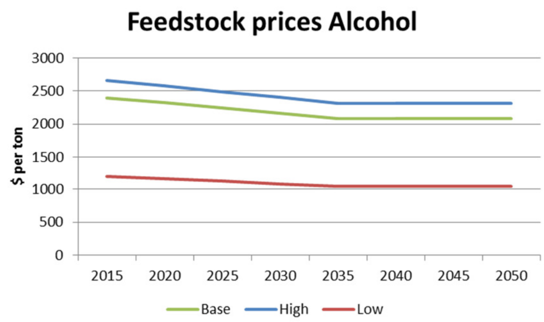



*Figure 43 feedstock prices of alcohol in US$/ton*

## 7.4 Biojet fuel prices (no incentives applied)

There does and will not exist yet a single biojet fuel price. Different technology-feedstock combinations result in different prices and price forecasts. Biojet fuel prices are dependent on the technology, the expected learning curves and above all on feedstock prices. The competitiveness of biojet fuels is further dependent on price developments of carbon and jet fuel. The next graphs show the outcomes of the model, which have been developed to calculate a variety of scenarios for biojet fuel prices (non-blended) for different technologies.

The biojet fuel prices in this section are based on the new policies scenario as an example. The results demonstrate the impact of progressive blending on the price of biojet fuels developing according to the percentages in Table 18. There are no other policy instruments assumed and it is for the purpose of these calculations also not based on any other instrument. Blending here has the sole purpose of increasing demand which in turn triggers learning.

The amount of biojet fuel blending influences the production capacity that is needed to meet required volumes, and therefore the timeline at which lower production cost can be reached: The more capacity is built, the faster learning improves economics. The numbers in the model can be changed to calculate the impact of higher of lower blending percentages on the price of biojet fuels. A higher percentage results in a faster learning curve.

*Table 18 Blend percentages*

| **2020** | **1%** |
|---|---|
| **2025** | 2% |
| **2030** | 3% |
| **2035** | 4% |
| **2040** | 5% |
| **2045** | 7% |
| **2050** | 10% |

With these assumptions, the model allows to make forecasts on the production costs for different types of biojet fuels. Figure 44 provides the expected biojet fuel price under the assumptions as explained in the previous section 7.3.

The figures below show the biojet fuel prices for different feedstock-technology combinations:

- The dark blue area is the feedstock price (SRMC = short run marginal cost);
- The light blue area are the fixed investment costs in conversion plants;
- The green, red and purple lines provide the estimated market prices including $CO_2$ prices (for the different regions), the black line is excluding $CO_2$;

Figure 44 shows that feedstock prices (Camelina oil or Jatropha oil) behave similar and are considered to behave equal to the price trends of other vegetable oil commodities (Soybean oil, Palm oil). In such feedstock price scenario, the resulting biojet fuel is not competitive against jet fuel.

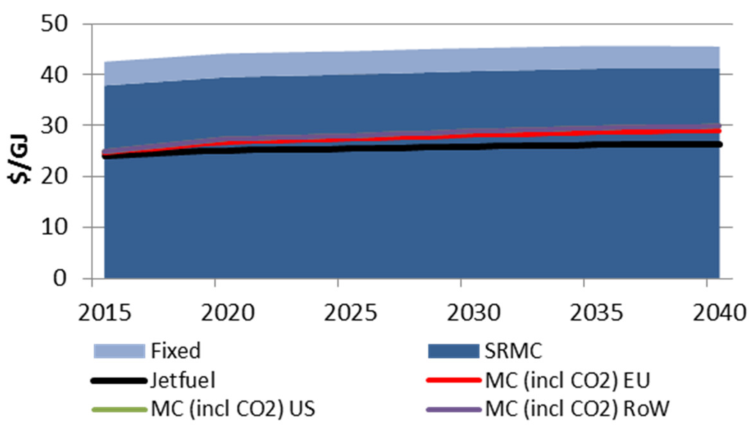



*Figure 44 Biojet fuel price based on HVO for Camelina and Jatropha*

As already explained, the price development for algae (see Figure 45) is speculative. The variable feedstock price determines for the largest part the final production cost of biojet fuel. Based on underlying assumptions, the biojet fuel price does not become cost competitive with jet fuel.

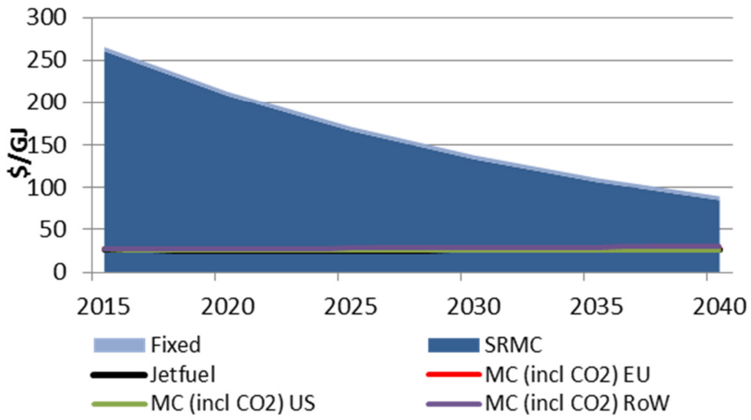



*Figure 45 Biojet fuel price based on HVO for algae*

Figure 46 shows that with FT-technology fixed (investment) costs and variable (feedstock prices) are relatively balanced. Prices are not yet competitive. However, the difference between the biojet fuel cost and market prices for jet fuel is not large. Cost reductions in the production process are possible. If feedstock price increases would be modest, the technology could become competitive in the foreseeable future.

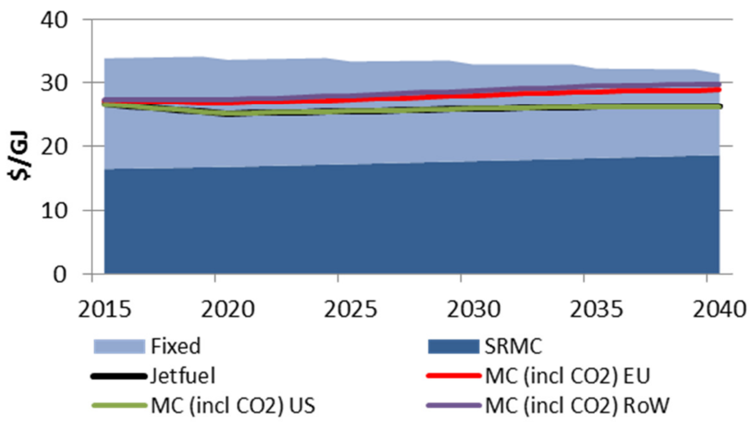



*Figure 46 Biojet fuel price for Fischer Tropsch (F-T)*

The production of alcohol from ATJ technology for the use in jet fuel is setting the production price relatively high (see Figure 47) because of the high cost for alcohol. Cost reductions have to be substantial in order to develop a cost competitive fuel.

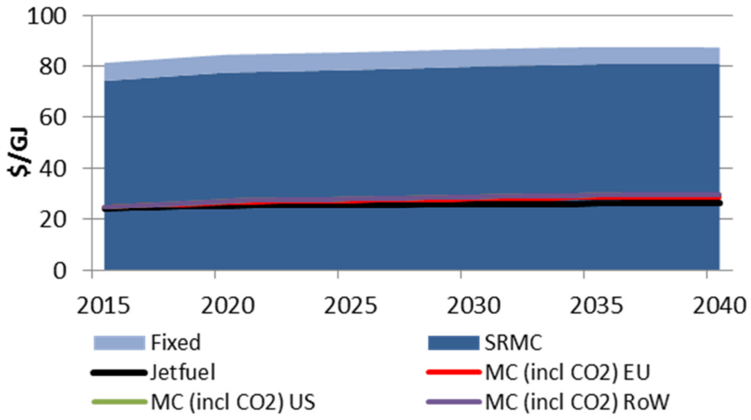



*Figure 47 Alcohol to jet fuel (ATJ)*

The outcomes clearly demonstrate that the feedstock prices are the most important factor in the case of HVO and ATJ. For the F-T process, the contribution is almost equally divided between feedstock prices and investment costs in the conversion plants.

## 7.5 Effects of carbon and jet fuel prices on the (blended) fuel price

A number of sensitivities have been performed in the model to demonstrate the impact of different blend percentages, different carbon prices, and different jet fuel prices on the blended fuel price. The base parameters in these sensitivities are kept constant as shown in **¡Error! No se encuentra el origen de la referencia.**Table 19 for the purpose of calculations in this section only.

*Table 19 Base parameters for analysis*

| **Blending %** | **5** |
|---|---|
| **$CO_2$ US$ per ton** | 10 |
| **Biojet fuel US$ per GJ** | 40 |
| **Jet fuel US$ per gallon** | 2,85 |
| **Jet fuel US$ per GJ** | 20,37 |

Jet fuel blend prices are presented in US$ per GJ. The first sensitivity (see Figure 48**¡Error! No se encuentra el origen de la referencia.**), is the resulting change in blended jet fuel prices because of different blending percentages, calculated for two different biojet fuel prices which are kept constant (30 and 40 US$ per GJ). Other key inputs are kept constant. A 3% blend would thus increase the blended jet fuel price by 2,5% if the underlying biojet fuel price is 40 US$ per ton.

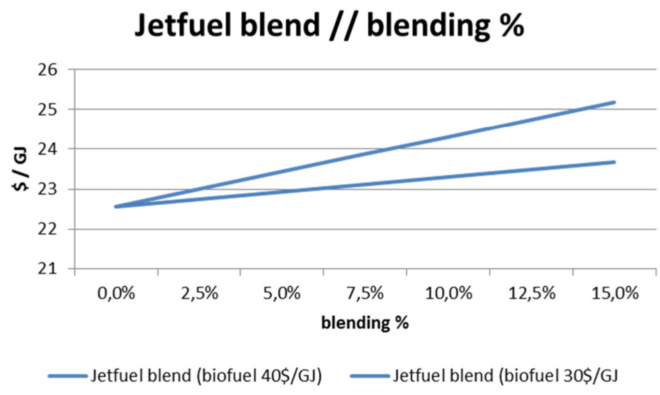



*Figure 48 Jet fuel blend prices at different blending percentage*

The next sensitivity is the impact of different carbon prices on the blended jet fuel price (see Figure 49**¡Error! No se encuentra el origen de la referencia.**). Within the range presented of up to 120 US$ per ton $CO_2$, the blended jet fuel price is always higher than the regular jet fuel price. The breakeven is at a carbon price of 250 US$ per ton, based on the base parameters in Table 19.

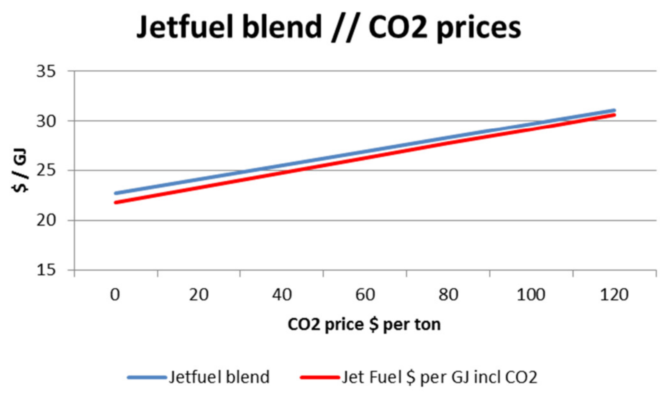



*Figure 49 Jet fuel blend prices in US$/GJ for different carbon prices*

The last sensitivity in this section is the resulting (blended) jet fuel price because of different biojet fuel prices. Figure 50**¡Error! No se encuentra el origen de la referencia.** illustrates the impact of higher biojet fuel prices on the blended jet fuel price. The price increase of the blend ranges from 2% to 9% depending on the biojet fuel price.

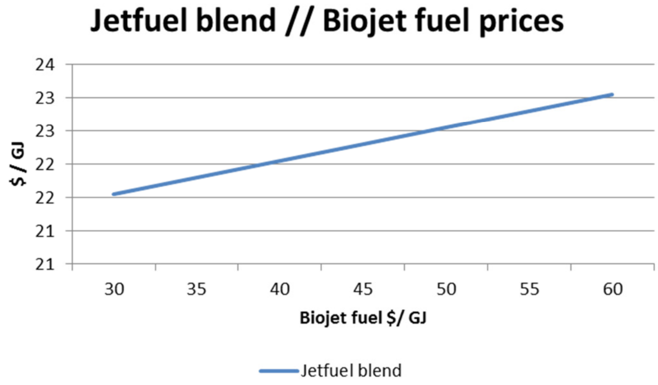



*Figure 50 Jet fuel blend prices for different biojet fuel prices*

# 8 Modelling policy options

## 8.1 Construction of policy options

The four policy options presented in chapter 6 are combinations of various instruments. For the purpose of modelling, the tool groups all instruments in three groups for facilitating the model's calculations:

1. Economic incentives that stimulate the use of biojet fuels: They can be used for R&D, for investments in conversion plants or as an incentive to feedstock to reduce costs. They can be set for the different technologies and feedstock involved. Economic incentives have a direct impact on the production cost of biojet fuels in the model. An overall budget limitation on the incentives can be applied in the model;
2. The introduction of mandates: Blending mandates at different years in the future are modelled to produce a system that gradually introduces a blending obligation to keep up with the growth of aviation, thereby capping $CO_2$ emissions. The output provides the required tons of biojet fuels to meet the mandate and the resulting carbon reduction achieved under the defined scenarios;
3. The introduction of a market price for carbon emissions: The assumption is that airlines will have to pay a carbon price. This either happens by acquiring carbon emission rights, or by paying a carbon tax. Both options are modelled identically in the tool. The model calculates at which prices substitution of conventional jet fuels with biojet fuels become economically feasible. At current carbon market prices, this has little impact.

Concerning mandates and the market price for carbon, the model looks into three separate regions: Europe, North America, and the rest of the world. Underlying data and increased modelling complexity make further regional divisions not possible.

Table 20**¡Error! No se encuentra el origen de la referencia.** summarises the construction of policy options. These policy options are combined in the model with described market scenarios and assumptions concerning technology learning curves and feedstock prices in order to research in more detail the possibilities of each policy option. A number of examples are then calculated with the model for illustration of those possibilities.

*Table 20 Modelling policy options*

| Policy Option instruments | Mandate | Incentive | Trading Mechanism |
|---|---|---|---|
| Option 1: Price driven | None | Incentives for investments, R&D, feedstock | Depending on scenario |
| Option 2: Obligation driven | Yes, according to assumptions | Limited incentives on investments | Depending on scenario |
| Option 3: Co-regulation | None | None | Yes |
| Option 4 | None | None | Depending on |

| Voluntarily driven | scenario |
|---|---|

## 8.2 Sensitivities and assumptions per policy option

The model provides alternative approaches and various combinations for inputs. This allows the model to make different combinations for the four policy options, the high, base and low possible prices for feedstock and learning curves, and the four market scenarios. This theoretically leads to hundreds of possible sensitivities per feedstock-technology combination.

In order to focus on the most important alternatives, a limited number of sensitivities have been selected for this report to analyse the consequences on the biojet fuel price.

The selections of sensitivities per policy option are consistent and in line with their expected developments (see also chapter 6). Based on this, certain market scenario's, feedstock prices and learning curves are applied to each policy option, combined with how much incentives are assumed (or not). For each option, the base or fast learning curve is applied. Table 21 summarizes the sensitivities applied for illustration to the four policy options.

*Table 21 Key sensitivities analysed per policy option*

| OPTION | | MARKET SCENARIO | FEEDSTOCK PRICES | LEARNING CURVES | CARBON MARKTET | INVEST. INCENTIVES | FEEDST. INCENTIVES |
|---|---|---|---|---|---|---|---|
| **Price driven** | 1A | Market forwards | High | High | No | 50% | 50% |
| | 1B | New policies | High | High | Yes | | |
| **Obligation driven** | 2A | Market forwards | Low | Base | No | 25% | None |
| | 2B | New policies | Base | Base | Yes | | |
| **Co-regulation** | 3A | 450 | Low | Base | Yes | None | None |
| | 3B | 450 | High | Base | Yes | | |
| **Voluntary driven** | 4A | Market forwards | Low | Base | No | None | None |
| | 4B | New policies | Base | Base | Yes | | |

**Option 1: Price driven**

This option assumes that national governments are willing to subsidise sufficiently to realise the ambition to enable biojet fuels to compete with fossil fuels. Large government support results into fast learning curves. Increased demand for biojet fuels (and increased competition) may result into high feedstock prices. $CO_2$ prices itself will not be sufficient throughout this period to generate the needed investments. Substantial government support is needed. Therefore the market forwards and new policies scenarios are the most likely environment for this option.

**Option 2: Obligation driven**

The government driven option assumes a mandate according to Table 18. Additional incentives are assumed to be limited resulting in learning curves that do not accelerate nor slow down. This option is especially likely in a world where carbon prices remain relatively low and therefore general demand for feedstock does not accelerate and consequently feedstock prices stay low within the Market forwards scenario (low fossil fuel prices for a prolong period). Feedstock prices will be higher if the New policies scenario is assumed which assumes higher fossil fuel and CO2 prices.

**Option 3: Co-regulation**

The co-regulation world puts its faith in a global agreement for the deployment of biojet fuels, and an international mechanism for trading biojet fuel certificates. Same as in option 1, investments in biojet fuels and the overall carbon price resembles the ambition to come to blending percentages as assumed, feedstock prices may be higher. Learning curves are assumed to follow the base case.

**Option 4: Voluntarily driven**

The voluntary option assumes no interference from governments through incentives or mandates. The aviation industry will set the targets itself on a voluntarily basis. In the current markets, with $CO_2$ prices at all-time lows, it is unlikely that biojet fuels will become competitive. Also if the market does recover, much more incentives are needed to justify the investments to realise biojet fuel blending.

## 8.3 Illustrative results

For all policy options, the proposed set of assumptions was modelled to analyse the impact of the different market scenarios, feedstock prices, learning curves and different levels of the support instruments on the biojet fuel price.

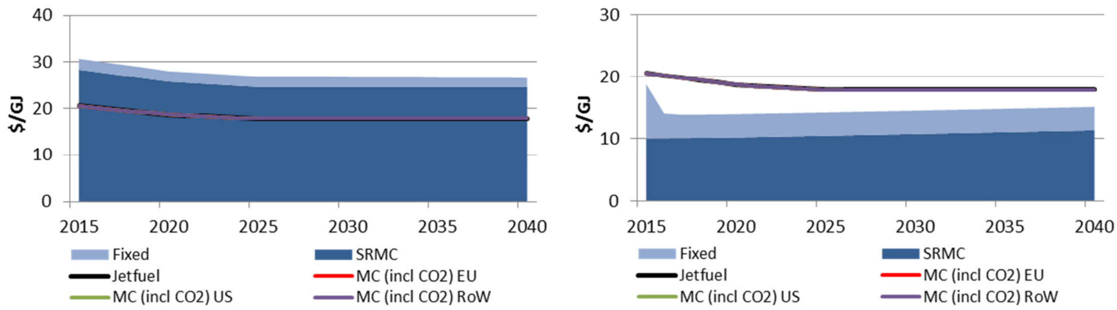
One important remark here is that all policy options lead in the model to certain growth rates of implementation of the technologies to produce biojet fuels. In theory, a binary decision is made whether to use biojet fuels or jet fuel as soon as the break-even thresholds are reached. However, in practice, biojet fuels will only penetrate the market gradually when it becomes profitable.. Due to the learning curve, prices will drop faster when more plants are being developed. The results therefore provide a rough idea of the impact of policy options especially as the model does not include a feedback loop of the impact of feedstock, carbon and jet fuel prices on biojet fuel prices on the one hand, and the impact of the levels of incentives on the other hand.

The exact impact of incentives on investments and feedstock, and of higher $CO_2$ prices on the number of plants the model assumes, needs to be carefully determined in order to optimise each policy option.

### 8.3.1 Option 1: Price driven

For this option, the model aims to calculate if substantial economic incentives can bring competitive prices within a reasonable time horizon under the assumptions of feedstock price, learning curves and amount of economic incentives described in Table 21.

Option 1A is the combination of fast learning curves and high feedstock prices under the Markets Forward scenario, and with 50% incentives on the feedstock price and 50% on needed investments (see Figure 51). This option still results in competitive prices for biojet fuels from Fischer-Tropsch using wood residues as feedstock, but not for HVO from Camelina or Jatropha.



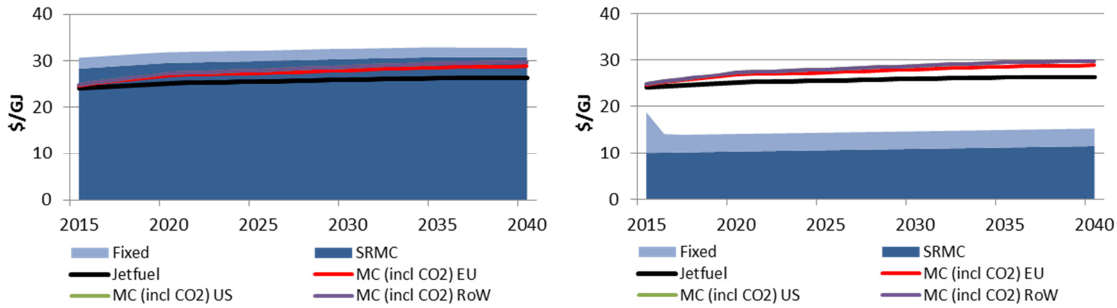

HVO: Camelina F-T: Wood residues

*Figure 51: Blended jet fuel prices for option 1A (Markets forwards scenario)*

Incentives for feedstock in the Fischer-Tropsch process can clearly be lower than for other technologies. To break-even with jet fuel, an incentive of just over 40% of the price of feedstock and 50% on the investment costs of the plants would be enough.

HVO biojet fuel from Camelina or Jatropha is, as a result of high feedstock prices selected for this option, still not competitive under the market forwards scenario. Incentives aiming at reducing the price of feedstock would have to cover 66% (instead of 50%) of the feedstock prices, together with 50% incentives on investment costs in order to make HVO biojet fuels cost competitive.

Option 1B is similar than option 1A but under the new policies scenario (see Figure 52).



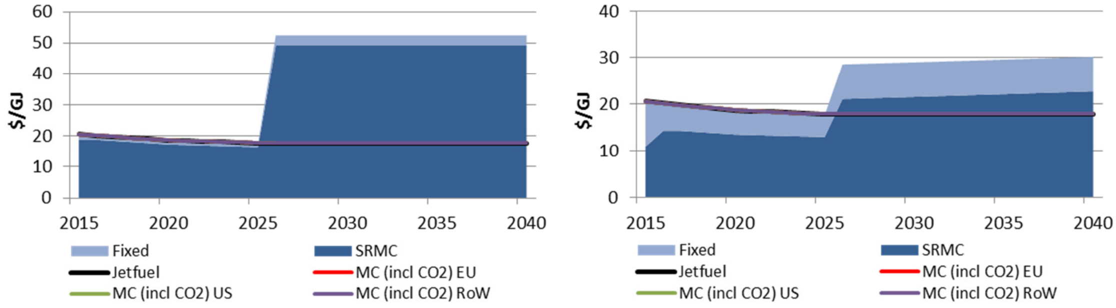

HVO: Camelina F-T: Wood residues

*Figure 52: Blended jet fuel prices for option 1B (New policies scenario)*

In option 1B, the price for biojet fuel from Camelina or Jatropha would improve slightly but not enough to become competitive: 55% of incentives on feedstock would be needed. Higher feedstock prices are compensated by substantial incentives whereas jet fuel prices remain at a relatively high level in this scenario. As can be expected, wood residues based biojet fuel could do with fewer incentives.

For both options 1A and 1B, the total incentives addressed to reduce the feedstock cost to make biojet fuels cost competitive, decrease by about 50% in case of assuming base prices for feedstock instead of high prices. This means that for such case, incentives to Camelina or Jatropha oil would have to be between 27% and 33% of the feedstock price to make biojet fuel competitive.

Incentives are needed for a relative long period of time; however, the major risk that option 1 faces is the uncertainty that incentives will stay over time. To illustrate this issue, a variation for option 1A has been modelled. This variation aims at making biojet fuels competitive between 2015 and 2025 (e.g. economic incentives are stopped in 2025 after 10 years of application). The results are shown in Figure 53. It can be concluded from these results that the required economic incentives are substantial and they cannot be supressed even after 10 years of being implemented. The main reason for this is the price of feedstock.



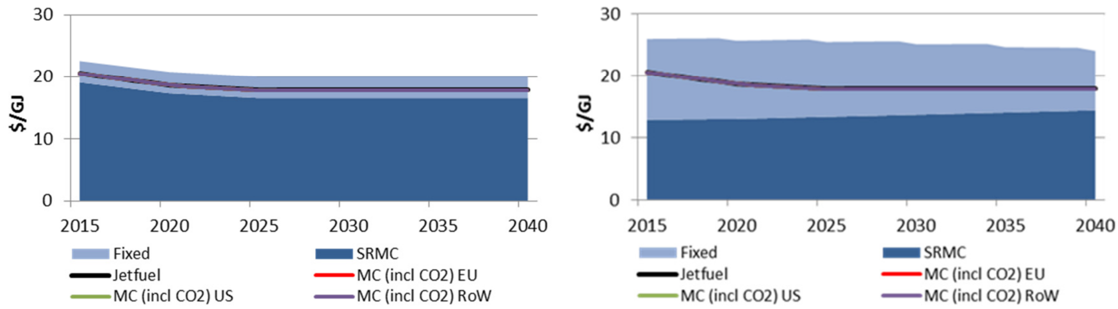

HVO: Camelina F-T: Wood residues

*Figure 53: Optimised option 1A with economic incentives applied only to the period 2015-2025*

## 8.3.2 Option 2: Obligation driven

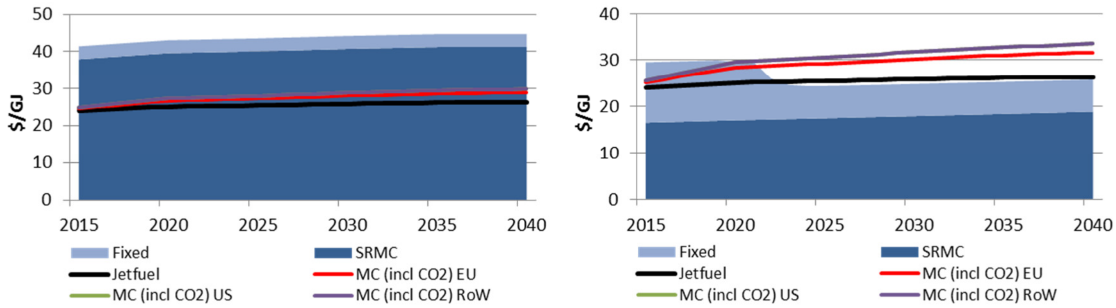
In the case of biojet fuels from wood residues under a new policies scenario (option 2B), the impact of an increasing mandate is having a positive effect on lowering the fixed costs (due to the effects of the F-T learning curve). However, biojet fuels based on the same feedstock, but under the markets forward scenario (option 2A), are not competitive. A much higher support of 42% would be needed to make biojet fuels from wood residues competitive in this scenario. The new policies scenario shows a different picture. Not only do the higher fuel prices have a positive impact, the introduction of a carbon price brings the total price of wood residues below the benchmark. As a consequence, many plants are being built which will bring the conversions costs down further due to the learning curve.

Camelina or Jatropha based biojet fuel is neither competitive in the markets forward scenario (not even with the low prices for feedstock), nor in the new policies scenario. It only needs another 10% of incentives to become competitive in the market forwards scenario. Higher fuel prices are more than offsetting the impact of the carbon prices in the new policies scenario, which worsens the overall competitiveness of Camelina and Jatropha based biojet fuels. Figure 54 shows the results for option 2A, and Figure 55 shows the results for option 2B.




HVO: Camelina F-T: Wood residues

*Figure 54: Blended jet fuel prices for option 2A (Markets forward scenario)*



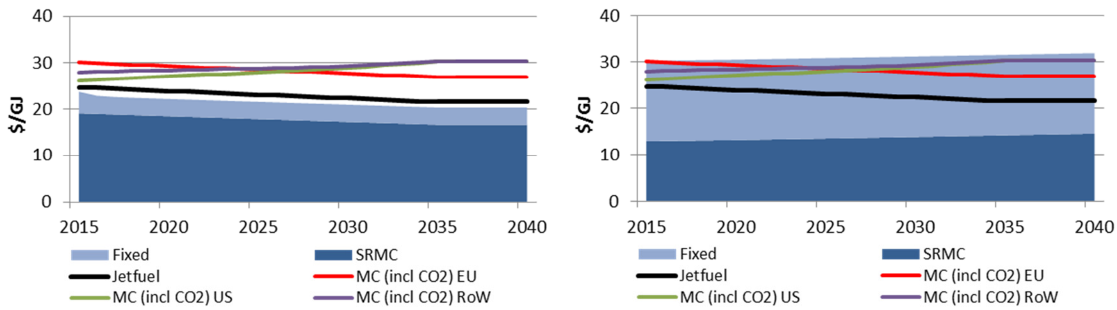

HVO: Camelina F-T: Wood residues

*Figure 55: Blended jet fuel prices for option 2B (New policies scenario)*

### 8.3.3 Option 3: Co-regulation

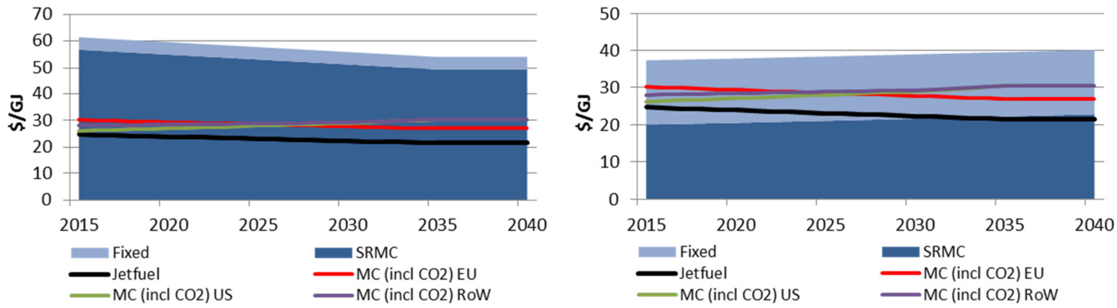
The results of option 2 apply fully to option 3. The difference of option 3 with respect to option 2 is that in co-regulation, the targets for blending and the rules for compliance are set up by the industry itself. Option 3 is therefore modelled under very different assumptions than option 2 to see the effects of other instruments such as the carbon price. Option 3 is modelled under a 450 scenario. In a 450 scenario, oil prices are low but carbon prices are very high, which may contribute to support investments. In a low feedstock price scenario (option 3A), Camelina and Jatropha based biojet fuel will be competitive, however wood residues based biojet fuel not yet because the relative impact of investment costs in the F-T process is much higher than in the HVO process. The investment needs in the production facilities are too high relative to the advantage of high $CO_2$ prices and low feedstock prices, but a small increase (3%) in overall $CO_2$ prices do lead to immediate results. This can be explained because as soon as the number of plants becomes high enough, the costs drop and it becomes competitive.

If feedstock prices are high (option 3B), both technologies are not competitive. Substantially higher $CO_2$ prices (roughly 200% higher) will be needed to make biojet fuels from wood residues competitive. Camelina or Jatropha based biojet fuel can effectively only be supported by direct economy support under this scenario. These scenarios clearly show the impact and risk of fluctuating (low and high) feedstock prices on the competitiveness of biojet fuel over time.




HVO: Camelina F-T: Wood residues

*Figure 56: Blended jet fuel prices for option 3A (450 scenario, plus low cost feedstock)*

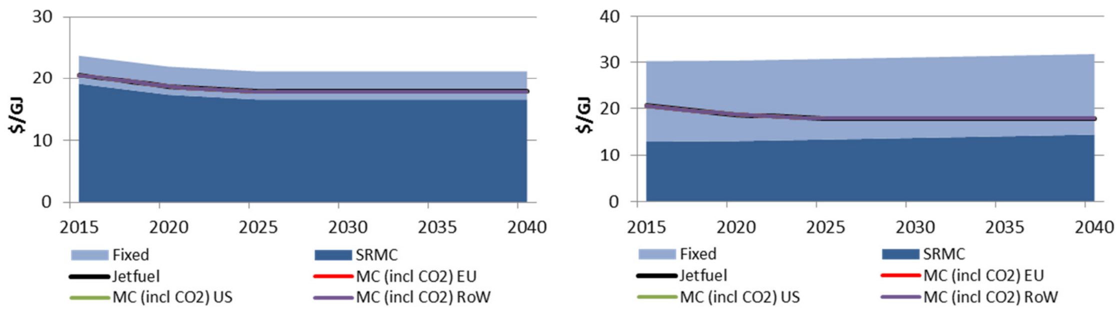



HVO: Camelina F-T: Wood residues

*Figure 57: Blended jet fuel prices for option 3B (450 scenario, plus high cost feedstock)*

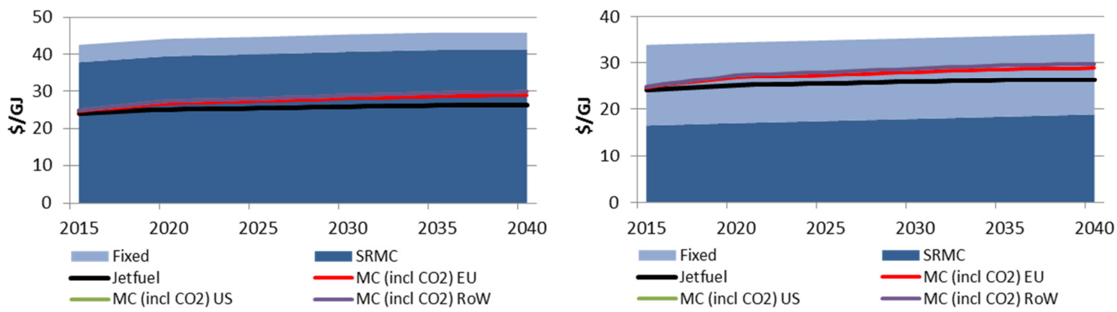
### 8.3.4 Option 4: Voluntary driven

Effectively this scenario means the world does not change in any substantial way. In the markets forward scenario, biojet fuel prices remain too high for Camelina and Jatropha based biojet fuels as well as for biojet fuels from wood residues. The new policies scenario includes the possibility of a carbon price, which improves the situation for wood residues slightly but not enough to become competitive on the long term.




HVO: Camelina F-T: Wood residues

*Figure 58: Blended jet fuel prices for option 4A (Markets forward scenario)*




HVO: Camelina F-T: Wood residues

*Figure 59: Blended jet fuel prices for option 4A (New policies scenario)*

## 8.4 The effects of more ambitious blending targets

Policy options have been modelled in section 8.3 following a conservative blending trend (see Table 18). If eventually a high blending trend is foreseen, either because of bigger ambition of the industry, or because it is imposed as a mandate upon the aviation sector, it is important to know what the impacts will be on the price of biojet fuel.

A higher blending trend will surely push for faster technologies learning curves, therefore reducing faster the investment needed for producing biojet fuels. A policy to move to a higher blending target will most likely coincide with a strong will to reduce $CO_2$ emissions as well. .

An alternative and more ambitious blending trend is set according to Table 22 for further analysis.

*Table 22: Higher blending target*

| Year | Blending mandate % |
|---|---|
| 2020 | 4 |
| 2025 | 10 |
| 2030 | 20 |
| 2035 | 30 |
| 2040 | 40 |

These ambitious targets would lead to the $CO_2$ emissions in line with IATA's ambitions.

### 8.4.1 Higher blending ambitions and policy option 1

F-T biojet fuels benefits most from direct incentives on investment. A scenario that includes a direct subsidy of 10% on investment for F-T is shown in Figure 60. F-T based biojet fuels would almost immediately become profitable. However, whether the model outcome is realistic is questionable. It is not unlikely that the learning curve is now too optimistic as it is uncertain if all funds allocated to F-T could speed up the learning curve this much.

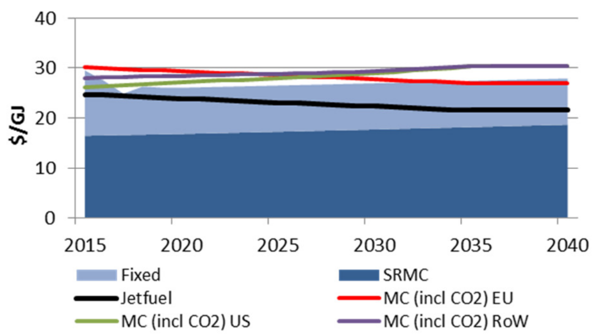



*Figure 60: Blended jet fuel prices (F-T) for higher blending rates, with incentives (450 scenario)*

HVO biojet fuels would benefit most from subsidies on feedstock. 25% direct incentive would make HVO competitive in the 2030s (including $CO_2$ benefits).

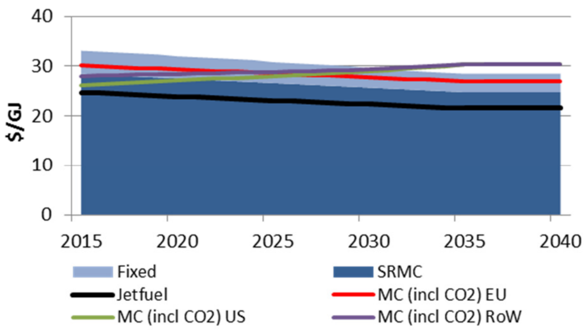



*Figure 61: Blended jet fuel prices (HVO) for higher blending rates (450 scenario)*

### 8.4.2 Higher blending ambitions and policy options 2 and 3

Calculations have been made under the scenarios New policies and 450 considering a more ambitious as a policy to move to a high blending mandate will most likely coincide with a strong will to reduce CO2 emissions. Learning curves and feedstock prices are at base levels.

Figure 62 shows the change in the price of jet fuel at different blends with fixed $CO_2$ prices (10 € per tonne) and jet fuel prices (2,85 $ per gallon which is 21,84 $ per GJ, or 22,57 $ per GJ including $CO_2$ prices).

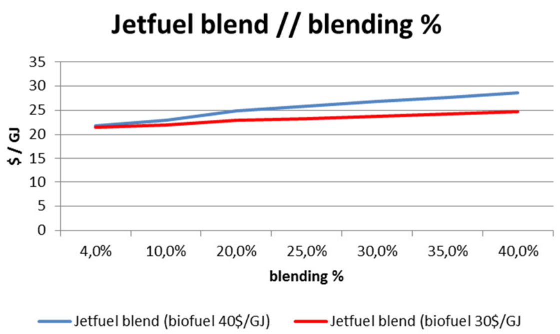
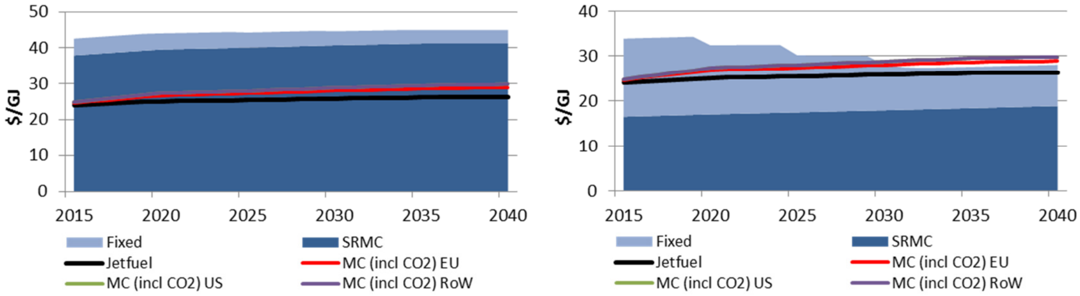



*Figure 62: Change in price of jet fuels at different blends, no incentives (higher ambitions)*

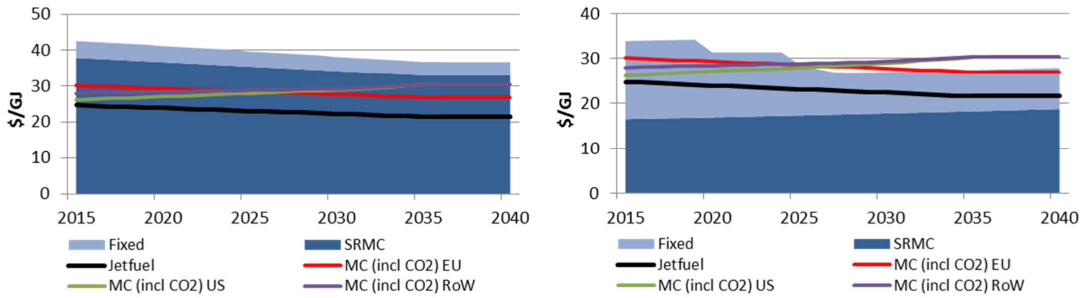
The first analysis (Figure 63) shows the development of the price of biojet fuel under the new policies scenario. No incentives are assumed, so this analysis corresponds to a variation of option 2 "obligation driven" or policy option 3 "co-regulation", both with no additional incentives. As can be expected, the HVO technology does not become competitive as feedstock prices are dominant. F-T however is competitive by 2030 as the technology becomes mature




HVO: Camelina F-T: Wood residues

*Figure 63: Blended jet fuel prices for higher blending rates, no incentives (New policies scenario)*

The second analysis (see Figure 64) shows the same calculations under the 450 scenario. Results for F-T are similar than with the new policies scenario. Results for HVO are much better now due to higher $CO_2$ prices. However, feedstock prices are still too high and biojet fuel will not become competitive over the entire horizon.




HVO: Camelina F-T: Wood residues

*Figure 64: Blended jet fuel prices for higher blending rates, no incentives (450 scenario)*

# 9 Conclusions and final recommendations

The production of biojet fuels is currently far more expensive than production of fossil jet fuels. Large cost reductions are thus needed for its further deployment. Feedstock price represents the largest share in the final cost of biojet fuel (50%-90%); technology related fixed cost is the next important component. Large cost reductions, especially on feedstock, are needed to make biojet fuels feasible.There is no clear winning technology. Cost reductions in capital investments can be (partly) achieved through learning and up-scaling. This needs the creation of a market (in terms of volume), investments for innovation and time. Key question is what the best possible way to develop competitive biojet fuels within the right time frame at the lowest possible cost is.

Key to realise competitive production of biojet fuels is:

- Sufficient supply of feedstock at low cost in order to maintain reasonable prices. Competition for feedstock from other industries is large (food, feed, chemicals, power, road transport) and this competition is expected to keep increasing.
- To reach economies of scale, technology (R&D, investments) subsidies are needed.
- Only very high $CO_2$ prices, or equivalent other biojet fuel incentives, in combination with low feedstock prices will possibly result in competitive biojet fuels; this combination is not likely in the foreseeable future, and a very high $CO_2$ price is not desirable because it puts a strong financial burden onto the airlines as long as a large part of fuel used is still conventional. Carbon trading can only support biojet fuels if carbon price is high enough, in practice multiples of current CER market levels. It cannot be expected that over the course of the next 7 years until 2020 this will materially change and thereafter it is highly uncertain how global carbon markets will develop.

A recent study performed by the Midwest Aviation Sustainable Biofuels Initiative (MASBI) "Fueling a Sustainable Future for Aviation" shows that an economic incentive of US$ 2 per gallon of biojet fuel would be needed in the US for bringing HEFA biojet fuel to a US$ 2.92 per gallon which is cost competitive with current fossil jet fuel price. This calculation is under the assumption of a relatively optimistic price of feedstock. The model developed in our study produces a similar result, with a required incentive of around US$1.50 per gallon of biojet fuel when modelling under similar assumptions.

The relevant question from everyone in the industry is the likelihood of assumptions, e.g. feedstock price, technology cost, and jet fuel price. While comparing our research with the MASBI report, it gets clear that the most sensitive assumption is future feedstock price. This is where it lays the largest risk for the competitiveness of biojet fuel prices. For technology costs, basically the assumptions in this study and the assumptions made by MASBI are quite similar.

The discussion among airlines and producers is what should be the risk to be taken relation to future price for feedstock. In our view, a more likely future price will be less optimistic than it is for MASBI; this just because of the growing other competing uses for biomass in the many different industries (food, chemistry, biofuels for road transport) also sourcing them internationally. If the cost pressure is larger on the feedstock side due to competing uses, then incentives likely have to be sustained for longer periods of time which is an important risk.

Our model estimates that for a more conservative cost development of feedstock, the incentive required would be of US$ 2.7 per gallon of biojet fuel. A 3% blend would thus increase the blended jet fuel price by 2.5% if the underlying biojet fuel price is 40 US$ per ton. For illustrative purposes, this means that the US market would require incentives amounting US$ 540 million annually for each 1% of blending on the basis of an annual consumption of 20 billion gallons of jet fuel a year by the US military and commercial aviation (as reported by the MASBI report). A global blending of 1% would require annual incentives of the order of US$ 1.8 billion.

## 9.1 The role and effectiveness of policy instruments

Basically, there are four types of different policy instruments that can influence the market competitiveness of biojet fuels: A broad range of possible economic instruments, Command and control instruments (mandates and other types of obligations), co-regulation instruments, and voluntary and collaborative instruments.

For biofuels in the road transport sector, each country has sought in general its own combination of instruments depending on its own target, the maturity of the sector and other country specific conditions. Aviation however is different and due to its technical considerations and the features of international operation that it has. Stakeholders in the biojet fuel value chain are dependent of each other. The impacts of policy instruments – both negative and positive – are interrelated and cannot be seen separately. It can be concluded that all relevant stakeholders – governments, producers and buyers – should cooperate and coordinate closely to maintain a level-playing field. This should be achieved preferably based on international negotiations. The risk of creating a disturbed market due to a variety of policy instruments exists. The international dimension of the aviation sector pleads therefore for global agreements and public-private partnerships.

No one single instrument can produce these benefits by itself. A well thought combination of instruments is needed to deal with all barriers. The policy instruments chosen need to support sufficient investments in order to follow the aviation sectors own ambition regarding emission reductions and follow the optimal learning curve per technology. If incentives are set too high, funds will be used for immature technologies, and if too low, technologies will not develop fast enough. Setting up obligations that require high blending in short periods of time would create an artificial demand and would stimulate the cheapest technology, which is not necessarily the optimal technology in the mid-term. In both cases, the risk of the creation of a non-self-sustained and disturbed market is high.

## 9.2 Policy options and scenarios

Four policy options with different combination of instruments have been selected for the aviation sector based on different criteria such as: trends in the aviation sector, experiences from the biofuels sector, suitability to choices of feedstock and technical pathways and their feasibility for international regulation. These policy options are:

- Policy option 1: Price driven (Economic instruments driven)
- Policy option 2: Obligation driven (Command and control instruments driven)
- Policy option 3: Co-regulation driven
- Policy option 4: Voluntary driven

Analysis of results for each:

1. Option 1 (price driven) establishes how much economic incentives are needed for an optimal market start-up and global deployment of biojet fuels with a 2% blending mandate reached in a time horizon of 10 years (2015-2025). This option shows that 50% of direct incentives for the construction of production plants (regardless feedstock/conversion technology) would be required for initial up-scaling. Additionally, for Camelina/Jatropha HVO biojet fuels up to 66% of incentives to feedstock would be needed in the first 10 years of deployment (depending on the price of feedstock). The Fischer-Tropsch route would require less subsidies to feedstock (up to 40%), but more subsidies to technology development as Fischer-Tropsch plants are still very expensive.

   Realistically, the burden of full economic support will not be carried by governments and its taxpayers, especially not in periods of economic recession. It is important to consider when analysing this option, that the chances for economic support may be further lowered as the national governments have limited control over the effectiveness of this money flow, as no targets or obligations are set yet.

2. Option 2 (obligation driven) facilitates the discussion with governments to receive economic support. Economic support needed is similar to option 1, but can be more tailor-made if adequate consensus negotiations take place. However, with this option, the biojet fuels sector will evolve following the ambition level of governments rather than the one of airlines. As governments must increasingly justify their budget spending in terms of effectiveness and targets achieved, they tend to take control over industry using command and control instruments, as a mandate for example. This allows governments to control targets, implementation and enforcement. The use of country mandates is the most common instrument used to deploy biofuels in the road transport sector often in combination with economic incentives.

   On the other hand, the introduction of a mandate for the aviation sector may facilitate the discussion with governments to receive some form of economic support to enable the sector in achieving the targets. However, for mandates to have a chance of being effective in the aviation sector, they would require flexible compliance rules. Blending mandates cannot be applied upfront to a nascent market in which biojet fuel prices have not yet reached certain stability. Stability of prices usually comes after learning and certain up-scaling has already happened. Mandates should therefore be implemented after economic incentives alone have resulted in this up-scaling. Mandates should also be designed to change gradually according to careful monitoring of achieved goals; otherwise the risk of excessive economic pressure on airlines and final users is not properly mitigated.

3. Option 3 (co-regulation) gives the aviation sector the possibility to demonstrate commitment and to receive economic support. In essence the economic incentives to make this option viable are similar to option 1 as well, but the pace and place of their introduction would be first discussed by the aviation sector. This option may also include an international trading mechanism for biojet fuels certificates. This mechanism may also involve other sectors (such as road transport), similar as RINs in the US or the biotickets in the Netherlands. Trading and compliance rules can be tailor made to accommodate the aviation industry specifics, e.g. the global perspective which risks level-playing field issues.

   This option can partially build on voluntary agreements. With the co-regulation option, the aviation sector retains control in the setting of its own targets and compliance rules, opposite to the obligation driven option in which those are established by governments.

The difficulty of this option is the complexity of its negotiations as they involve different interests from several parties.

4. Option 4 (voluntary driven) is basically the business as usual case. It has become clear by now that voluntary agreements alone are not sufficient to break the vicious circle of market start-up and cost reductions. There will always be airlines that are leading the deployment of biojet fuels. They will use more biojet fuels than committed to. They voluntarily go one step further than the majority with innovative solutions and new forms of cooperation. Examples are the KLM Corporate programs, and procurement initiatives or the formation of strategic alliances. These types of initiatives can well exist next to the other policy options and have minimal financial risk.

While all researched options would bring different advantages and disadvantages for the deployment of biojet fuels, the order of implementation of instruments is crucial. A market start-up will only happen if firm support to technology development and technology commercialisation is given (in the way of economic incentives). Only then, other policy instruments will be effective in shaping the biojet fuel market and its evolution. It is especially relevant to mention that blending mandates would cause more harm than benefits if they are applied in an immature market when biofuel prices have not yet reached stability.

## 9.3 Further research needs

The following research needs are identified to help IATA in building up a solid position regarding the promotion and deployment of biojet fuels in the aviation sector:

- More in-depth research on the technical specifications of option 3 (co-regulation) and the possibilities to embed this in a global trading or carbon off-setting system as currently discussed at ICAO;
- As a follow-up, elaboration of a detailed roadmap on the deployment of biojet fuels based on a selected policy option, with responsibilities of different stakeholder groups;
- Development of a roadmap to promote the development of second generation biofuels and biojet fuels in the European Union, anticipating 1) the approval of the proposal on capping the use of conventional biofuels and 2) discussion on new targets after 2020;
- Scenarios development on the availability of feedstock resources for biojet fuels considering sustainability discussions (ILUC, carbon debt), competition with biofuels for road transport and competitive uses and their sustainability performance when used for biojet fuels (in comparison with other end-uses).

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