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Economic, social and environmental impact of European alternative jet fuel market regulations

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Executive summary

This report explains the impact of a hypothetical implementation of a mandate to produce 2% or 4% of alternative jet fuel in the EU by 2035 on the stakeholders involved. This was achieved through the creation of the ITAKA Scale Up Model (ISUM).

The report provides insight of the repercussions that the mandate would have on every step of the different value chains, as well as on the airlines that would be expected to buy the alternative jet fuel. It shows the economic, social and environmental impact of 64 possible scenarios through the analysis of more than 20 combinations of feedstock-conversion technologies based on scientific publications of techno-economical analyses. ISUM forecasts costs for each alternative and distributes the market share among those with a premium less than 60% over fossil jet fuel.

Results show that, for every scenario, there are a series of feedstocks that compete to penetrate the alternative jet fuel market. These feedstocks include several types of residues and crops. Municipal Solid Waste, forest residues, Used Cooking Oil, tallow oil and corn stover are the residues expected to uptake more than 50% of the total residues in most scenarios. Camelina derived oil and short rotation trees are the crops with better forecast. Due to the cost and variability of these feedstocks, the market generated ranges from 100MM€ to 800MM€, entailing the creation of 1,000 to 12,000 direct jobs. This variability happens because, for some pathways, the feedstock is very expensive but the conversion cost very cheap, and vice versa for other pathways.

When considering 2nd generation feedstocks only, imported feedstocks from outside the EU are negligible. Camelina and MSW would be the most demanded feedstocks until the appearance of HDCJ pathway, which seems very competitive with forest residues as a feedstock. Feedstock logistics market is expected to be in the range of 50MM€ to 340MM€, generating from 800 to 3,000 direct jobs.

Regarding conversion technology, 6 to 9 facilities are required to meet the 2% mandate, and 11 to 15 for the 4% mandate. Four different conversion technologies will be competitive with the information gathered from the literature: HEFA, FT, ATJ and HDCJ. Direct employment generated for the 2% mandate is about 400 and it is doubled for the 4% mandate.

The average premium to be paid by airlines in 2035 will depend greatly on the fossil jet fuel cost. For high fossil fuel cost scenarios (considering 2.5% annual increase), the premium will range 8-13% for 1st generation and 15-18% for 2nd generation. For low fossil cost scenarios (0.5% annual increase), premium will range 22-34% for 1st generation and 29-41% for 2nd generation.

The model forecasts the fuel consumption in the main hubs in Europe, and its distribution among the main airlines flying out of those hubs. This allows estimating the costs to be paid by each airline if the fuel was only distributed to those hubs. The conclusions offer different alternatives of how this cost could be distributed among the rest of the airlines flying in the EU.

The cost efficiency of CO2 reduction ranges 29-60 €/CO2t for high fossil fuel cost and 60-110 €/CO2t for low fossil fuel. The emissions savings expected for 2035 are circa 7 million tons and around 62 million tons considering the 2018-2035 timeframe.

The viability of this industry depends largely on exogenous factors, especially the price of fossil jet fuel; therefore, it is paramount to develop a long-term framework for the development of the most economic and environmental efficient pathways.

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Abbreviations

ASTM	American Society for Testing and Materials
ATJ	Alcohol to Jet
BSE	Bovine spongiform encephalopathy
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CO_2	Carbon Dioxide
CT	Conversion Technology
DSHC	Direct Sugar to Hydrocarbon
EC	European Commission
ETS	Emission Trading System
EU	European Union
FGG	Fast growing Graminneas
FL	Feedstock logistics
FP	Feedstock production
FT	Fischer-Tropsch
GMBMs	Global Market Based Measures
H	Hypothesis, High camelina oil costs
h	Low camelina oil costs
HDCJ	Hydroprocessed Depolymerized Cellulosic Jet
HEFA	Hydroprocessed Esthers with Fatty Acids
IA	Impact on airlines
ISUM	ITAKA Scale Up Model
ITAKA	Initiative Towards Sustainable Kerosene for Aviation
JL	Jet fuel logistics
L	Low HEFA capital costs
l	Low camelina oil cost
LCA	Life Cycle Analysis
LCC	Low Cost Carrier
MBM	Market Based Measures
MSW	Municipal Solid Wastes
MTOW	Maximum Take Off Weight
Mt	Million tons
PKT	Passenger Kilometre transported
RED	Renewable Energy Directive
RDF	Refuse-derived fuel
RTK	Revenue Tonne Kilometre

SK	Synthetic Kerosene
SKA	Synthetic Aromatic Kerosene
SRT	Short Rotation Trees
TKT	Tonne Kilometre transported
UCO	Used Cooking Oil
W/ MSW	Scenario with MSW-FT pathway
W/o MSW	Scenario without MSW-FT pathway

1 Context and background

1.1 Introduction

The ITAKA Scale-Up Model was first envisaged as a tool to identify the requirements and barriers that would encounter the camelina-based alternative jet fuel industry when trying to reach European wide commercial market. However, camelina-based alternative jet fuel is not the only feedstock approved to create alternative jet fuel, and the HEFA process used to produce fuel in ITAKA is not the only process approved for commercial use. Furthermore, since the scaling up entails several years, there are more pathways expected to be introduced in the near future. Therefore, an overall study of the alternative jet fuel industry in Europe was required in order to estimate the possible scalability of the camelina-based alternative jet fuel industry.

The greater scope of the model has allowed the researchers involved to study many aspects of the value-chain. Studying the overall value-chains permitted retrieving economic information of the different industries involved: feedstock production, alternative jet fuel conversion, logistics, and aviation. Furthermore, the socio-economic information at the different levels of the value-chain was calculated.

The report first describes the guidelines used for scaling up the production of commercial alternative jet fuel. It provides details of the scenarios tested and the base scenario of the model. The different steps that the model executes for each simulation are explained in detail, providing their output, main assumptions and examples. Several hypotheses for each step of the value chains are stated and either validated or disavowed through the simulations. The conclusions of at the end of the report present if such hypotheses were valid. The results are presented through graphs for each step of the value chain and for the different scenarios presented. Specific simulations for the base scenario and analysis of their results were carried out.

1.2 Relation with other deliverables

This report has been developed in such a way that it contains the information that was initially expected to be reported in three different deliverables. Due to the close connections among these deliverables, the concatenation has been thought useful for the reader. This report contains the information of the following initial Deliverables:

- D5.13 Report of economic, social, and regulatory implications: Report of economic, social, and regulatory implications of large-scale biofuel utilisation in aviation.
- D5.14 Recommendations to solve potential barriers: Recommendations to solve potential barriers to large-scale commercialization and recommendations for further research.
- D5.15 Guidelines for scaling up: Guidelines for scaling up and reporting scenarios.

1.3 Structure of the document

This report is structured in the following manner:

- Section 1 includes the introduction to the document.
- Section 2 shows the model description.
  - Section 2.1 introduces the methodology and the scenarios of the model.
  - Section 2.2 provides a description of the model in detail. It is divided into the different sections of the model. For each section, the expected output, assumptions, methodology and hypotheses are explained.

        - Feedstock production
        - Feedstock-pathway combination cost forecast
        - Market penetration
        - Conversion technology
        - Feedstock logistics
        - Alternative jet fuel logistics
        - Impact on airlines
        - Environmental impact
        - Camelina specific results
- Section 3 provides the results and the first analysis of the simulations. It is distributed in the following manner:
        - Feedstock production
        - Feedstock-pathway combination cost forecast
        - Market penetration
        - Conversion technology
        - Feedstock logistics
        - Alternative jet fuel logistics
        - Impact on airlines
        - Social impact
        - Environmental impact
        - Camelina specific results
    -
- Section 4 details the conclusions obtained in the model. It is structured as follows:
    - Section *4.1 Revision of hypotheses* lists the hypotheses made prior to the simulations and defines whether the results can be used to validate those hypotheses.
    - Section *4.2 Conclusions* summarizes the conclusions of the model, first for each step of the value chain and then for transversal factors such as social impact. Final conclusion and general remarks are also included.
- *Annex I. Demand* provides a full analysis of the methodology used to forecast fuel consumption.
- *Annex II. Results* details the results of the simulations in table format.

2 Guidelines for scaling up

2.1 Methodology and scenarios

The model is designed to allocate certain amounts of alternative jet fuel among different alternatives in the 2017-2035 timeframe.

Due to the very expensive cost of alternative jet fuel in the current days, the model is based on a hypothetical regulatory obligation of producing a certain percentage of alternative jet fuel in Europe.

This obligation is hypothetically established through a mandate that indicates two main factors: the period for implementation and the percentage required. For simplification purposes, the model establishes an annual linear increment of alternative jet fuel production requirements. These variables can be modified in the model to analyse different scenarios in the future. The model considers 2% and 4% of the expected 2035 jet fuel consumption as mandate requirements of alternative jet fuel.

Since the demand of alternative jet fuel is based on the European jet fuel consumption, it was required to model the European air traffic demand, and estimate the evolution of traffic growth. This was performed applying the forecasted trends of Airbus and traffic classification of Eurocontrol. Table 1 shows the trends used to estimate traffic growth from Airbus long term forecast, and the classification of air traffic based on Eurocontrol. Further information is detailed in *Annex I. Demand*.

Table 1 – Airbus forecast and Eurocontrol traffic classification

From Airbus forecasts	Growth intra-European flights	3.3%
	Growth extra-European flights	4.9%
From EC ETS study	Intra-European flight consumption	41.0%
	Extra-European flights consumption	59.0%
	Fuel efficiency gain per year	1.0%

The main exogenous variable considered in the model is the price of fossil jet fuel and its evolution throughout the timeframe studied. This variable will be the fossil jet fuel price increase per year in terms of percentage, which will be used to generate different scenarios. The model considers an annual increment of 0.5% and 2.5% as fossil jet fuel price scenarios. Table 2 summarizes the different variables defining the scenarios.

Table 2 - Variables of scenarios

Variables	Description	Options considered
Percentage of alternative jet fuel to be produced	This will be considered as a ***mandate*** to be met in 2035.	The model considers 2% and 4% as the two options

Success of MSW pathway	The use of Municipal Solid Waste (RDF) as feedstock has been explored, but not proven in the Fischer-Tropsch conversion pathway. If it were successful, its economic advantage would diminish greatly the penetration of other feedstocks or pathways, therefore its availability will be considered a variable in the scenarios.	*With MSW* and *without MSW* options are considered.
Jet fuel price annual increase	The cost jet fuel is key in finding available alternatives. The initial cost of jet fuel in the model is 501.59 €/t (1.5€/gal)	Two options are considered: an annual increase of 0.5% and 2.5%.
Use of 1st or 2nd generation feedstocks	The model discriminates between 1st and 2nd generation feedstocks (considering camelina a second-generation feedstock).	1st generation feedstocks or 2nd generation feedstocks are the options considered.
Camelina oil price	Since the project is focused on camelina, and its commercial cost is expected to be indexed in the future as a commodity	Two prices are considered: 500€ and 700€ euros per ton.
HEFA conversion capital costs	Due to the variability and uncertainty in the capital costs for the HEFA process	Two options are considered in the scenarios: 40€ and 110€ per ton.

These variables will provide sufficient information to understand the impact of each of them on the results. The permutations among all the options provide the 64 different scenarios to be analysed.

Base scenario

A *base scenario* was selected based on the researchers' experience and expectations. Of course, some of the variables are completely unknown, such the volatile fossil fuel prices, but these assumptions are necessary to provide insight of the most probable situation. The scenario considered as "Base scenario" is described by the options shown in Table 3.

Table 3 - Base scenario definition

Variable	Option selected
Mandate percentage of alternative jet fuel to be met	4%
MSW availability	MSW available
Annual fossil jet fuel price increase	0.5%
1st or 2nd generation	2nd generation
Camelina oil price	500€ per oil ton
HEFA capital expenses	40€ per biojet produced

This base scenario is optimistic concerning the availability of MSW and the camelina oil price, but a bit pessimistic on the low increase of fossil jet fuel price increase.

The latest update of the European Renewable Energy Directive limits the production of alternative fuel for transportation from crops to 7%. The 4% mandate considered in the model is well below that level; therefore, the model does not consider limiting alternative jet fuel from crops.

2.2 Model description

The model performs a sequence of calculations for any given scenario in the following order:

1. Feedstock cost calculation

2. Feedstock-pathway combination cost forecast.
3. Market penetration calculation
4. Conversion facilities calculations
5. Feedstock logistics calculation
6. Alternative jet fuel logistics calculation
7. Impact on airlines
8. Environmental impact
9. Camelina-related results

The following sections describe each of these steps in detail.

2.2.1 Feedstock production

Expected output

The main objective of this section of the model is to calculate the feedstock cost for the selected feedstocks.

Feedstock selection

The selection of feedstocks is based on the sources of information used to generate the model, which are mainly scientific publications of techno-economic analysis and assessments of the different pathways. The information from the ITAKA project has also been used, although this information is not as easy to gather, as it would seem due to the sensibility of these data.

The different techno-economic analyses, while they are quite similar in the methodology used, tend to differ in the year of the publication, the place of the study, the currency used, and the operating unit costs. Therefore, great effort has been made to harmonise the different sources of information in order to have comparable results.

Additionally, not all combinations of feedstocks and conversion pathways have been found, and certain hypotheses have been made in order to estimate the cost for those combinations.

The feedstocks of the model are described in Table 4.

Table 4 - Feedstock output description.

Model output	Description
Vegetable oil	Includes vegetable oil feedstocks for HEFA from the following sources: camelina, rapeseed, soy, sunflower, coconut, babasu, jatropha, palm, microalgae, macroalgae and salicornia.
European	Includes vegetable oil feedstocks from the following sources: camelina, rapeseed, soy and sunflower.
Imported	Includes vegetable oil feedstocks from the following sources: coconut, babasu, jatropha, palm, and salicornia.
Tallow	Considered a residue consisting of animal fat for HEFA production (Milbrandt, et al., 2013), (Seber, et al., 2013).
MSW	Municipal solid waste used for F-T (Solena group, 2010).
UCO	Used Cooking Oil used for HEFA production (Seber, et al., 2013).
Forest residues	Considered for F-T (Stratton, et al., 2010) and ATJ (Atsonios, et al., 2014).
SRT	Short rotation trees, sometimes referred as Short Rotation Woody Crops, used in several studies for HDCJ (Hayward, et al., 2015), Fischer-Tropsch (Milbrandt, et al., 2013) and ATJ (Crawford, 2013).
Sugarcane	Considered for DSHC (Klein-Marcuschamer, et al., 2013), (Staples, et al., 2014), (Trivedi,

	2014), and ATJ (Yao, et al., 2017)
Switchgrass	Considered for F-T (Stratton, et al., 2010), (Trivedi, 2014), DSHC (Staples, et al., 2014) and ATJ (Yao, et al., 2017).
Corn grain	Considered for DSHC production (Staples, et al., 2014), and ATJ (Yao, et al., 2017).
Corn stover	A residue considered for F-T (Agusdinata, et al., 2011), (Milbrandt, et al., 2013), (Stratton, et al., 2010), (Swanson, et al., 2010), and DSHC (Davis, et al., 2013), (Trivedi, 2014), and HDCJ (Kalnes, 2010), (Milbrandt, et al., 2013), (Petter & Tyner, 2013), (Wright, et al., 2010).
Tall oil + TCO	Tall oil is a viscous yellow-black liquid obtained as a by-product of the Kraft process of wood pulp manufacture when pulping mainly coniferous trees used for the HEFA process. TCO (Technical Corn Oil) is a residue generated during the ethanol production used in the HEFA process.

Table 5 summarizes the pathway-feedstock combinations studied and the references found to complete the model:

Table 5 - Sources of information.

Pathway	Type	Feedstock	Source
HEFA	Crops	Rapeseed	(Miller, 2012), (Stratton, et al., 2010), (Trivedi, 2014)
		Soy	(Milbrandt, et al., 2013), (Pearlson, 2011), (Stratton, et al., 2010), (Trivedi, 2014)
		Palm	(Stratton, et al., 2010), (Trivedi, 2014)
		Salicornia	(Stratton, et al., 2010)
		Camelina	(Agusdinata, et al., 2011), (Miller, 2012), (Honeywell, 2011)
		Jatropha	(Honeywell, 2011), (Stratton, et al., 2010), (Trivedi, 2014)
		Microalgae	(Agusdinata, et al., 2011), (Ames, 2014), (Carter, 2012), (Klein-Marcuschamer, et al., 2013), (Milbrandt, et al., 2013), (Honeywell, 2011), (Stratton, et al., 2010)
	Residues	UCO	(Seber, et al., 2013)
		Tallow	(Milbrandt, et al., 2013), (Seber, et al., 2013), (Honeywell, 2011)
F-T	Residues	Forest residues	(Stratton, et al., 2010)
		Corn stover	(Agusdinata, et al., 2011), (Milbrandt, et al., 2013), (Swanson, et al., 2010), (Stratton, et al., 2010),
		RDF	(Proctor, 2014), (Solena group, 2010)
	Crops	Switchgrass	(Agusdinata, et al., 2011), (Milbrandt, et al., 2013), (Stratton, et al., 2010),
		SRT	(Agusdinata, et al., 2011), (Milbrandt, et al., 2013), (Hayward, et al., 2015)
DSHC	Residues	Corn stover	(Davis, et al., 2013), (Trivedi, 2014)
	Crops	Switchgrass	(Davis, et al., 2013), (Staples, et al., 2014), (Trivedi, 2014)
		Sugar Cane	(Klein-Marcuschamer, et al., 2013), (Staples, et al., 2014), (Trivedi, 2014), (AMYRIS, TOTAL, 2012)
		Corn grain	(Staples, et al., 2014)
Alcohol-to-Jet	Crops	Switchgrass	(Yao, et al., 2017),
		Corn grain	(Yao, et al., 2017)
		SRT	(Crawford, 2013)
		Sugarcane	(Yao, et al., 2017)
	Residues	Forest residues	(Atsonios, et al., 2014)
HDCJ	Residues	Corn Stover	(Milbrandt, et al., 2013), (Petter & Tyner, 2013), (Wright, et al., 2010), (Kalnes, 2010)
		Forest residues	(Kalnes, 2010)
	Crops	SRT	(Hayward, et al., 2015), (Kalnes, 2010)

Feedstock cost calculation

The cost of feedstock for each pathway was in some cases extracted directly from the different sources, with the cost updated to 2015. In cases where the feedstock is indexed as a commodity, the prices have been obtained from www.indexmundi.com. In other cases, the global cost of ton alternative jet fuel is given by the source technical paper. Subtracting the capital and operating expenses (if available from another source), we could obtain the feedstock cost (considering similar coproduct income).

Annual European production and annual global production for the year 2015 was used to identify the percentages of expected EU oil feedstock production and expected imported oil feedstock.

Table 6 depicts the costs considered for each feedstock.

Table 6 - Feedstock cost per ton.

Pathway	Feedstock	Cost per ton (€)	Source
HEFA	Rapeseed	705	(Indexmundi, 2017)
	Soy	624	(Indexmundi, 2017)
	Sunflower	919	(Indexmundi, 2017)
	Palm	569	(Indexmundi, 2017)
	Coconut	902	(Indexmundi, 2017)
	Salicornia	800	Based on expert judgement
	Camelina	500-700	Input variable
	Babasu	900	Based on expert judgement
	Jatropha	769	(Indexmundi, 2017)
	Microalgae	1500	(Klein-Marcuschamer, et al., 2013)
	UCO	570	(Taconi, 2013)
	TCO	900	Neste personal communication
	Tallow	633	(Alberici & Toop, 2013)
	Tall Oil	750	(SEAIR, 2016)
F-T	Forest residues	60	(Atsonios, et al., 2014)
	Corn stover	70	(Swanson, et al., 2010)
	RDF	34	(Solena group, 2010)
	Corn grain	205	(Staples, et al., 2014)
	Switchgrass	53	(Staples, et al., 2014)
	SRT	66	(Hayward, et al., 2015)
	Halophytes	53	(Staples, et al., 2014)
DSHC-FTJ-SIP-DFSTJ	Corn stover	70	(Swanson, et al., 2010)
	Switchgrass	53	(Staples, et al., 2014)
	Sugarcane	42	(Staples, et al., 2014)
	Corn grain	205	(Staples, et al., 2014)
Alcohol-to-Jet	Sugarcane	42	(Staples, et al., 2014)
	Corn grain	205	(Staples, et al., 2014)
	Switchgrass	53	(Staples, et al., 2014)
	Forest residues	60	(Atsonios, et al., 2014)

	SRT	66	(Hayward, et al., 2015)
HDCJ	Corn stover	66	(Hayward, et al., 2015)
	Forest residues	60	(Atsonios, et al., 2014)
	SRT	66	(Hayward, et al., 2015)

Feedstock production hypotheses

The following hypotheses are later analysed with the results of the model:

- FP.H1: Residues are expected to be much cheaper that other sources, therefore those feedstock-pathway combinations using residues are expected to become more viable and extended than other alternatives.
- FP.H2: Camelina is expected to become the most used feedstock if considered 2nd generation feedstock if MSW-FT is not feasible and if its price is less than 700€/ton of oil.
- FP.H3: MSW will be the most used feedstock if available due to its low cost.

2.2.2 Feedstock logistics

Expected output

This step provides the cost to transport the feedstock required and the direct employment generated.

Model assumptions

The feedstock transportation distance varies greatly on the pathway. Those pathways with less dense feedstock need to be designed in such a way that the distance to transport the initial feedstock is minimised. In other cases such as ITAKA, the logistics does not impact the product cost as much and it can be imported from overseas, due to the high energy density.

In the model, the price of each feedstock does not consider this calculation of logistics costs as an input. However, it is used to estimate the market generated and the related employment. The model assumes that the average distance for the feedstock will be 200 km, based on the camelina grain transportation distance of ITAKA. The tons-km of each feedstock are multiplied by 0.065 € (Eleftheriadis, 2012) in order to calculate the economic market generated. 26% (Truckers report, 2017) of that value is considered to be spent in direct jobs at a general labour cost of 50.000€ per year to companies, which is used to calculate direct employment created. It is probable that the distance to transport feedstock is lower than 200 km; therefore the results obtained must be assessed considering this aspect.

2.2.3 Feedstock-pathway combination cost forecast

Expected output

The objective of this section is to calculate the cost to produce alternative jet fuel for all the feedstock-pathway combinations.

Cost of conversion

The different sources of information provide different costs for producing alternative jet fuel. For this project, a great effort has been made to try to find the differences in the hypotheses made in each paper to justify the differences in cost. For each feedstock-pathway combination, the alternative jet fuel cost has been divided into feedstock cost, capital expenses, operating expenses and coproduct income. This way it has been possible to modify each factor to account for efficiency gains, or impact in commodity prices.

In the case of camelina, different feedstock and capital expenses are considered in the scenarios as shown in section *2.1 Methodology and scenarios*. The model is designed this way because the cost of camelina oil is unknown and depends on the oil market, and this way we are able to estimate its penetration for different prices.

Model assumptions

The model estimates de cost of producing alternative jet fuel for each feedstock-pathway combination taking into account several aspects:

- Operating and capital costs are based on the different references of the project. Please refer to Table 6 to see the references used for each feedstock and pathway. The project purpose was to identify the Minimum Fuel Selling Price for each feedstock-pathway combination. It is not within the scope of the project to study how the different costs are distributed within each pathway; however, the costs of the HEFA pathway has been distributed into feedstock, capital costs, operating costs, and co-product benefits to apply the learning rate as explained below. The initial MFSP is the price under column “2016” of Table 7. This price already considers earnings due to selling co-products.
- General efficiency gain per year: This variable is considered to take into account the continuous improvement of the different pathways throughout the years (also known as the “Learning Rate” (Hayward, et al., 2015)). This takes place due to scientific and technological improvements along the different pathways. The model applies 1.5% efficiency gain to the MFSP of each pathway. However, this efficiency gain is not applied to the feedstock when it is indexed in the market. Even when a pathway is not commercially producing alternative jet fuel, then model considers that the efficiency is improved at laboratory scale.
- With the application of the learning rate on alternative jet fuels, and the increase of the jet fuel price, the premium gap is reduced throughout the years. This gap has a limit since the alternative jet fuel is expected to be always sold at a larger price than fossil jet fuel due to better image for its users. The minimum price reached by each pathway will therefore be limited to 110% of fossil jet fuel price. A minimum premium of 10% is considered for this model.

Feedstock-pathway combination cost

Table 7 shows the forecast of the cost. As explained above, the price of 2016 is reduced by the learning rate, except for those pathways that use feedstock indexed in the market. For these pathways, the feedstock costs remain constant, while the operating and capital costs are reduced by the learning rate.

Table 7 - Pathway price per feedstock and year. (€/ton)

Conversion Technology	Feedstock	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
HEFA	Rapeseed	999	994	992	989	987	985	982	980	978	976	973	971	969	967	965	963	961	959	957	955
	Soy	904	899	897	894	892	889	887	885	883	880	878	876	874	872	870	868	866	864	862	860
	Sunflower	1251	1246	1244	1241	1239	1236	1234	1232	1230	1227	1225	1223	1221	1219	1217	1215	1213	1211	1209	1207
	Palm	839	834	832	829	827	825	822	820	818	816	813	811	809	807	805	803	801	799	797	795
	Coconut	1445	1440	1438	1435	1433	1430	1428	1426	1423	1421	1419	1417	1415	1413	1411	1409	1407	1405	1403	1401
	Salicornia	1111	1106	1104	1101	1099	1096	1094	1092	1090	1087	1085	1083	1081	1079	1077	1075	1073	1071	1069	1067
	Camelina	758	753	751	748	746	744	741	739	737	734	732	730	728	726	724	722	720	718	716	714
	Babasu	1229	1224	1221	1219	1216	1214	1212	1210	1207	1205	1203	1201	1199	1196	1194	1192	1190	1188	1186	1185
	Jatropha	1075	1070	1067	1065	1063	1060	1058	1056	1053	1051	1049	1047	1045	1043	1041	1038	1036	1035	1033	1031
	TCO	1229	1224	1221	1219	1216	1214	1212	1210	1207	1205	1203	1201	1199	1196	1194	1192	1190	1188	1186	1185
	Microalgae	1793	1792	1791	1791	1791	1790	1790	1789	1789	1789	1788	1788	1788	1787	1787	1787	1786	1786	1786	1785
	UCO	834	830	827	825	823	820	818	816	814	811	809	807	805	803	801	799	797	795	794	792
	Tallow	934	928	925	923	920	917	915	912	910	907	905	902	900	898	895	893	891	889	887	884
	Tall Oil	1059	1054	1051	1049	1046	1044	1041	1039	1036	1034	1032	1030	1027	1025	1023	1021	1019	1017	1015	1013
F-T	Forest residues	1590	1573	1557	1540	1524	1509	1493	1478	1463	1448	1434	1419	1405	1391	1378	1364	1351	1338	1325	1312
	Corn stover	1500	1484	1469	1453	1438	1424	1409	1395	1380	1366	1353	1339	1326	1313	1300	1287	1274	1262	1250	1238
	MSW	797	788	780	772	764	756	748	741	733	726	718	711	704	697	690	684	677	670	664	658
	Corn grain	1448	1433	1418	1403	1389	1375	1360	1347	1333	1319	1306	1293	1280	1267	1255	1243	1231	1219	1207	1195
	Switchgrass	1991	1971	1950	1930	1910	1890	1871	1851	1833	1814	1796	1778	1760	1743	1726	1709	1692	1676	1659	1643
	SRT	2100	2078	2056	2035	2014	1993	1973	1952	1933	1913	1894	1875	1856	1838	1820	1802	1784	1767	1750	1733
	Halophytes	1847	1827	1808	1789	1771	1753	1735	1717	1699	1682	1665	1649	1632	1616	1600	1584	1569	1554	1539	1524
	Macroalgae	4673	4624	4576	4528	4481	4435	4390	4345	4301	4257	4214	4172	4131	4090	4049	4010	3971	3932	3894	3857
DSHC-FTJ-SIP-DFSTJ	Corn stover	1656	1639	1621	1605	1588	1572	1556	1540	1524	1509	1493	1478	1464	1449	1435	1421	1407	1393	1380	1367
	Switchgrass	2176	2153	2131	2108	2087	2065	2044	2023	2002	1982	1962	1943	1923	1904	1885	1867	1849	1831	1813	1796
	Sugarcane	1533	1517	1501	1486	1470	1455	1440	1426	1411	1397	1383	1369	1355	1342	1329	1316	1303	1290	1278	1266
	Corn grain	2051	2030	2008	1987	1967	1947	1927	1907	1888	1869	1850	1831	1813	1795	1777	1760	1743	1726	1709	1693
	Sugar beet	1533	1517	1501	1486	1470	1455	1440	1426	1411	1397	1383	1369	1355	1342	1329	1316	1303	1290	1278	1266
ATJ	Sugarcane	1125	1113	1102	1090	1079	1068	1057	1046	1035	1025	1015	1005	995	985	975	965	956	947	938	929
	Corn grain	1184	1171	1159	1147	1135	1123	1112	1101	1089	1078	1068	1057	1046	1036	1026	1016	1006	996	986	977
	Switchgrass	1617	1600	1584	1567	1551	1535	1519	1504	1488	1473	1459	1444	1430	1415	1402	1388	1374	1361	1348	1335
	Forest residues	1641	1624	1607	1590	1574	1557	1541	1526	1510	1495	1480	1465	1450	1436	1422	1408	1394	1381	1367	1354
	SRT	1096	1084	1073	1062	1051	1040	1029	1019	1009	998	988	978	969	959	950	940	931	922	913	905
HDCJ	Corn stover	1043	1032	1021	1011	1000	990	980	970	960	950	941	931	922	913	904	895	886	878	869	861
	Forest residues	897	888	879	870	861	852	843	834	826	817	809	801	793	785	778	770	762	755	748	741
	SRT	975	965	955	945	935	926	916	907	897	888	879	871	862	853	845	837	829	821	813	805

2.2.4 Market penetration

Expected output

The market penetration section of the model provides the following output:

- Distribution of market demand among the different options available.
- Jet fuel required from each conversion technology.
- Volumes of feedstocks required to be produced.
- Market generated for each feedstock.
- Jet fuel required from each feedstock.
- Emissions per combination.

Model assumptions

The market penetration of the different pathways is based on the cost of each combination calculated in the previous step. The model considers the following assumptions:

- Approval years for the different pathways: These years are estimated based on the status of each pathway and the latest information obtained from ASTM.
- Use of food competitive feedstocks: The model considers 1st and 2nd generation feedstocks in different scenarios, including camelina as 2nd generation feedstock.
- CO_2 cost. The cost of emissions will increase the cost of fossil fuel, reducing the gap between the fossil price and the alternative jet fuel.
- 60% of maximum premium for market entry. This means that the maximum cost of the alternative jet fuel to enter the market is the cost of fossil jet fuel multiplied by 1.6.
- The cost of fossil fuel is modified based on the scenario modelled (0.5% or 2.5% annual increase).
- The amount of alternative jet fuel required in the market is calculated based on a linear trend to meet the regulation scenario.
- The alternative jet fuel total market is allocated among the viable alternatives based on their individual potential (the cheaper the alternative, the higher its penetration).

The share of the market covered by each option is based on this potential, and this potential is calculated based on the premium of each combination, using the formula shown in **¡Error! No se encuentra el origen de la referencia.**.

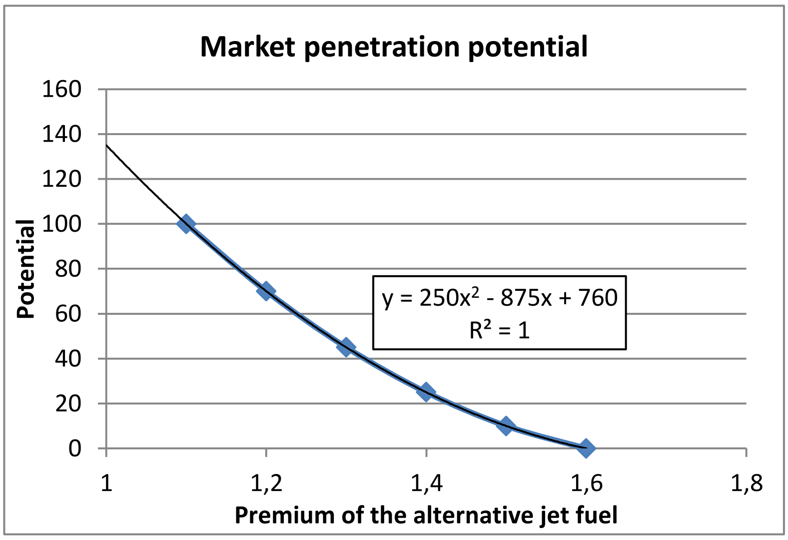

Figure 1 - Market penetration potential

Market penetration example

As an example, Table 8 shows the market penetration for the base scenario:

Table 8 - Market penetration for base scenario

Conversion Technology	Feedstock	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
HEFA	Salicornia	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Camelina	90.4%	78.0%	69.5%	63.6%	59.1%	55.1%	51.1%	48.0%	44.3%	41.0%	38.3%	36.1%	34.2%	32.6%	30.7%	29.1%	27.7%	26.5%	25.4%	24.2%
	Babasu	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Jatropha	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Microalgae	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	UCO	0.0%	0.0%	0.0%	0.0%	0.0%	1.1%	3.5%	5.3%	6.6%	7.5%	8.2%	8.8%	9.2%	9.5%	9.7%	9.8%	9.8%	9.9%	9.8%	9.8%
	Tallow	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Tall Oil	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
F-T	Forest residues	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Corn stover	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	MSW	9.6%	22.0%	30.5%	36.4%	40.9%	43.8%	45.4%	46.7%	46.5%	45.8%	45.2%	44.7%	44.3%	43.8%	42.7%	41.7%	40.8%	40.0%	39.1%	38.0%
	Switchgrass	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	SRT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Halophytes	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Macroalgae	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
DSHC	Corn stover	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Switchgrass	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Sugar beet	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ATJ	Switchgrass	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Forest residues	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	SRT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
HDCJ	Corn stover	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	1.5%
	Forest residues	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.6%	5.7%	8.3%	10.4%	12.3%	13.9%	15.1%	16.1%	17.0%	17.7%	18.3%	18.7%
	SRT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	1.8%	3.3%	4.7%	5.9%	7.0%	7.9%

The market penetration section of the model also allows the researchers to obtain other information, which is reported as outputs. The different amounts of feedstocks were calculated for each scenario. Table 9 shows the amounts of feedstock required for the base scenario.

Table 9 - Feedstock required for base scenario (Thousands of tons).

Feedstock	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Camelina	0.0	146.9	273.4	382.0	472.4	554.5	614.4	662.8	707.7	750.2	790.8	828.4	852.0	875.1	897.8	920.4	938.3	951.0
UCO	0.0	0.0	0.0	7.6	32.3	61.7	91.9	121.8	152.0	182.3	212.6	242.4	268.0	293.0	317.6	341.8	364.0	383.6
Forest residues	0.0	0.0	0.0	0.0	0.0	0.0	163.7	419.0	696.2	990.8	1299.1	1615.8	1911.7	2208.0	2504.4	2800.5	3081.4	3341.5
Corn stover	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	168.8	553.5
SRT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.0	176.7	346.2	522.8	705.3	888.5	1068.4
MSW	0.0	682.9	1532.1	2464.6	3405.6	4376.0	5229.0	6014.0	6785.9	7546.9	8298.3	9025.0	9597.3	10157.0	10706.3	11246.8	11723.9	12126.0

2.2.5 Conversion technology

Expected output

The objective of this section is to calculate the following:

- Amount of conversion facilities required for each pathway
- Direct employment generated

Model assumptions

The project considers five different conversion pathways:

- HEFA
- FT
- DSHC
- ATJ
- HDCJ

While some of these pathways have not been approved yet, the model permits their introduction in the future. For this project, the model considers that the first four pathways will be available at the start of the mandate period, and that HDCJ will be approved for aviation use by 2021.

From the different literature studied, different standard production volumes have been considered in the model for the different types of facilities. The volumes considered are shown in Table 10.

Table 10 - Maximum production capacity per conversion technology facility (tons/year)

HEFA	300 000
FT	200 000
DSHC	200 000
ATJ	200 000
HDCJ	300 000

Conversion facilities example

Once the distribution per feedstock-pathway is accomplished in the market penetration step, we are able to calculate the amount of alternative jet fuel to be produced per conversion pathway for each year, as shown in Table 11.

Table 11 - Alternative jet fuel per conversion pathway for base scenario (thousands of tons)

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
HEFA		117.5	218.7	311.6	403.7	492.9	565.0	627.7	687.8	746.0	802.7	856.7	896.0	934.5	972.4	1,009.8	1,041.8	1,067.8
FT		67.4	151.1	243.1	335.9	431.6	515.7	593.1	669.2	744.3	818.4	890.0	946.5	1,001.7	1,055.8	1,109.2	1,156.2	1,195.9
DSHC																		
ATJ																		
HDCJ							28.7	73.5	122.1	173.8	227.9	287.2	376.3	467.5	560.4	654.6	760.3	879.7

These quantities are divided by the capacity for each type of facility to calculate the amount of conversion facilities required for each technology. Figure 2 and Table 12 show the facilities required for the base scenario:

Table 12 - Facilities required for base scenario.

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
HEFA	-	1	1	2	2	2	2	3	3	3	3	3	3	4	4	4	4	4
FT	-	1	1	2	2	3	3	3	4	4	5	5	5	6	6	6	6	6
DSHC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ATJ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HDCJ	-	-	-	-	-	-	1	1	1	1	1	1	2	2	2	3	3	3

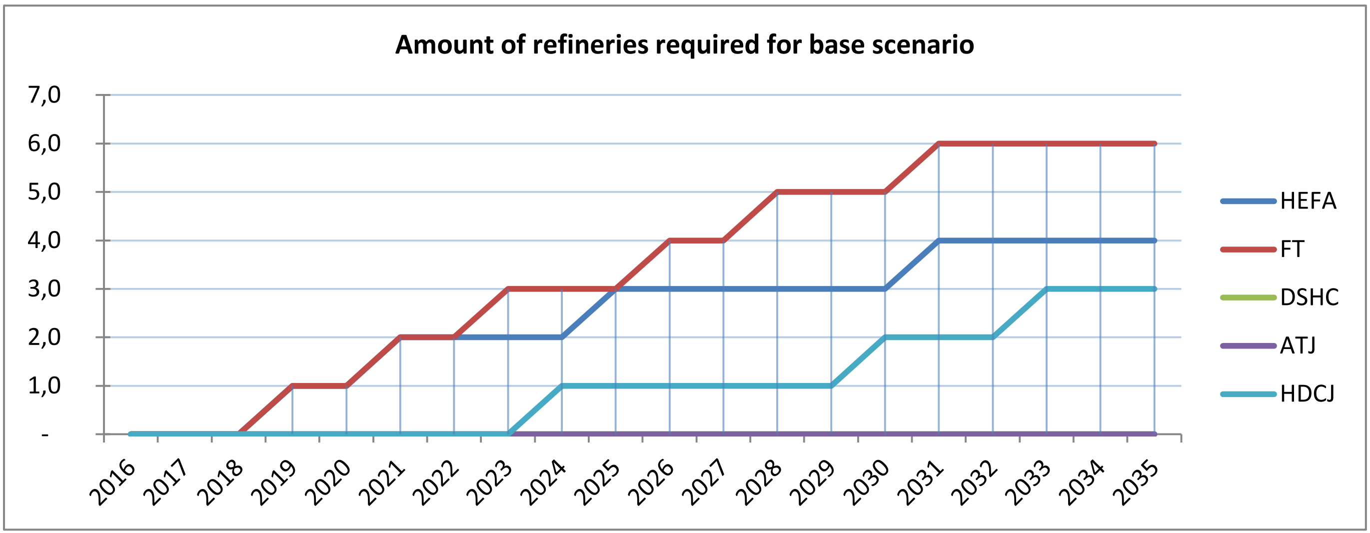

Figure 2 - Conversion facilities required per technology

Employment generated

The amount of conversion facilities is used to calculate the employment generated based on 70 people per facility[1].

Conversion technology hypotheses

CT.H1: Due to efficiency gains, as time passes more technologies will be able to compete with fossil fuels.

CT.H2: Some alternative fuels will suffer a bubble effect, covering large parts of the market while other alternatives are not competitive. However, with time, other alternatives will enter the market, increasing the distribution among the alternatives.

[1] Based on personal communication with Neste.

2.2.6 Alternative jet fuel logistics

Expected output

The objective of this step is to calculate the costs and direct employment generated in this step of the value chain.

Model assumptions

The model considers distributing the alternative jet fuel to a reduced number of airports selected among the densest European traffic areas. This was designed to be proportional to the total amount of fuel uplifted for commercial flights in those areas. In that way, the level of blend would be equal for all the flights operating on the selected airports.

This study has considered the five areas with most commercial air traffic in the European Union:

- London (Airports of Heathrow, Gatwick, Stansted, Luton and London City)
- Paris (Charles de Gaulle, Orly and Beauvais)
- Frankfurt (Frankfurt Main and Hahn)
- Amsterdam (Schiphol)
- Madrid (Barajas)

Annex I. Demand presents a full description of the work done to estimate the demand of the model.

In order to save logistics costs for the value chain, we have considered the conversion facilities to be within 100 km of the airport where the alternative jet fuel is to be loaded. The transportation to the airport is considered to be executed via pipeline. The transportation costs are considered to be 0.02€ per ton·km([2]). Normally, the alternative jet fuel needs to be mixed with fossil jet fuel, which would require transporting double the volume, however, only the cost for the alternative jet fuel is calculated. The direct employment generated has been calculated considering that 70% of the costs are due to labour and with 50 000 € as annual salary.

[2] Personal communication with CLH.

2.2.7 Impact on airlines

Expected output

The objectives of this section are the following:

- Calculate the amount of alternative jet fuel that is loaded to each airline.
- Calculate the average premium.
- Calculate the additional costs for each airline.

Model assumptions

The alternative jet fuel to be uploaded by the main aircraft operators was estimated using only the top 3 operators of each airport; therefore, not all of the alternative jet fuel has been distributed to the different aircraft operators. However, it is possible to estimate the premium to be paid by the airlines.

Table 13 shows the information obtained for the different airlines:

Table 13 - Information output for airlines

Total alternative jet fuel produced (tons)	tons
Premium per ton (€)	€
Total cost of alternative jet fuel (€)	€
Total premium (€)	€
Premium	%

The airlines included in the study include the following:

- British Airways
- Air Lingus
- Lufthansa
- EasyJet
- Norwegian
- Air France
- Aerienne
- KLM
- KLM City Hopper
- Iberia
- Air Nostrum
- Air Europa
- Lufthansa CityLine
- Tyrolean Airways

Impact on airlines hypotheses

IA.H1: Hub airlines will be greatly affected because the alternative fuel will be distributed to main cities' airports.

2.2.8 Environmental impact

Expected output

The objective of this section is to gather the information related to environmental impact for each scenario.

Environmental impact example

Given that the share per pathway was obtained, and that the LCA for most pathways is available in the literature, the total savings of emissions for the different scenarios could be calculated as shown in Table 14.

Table 14 - Emissions evolution for base scenario

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Amount of alternative fuel (thousands of tons)	0.0	184.9	369.8	554.7	739.6	924.5	1109.4	1294.3	1479.2	1664.1	1849.0	2033.9	2218.8	2403.7	2588.6	2773.5	2958.4	3143.3
Average emissions per ton (CO_2 tons)	0.00	0.89	0.87	0.88	0.88	0.88	0.90	0.91	0.92	0.93	0.93	0.94	0.95	0.95	0.96	0.97	0.97	0.97
Saved emissions	0.0%	71.7%	72.4%	72.1%	72.0%	71.9%	71.6%	71.2%	70.9%	70.6%	70.4%	70.2%	69.9%	69.7%	69.5%	69.4%	69.2%	69.2%
Alternative fuel emissions (thousands of tons)	0.0	164.5	321.6	487.6	652.2	817.5	993.0	1174.3	1357.0	1540.9	1725.6	1911.6	2102.7	2294.1	2485.7	2677.6	2867.5	3054.5
Saved emissions (thousands of tons)	0.0	417.9	843.2	1259.7	1677.5	2094.7	2501.6	2902.7	3302.4	3701.0	4098.7	4495.1	4886.5	5277.5	5668.3	6058.9	6451.4	6846.8

2.2.9 Camelina specific results

Expected output

The objective of this section is to calculate the amount of hectares required for each scenario and the employment generated.

Model assumptions

Given that the model was firstly focused on the requirement and impact of producing camelina, this section provides insight of the alternative jet fuel produced from camelina.

Based on the camelina oil required, obtained in the market penetration section, we were able to estimate the amount of grain using standard crushing procedures (without solvent). Information regarding the amount of grains per hectare has been obtained from other projects and from the ITAKA project. This information is used to calculate the amount of camelina hectares required to meet the volumes required.

Different scenarios are considered regarding the price of camelina, which is used to calculate the employment generated, considering that 80% of the price is used for manpower at 50.000€ of annual salaries.

3 Analysis of results

This section presents and analyses the results obtained in the simulations completed with the model. The tables with the data of the figures can be obtained in *Annex II. Results*.

The legend of the graphs is summarised in the following table:

Table 15 - Legend of figures

1st gen	1st generation of feedstocks
2nd gen	2nd generation of feedstocks
2.50%	High fossil fuel price annual increase
0.50%	Low fossil fuel price annual increase
2%	Low percentage of fuel that must be alternative in 2035
4%	High percentage of fuel that must be alternative in 2036
W/ MSW	MSW is a proven alternative feedstock
W/o MSW	MSW cannot be used as feedstock
L	Low HEFA capital expenses (40 €) per ton of fuel.
H	High HEFA capital expenses (110 €) per ton of fuel.
l	Low camelina oil price (500 €/t)
h	High camelina oil price (700 €/t)

This section has been written following first the alternative jet fuel value chain, and later tackling the camelina specific case, and finally global social and environmental indicators. The base scenario can be observed in a red box in all the figures.

3.1 Feedstock production

Alternative jet fuel allocation by feedstock

One of the key outputs of the model is the distribution of alternative jet fuel among the different feedstocks for the different scenarios. Figure 3 shows this distribution, from which we can extract key information.

The following observations can be made from the results:

- The distribution in terms of percentage is the same regardless of the mandate scenario.
- The difference between the 1st and 2nd generation scenarios is that the vegetable oil share is reduced for 2nd generation, which makes sense due to the restriction of palm oil.
- As expected, the amount of vegetable oil decreases in all scenarios of 2nd generation, and in cases of low fossil fuel price growth and high camelina oil cost, it does not meet the 60% premium limit.
- For high growth of fossil jet prices, there are several feedstocks entering the market: Tall oil, TCO, Corn grain and sugarcane (for 1st generation), and tallow oil.
- For low growth of fossil jet prices, MSW is the largest feedstock used, if its technology is proved successful. Otherwise, forest residues, vegetable oil, UCO, and short rotation trees uptake most of the market, with a small share for corn stover.

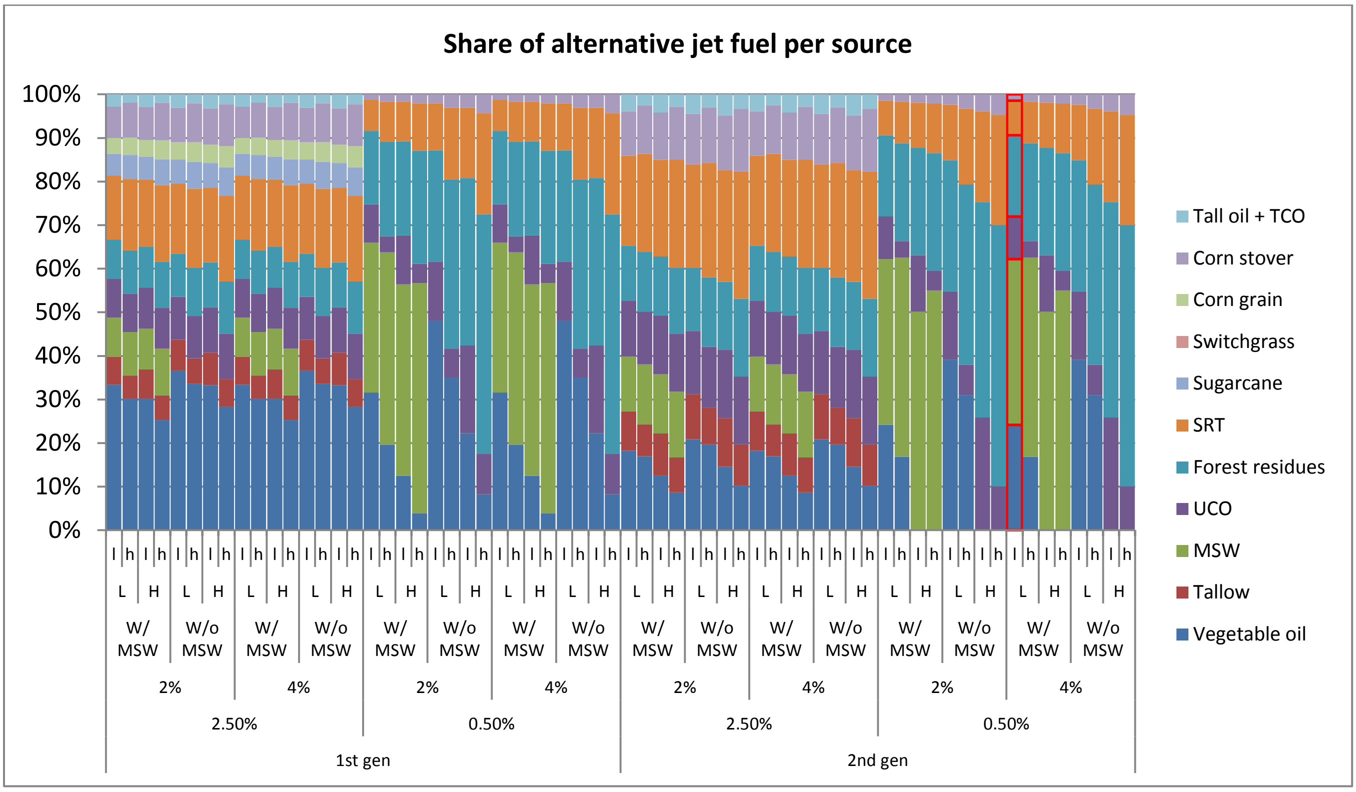

Figure 3 - Source of alternative jet fuel for 2035

If we group together crop and residual feedstocks, we obtain interesting results shown in **¡Error! No se encuentra el origen de la referencia.**. It is important to keep in mind that finding a use to a residue changes its nature, becoming a co-product that can be sold, subject to market dynamics, the volatility of the residues' cost is unknown in the long term.

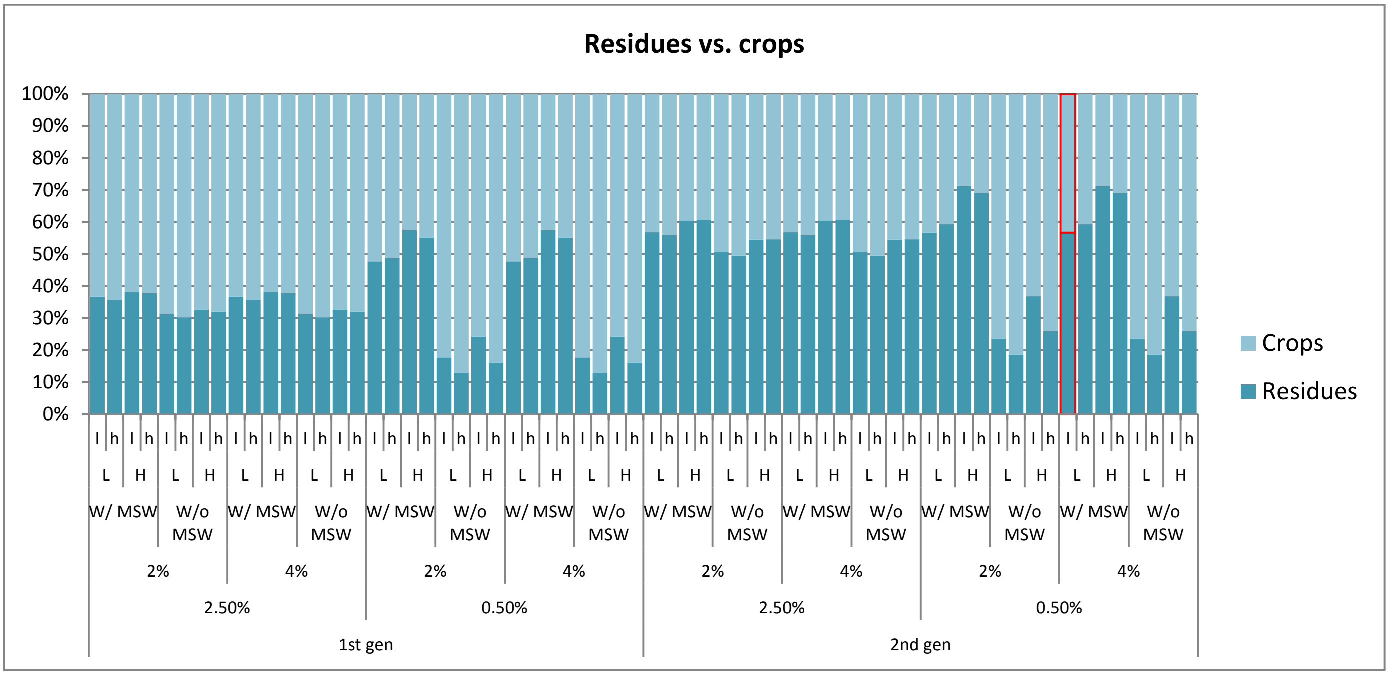

Figure 4 - Residues versus crops

Feedstock production requirements

Depending on the efficiency of the conversion pathway, the model estimates the amount of each type of feedstock required to meet the quantities of jet fuel calculated.

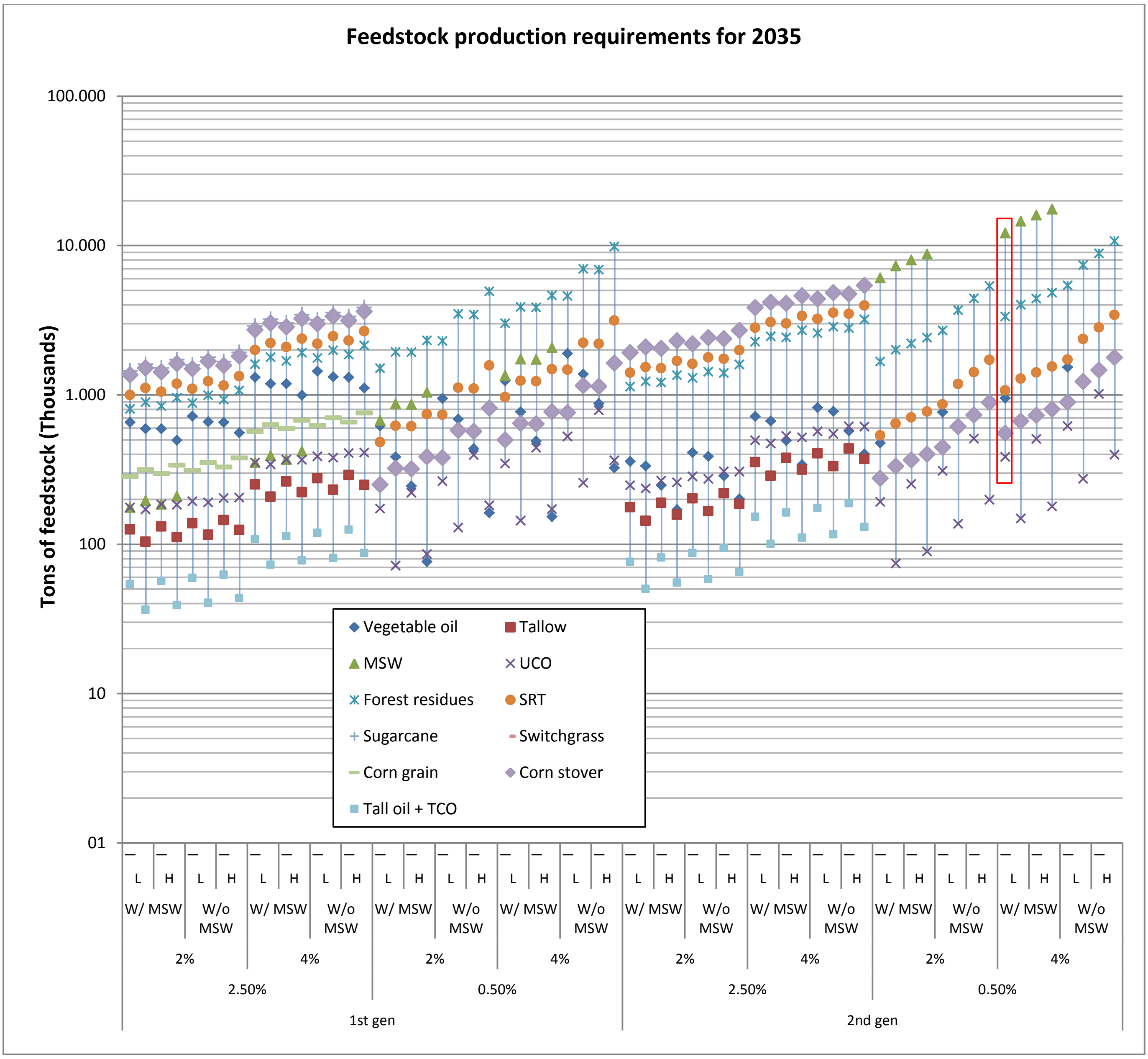

Figure 5 - Feedstock production requirements for 2035 (Base scenario in red rectangle)

Figure 5 shows the feedstock mass (tons) required for the year 2035 for the scenarios studied. It is important to notice that forest residues and MSW have a very low feedstock to biofuel mass ratio (about 1/12), while vegetable oil for example has a ratio of 0.80 (Pearlson, 2011).

Analysis per feedstock

Figure 6 depicts the market generated per feedstock in 2035. This has been calculated by multiplying the quantities required for each feedstock by the prices found in the literature explained in Section *2.2.1 Feedstock*.

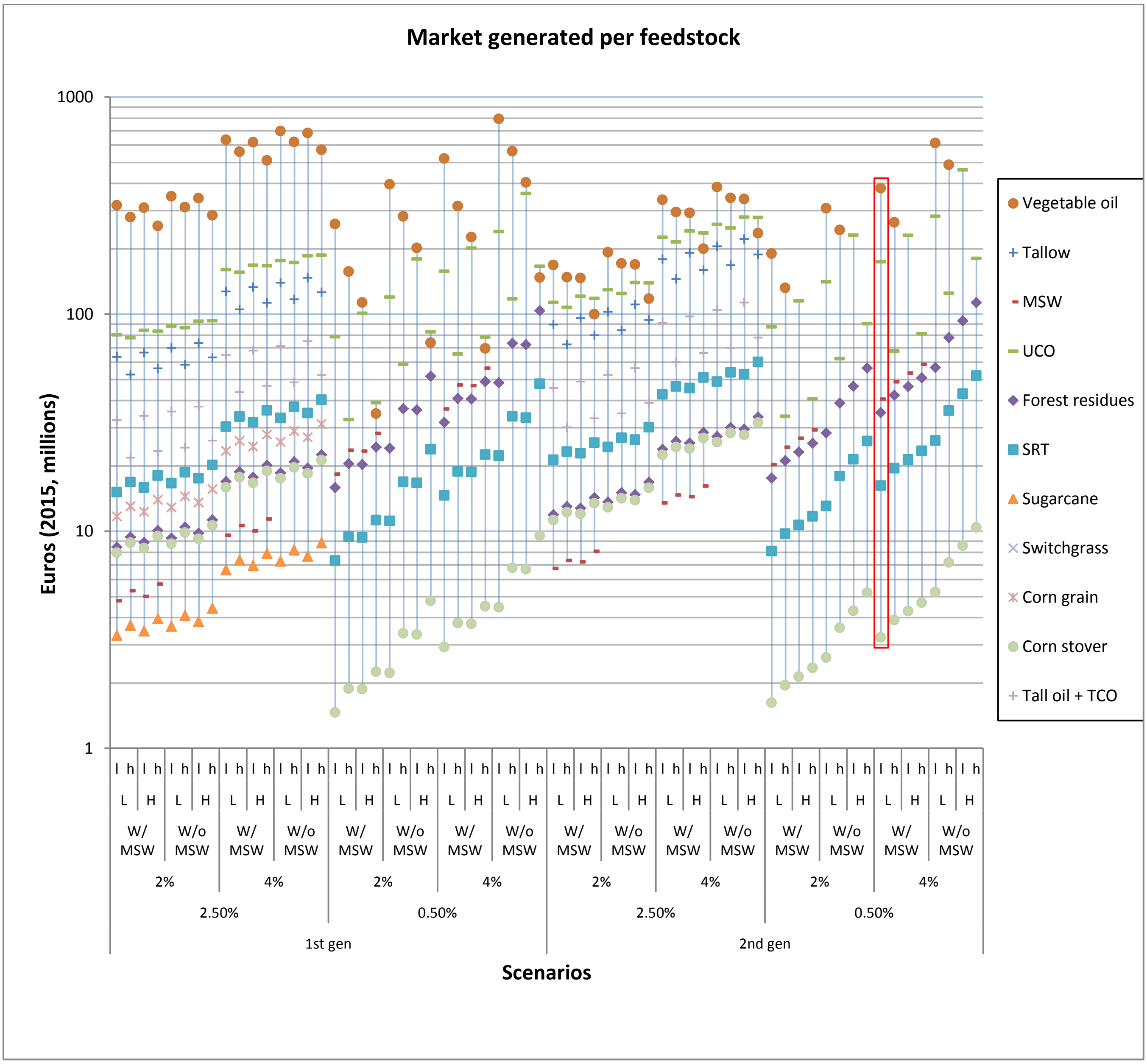

Figure 6 - Market generated per feedstock.

Since HEFA has the highest feedstock to biojet mass ratio, and the feedstock is the most expensive part of its pathway, vegetable oil, UCO, tallow, TCO and tall oil generate higher markets than the rest of feedstocks.

Imported and European oil

Figure 7 shows the origin of the vegetable oil. Table 4 in section *2.2.1 Feedstock production* explains the differences of European and imported oil.

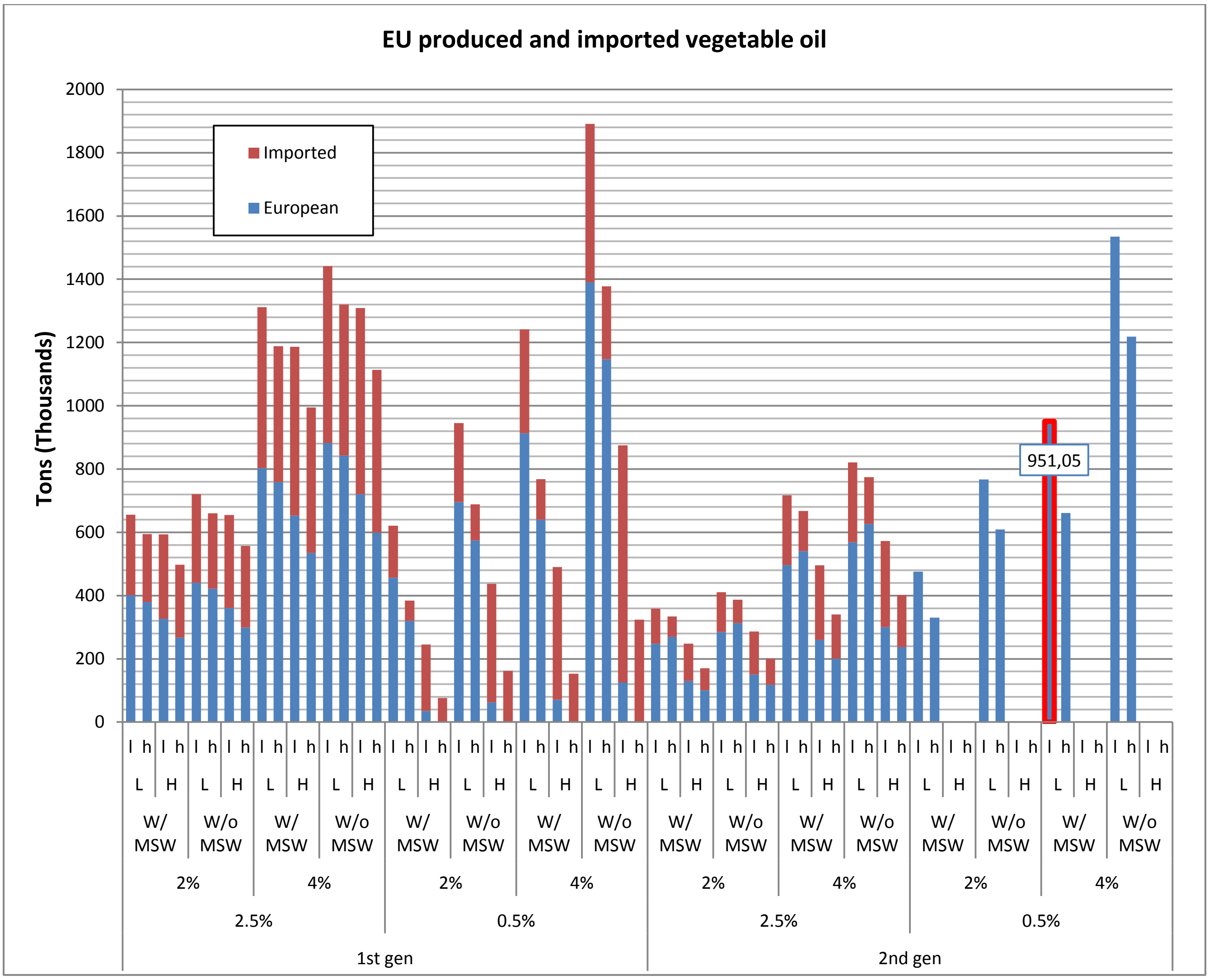

Figure 7 - EU produced and imported vegetable oil.

The following was observed from the results:

- Larger amount of imported oil is shown in the case of 1st generation, due to the cheap import of different feedstocks.
- In the case of 2nd generation scenarios, the cost of fossil fuel will affect the types of feedstocks that meet the premium requirements. Especially in low fossil fuel cost, where all oil is expected to be produced in Europe (from camelina).
- For the base scenario, 951,000 tons of camelina oil would be required.
- The maximum expected camelina demand will be just over 1.4 million tons.

Base Scenario

Figure 8 shows the distribution of the alternative jet fuel based on the feedstock for the base scenario.

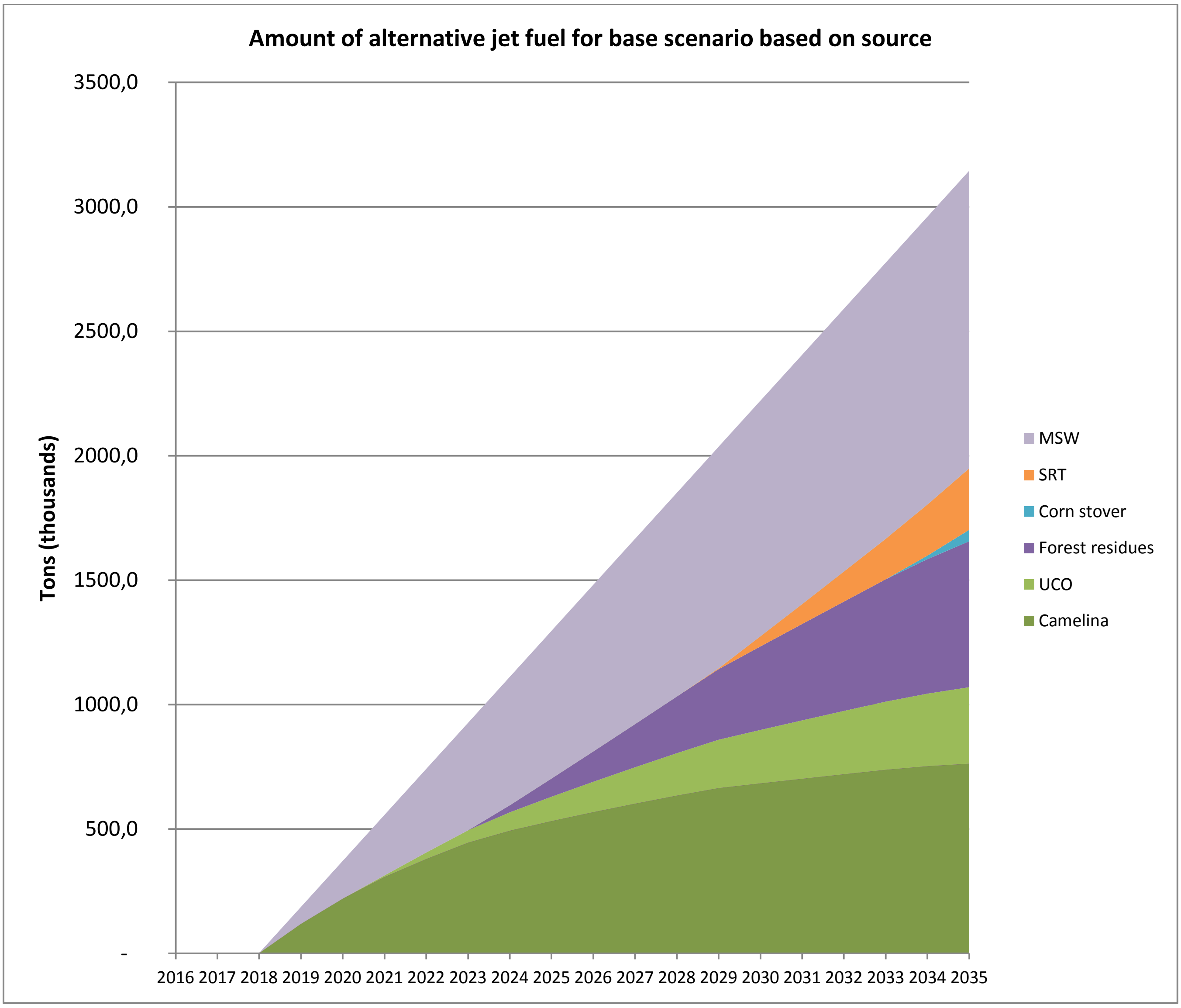

Figure 8 - Amount of alternative jet fuel based on origin for base scenario.

The following can be observed from the results:

- The base scenario shows that MSW and camelina will be the main feedstocks.
- In the mid ‘20s, UCO and forest residues are expected to penetrate the market.
- Finally, in last part of the period, SRTs and corn stover will reach competitive prices to enter the market.

3.2 Feedstock logistics

Figure 9 depicts the market generated by the feedstock logistics of the model.

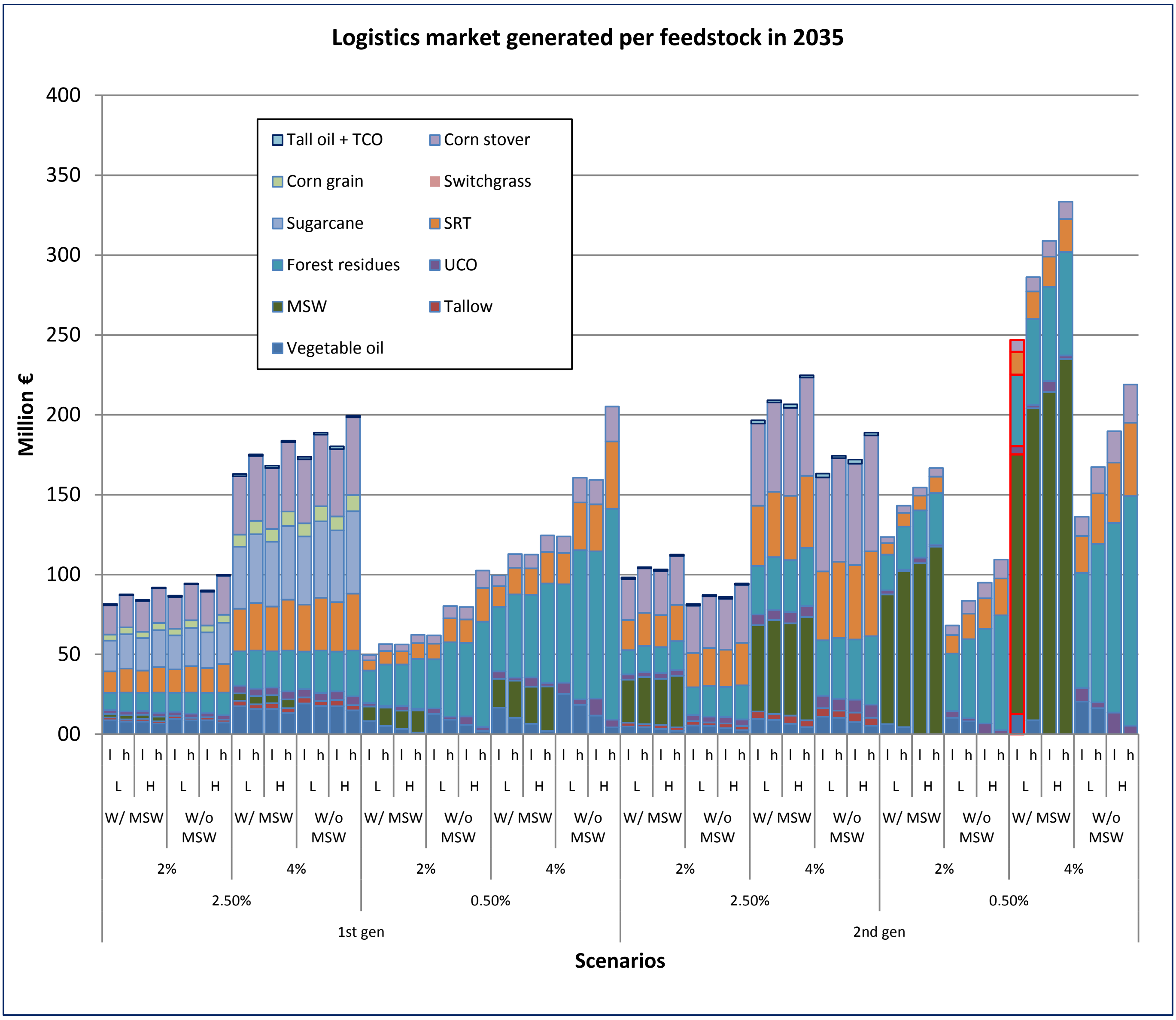

Figure 9 - Logistics market generated per feedstock

One important factor for these values is the ratio of tons of feedstock required per ton of jet fuel produced for the different pathways. The following observations can be made from the results:

- The simulations show that those scenarios with higher HEFA production have less feedstock required, lowering the logistics costs.
- Residues such as MSW and forest residues require transporting a lot of mass for their respective pathways.
- For the base scenario, MSW will uptake most of the logistics costs.
- It is important to keep in mind that the average transportation distance has been set to 200km. This could be reduced for certain types of facilities, especially low-density feedstock pathways. Reducing these figures down to one half.

3.3 Conversion technology

Amount of conversion facilities

Figure 10 shows the amount of conversion facilities required by 2035 for the different scenarios depicting the type of technology used. Figure 11 shows the amount of required facilities in a cumulative manner.

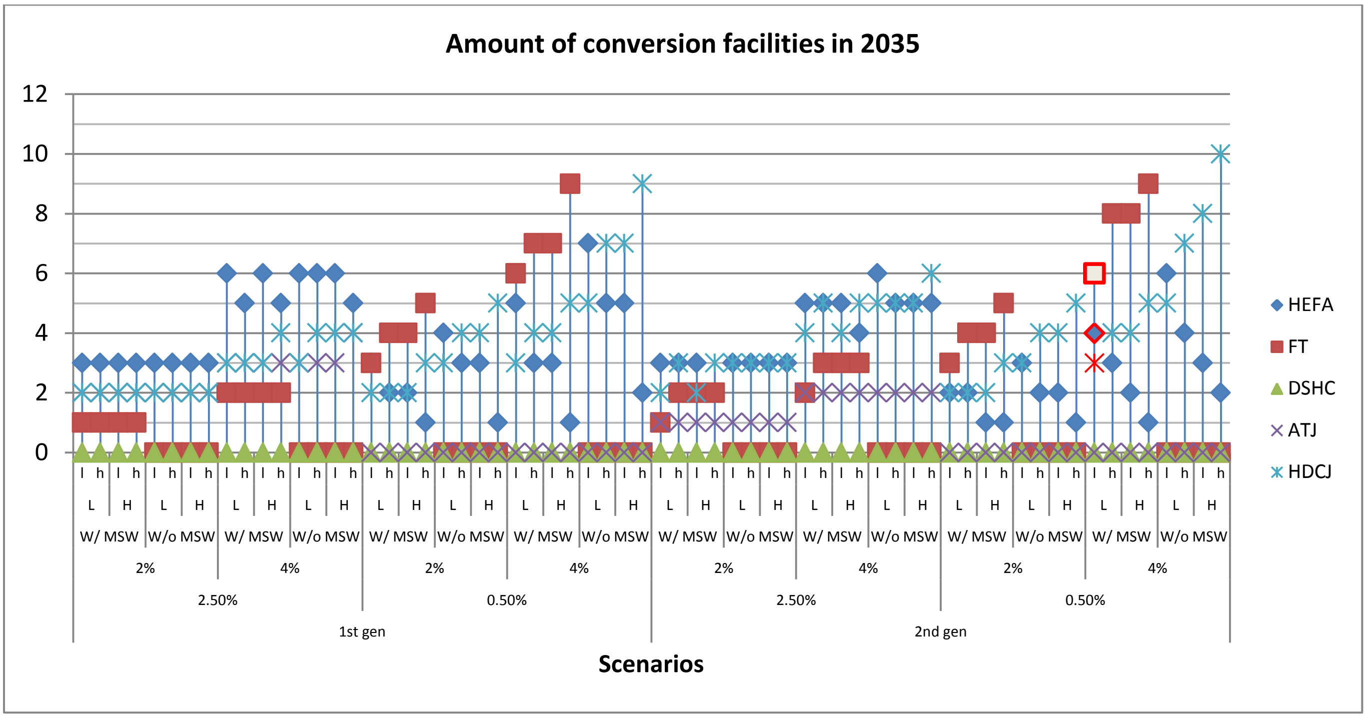

Figure 10 - Amount of conversion facilities in 2035.

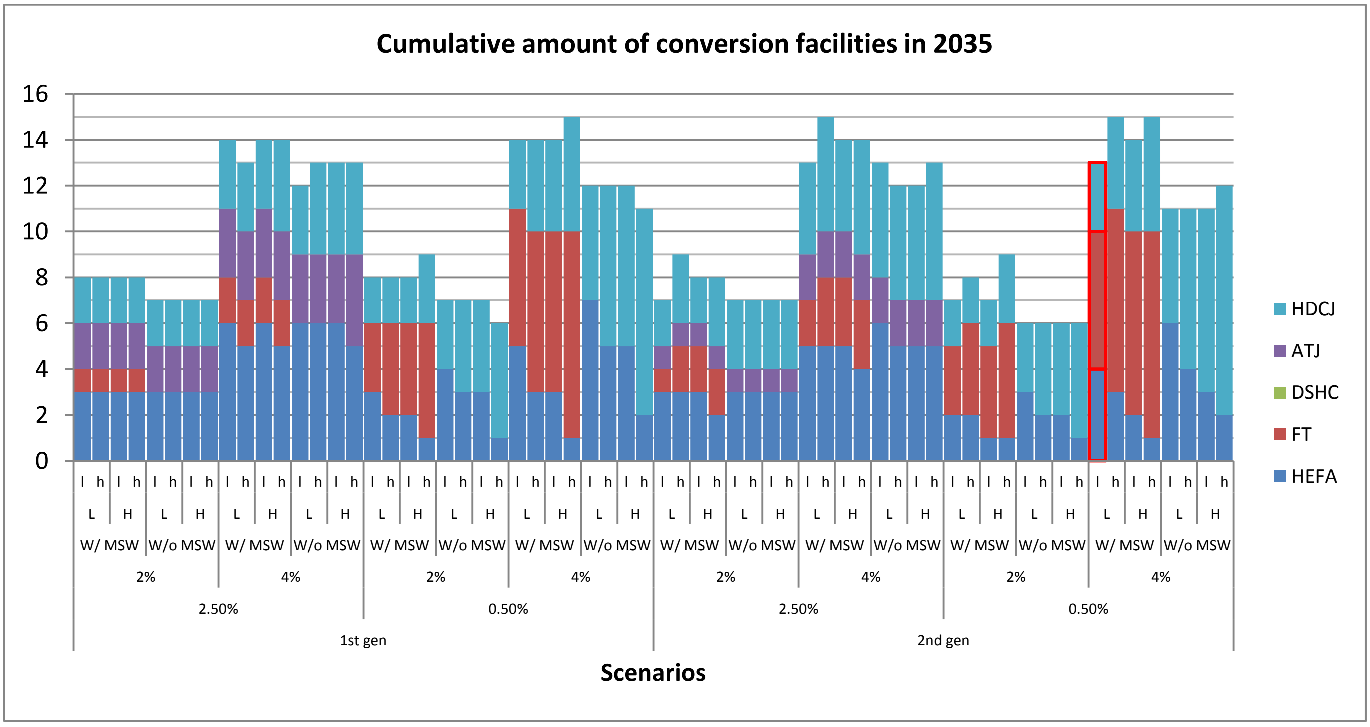

Figure 11 - Cumulative amount of conversion facilities in 2035.

The following observations can be made:

- The total amount of refineries required in total are in the range of 6 to 16. These are very rough figures since the conversion facilities in the model are in the capacity range of 200,000 to 300,000 t/year. In reality, the conversion facilities can reach higher capacity; however, the production will typically include many types of products.
- FT is basically only in the market if the MSW pathway is available, reaching high quotas of 8-9 if fossil fuel price is low.
- HEFA and HDCJ compete in the market in all scenarios. HEFA has higher penetration in high fossil fuel price scenarios.
- For the Base Case, about 6 FT, 4 HEFA, and 3 HDCJ conversion facilities are expected to be required.
- The model shows that DSHC is too expensive to meet the premium criteria from the information gathered in the literature.

Base scenario

Figure 12 shows the demand of alternative jet fuel for the base scenario throughout the years. This is based on the change of premium for each feedstock-conversion technology combination. The price of each combination changes due to value-chain efficiency gains and depending on the fossil fuel price increase the premium is modified.

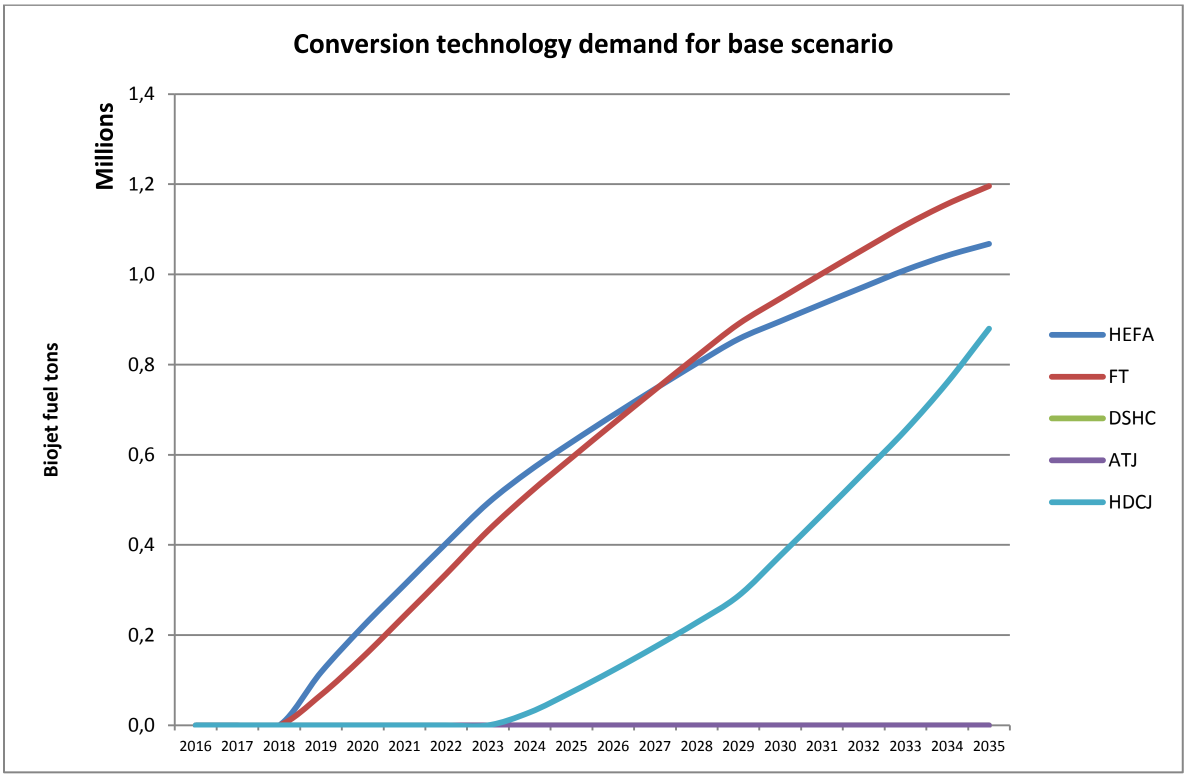

Figure 12 - Conversion technology demand for base scenario.

Figure 13 shows the amount of conversion facilities required for the base scenario demand shown in Figure 12.

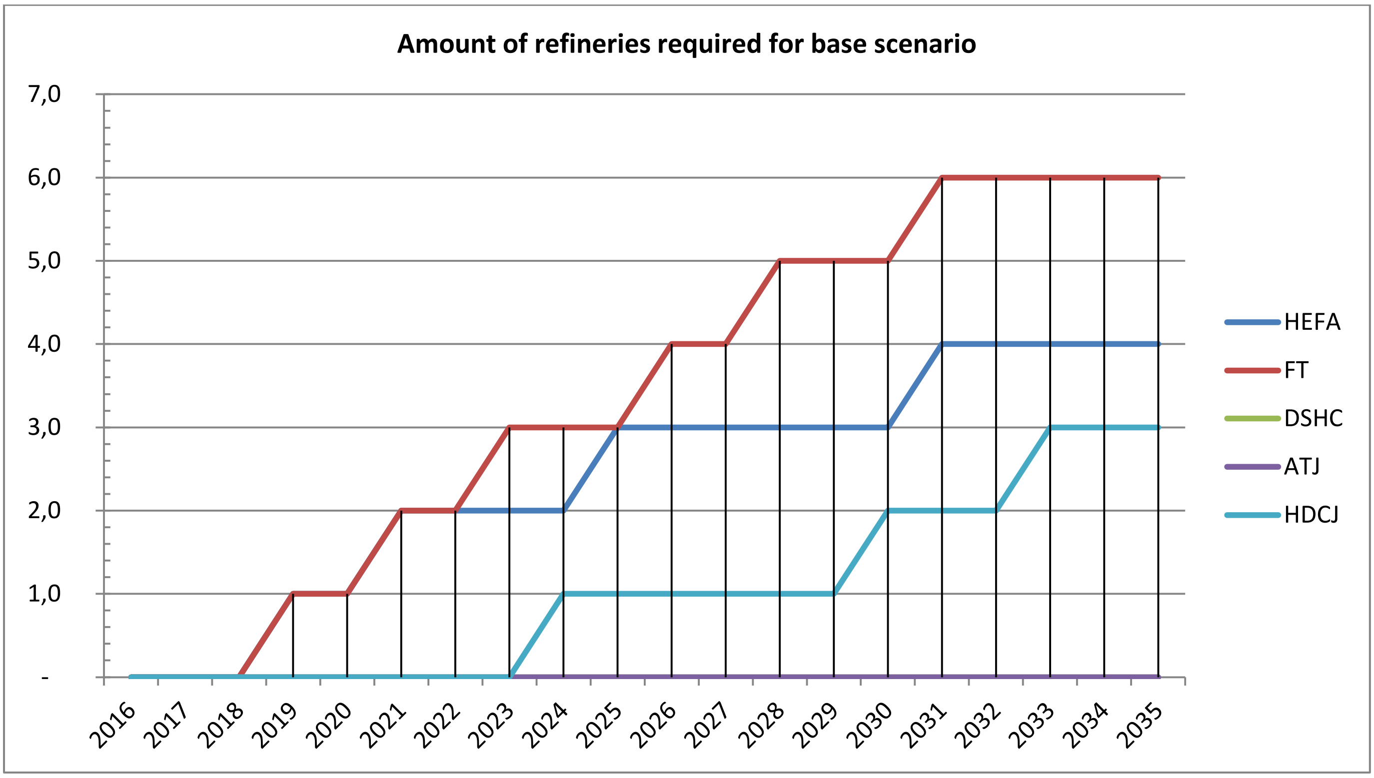

Figure 13 - Amount of refineries required for base scenario.

The base scenario evolution provides us the following information:

- The base scenario shows how the market is distributed mainly between HEFA and FT until the irruption of HDCJ.
- While FT and HEFA have similar market in terms of alternative jet fuel tons until 2024, fewer facilities are required to produce them in the HEFA pathway.
- ATJ and DSHC are not expected to be price competitive until 2035 with the information obtained in the research for the base scenario. Although, due to the volatility of fossil jet fuel prices, there is a high chance for the base scenario not to occur, allowing other pathways to be price competitive.

3.4 Alternative jet fuel logistics

Figure 14 shows the alternative jet fuel tons-kilometres for the different scenarios.

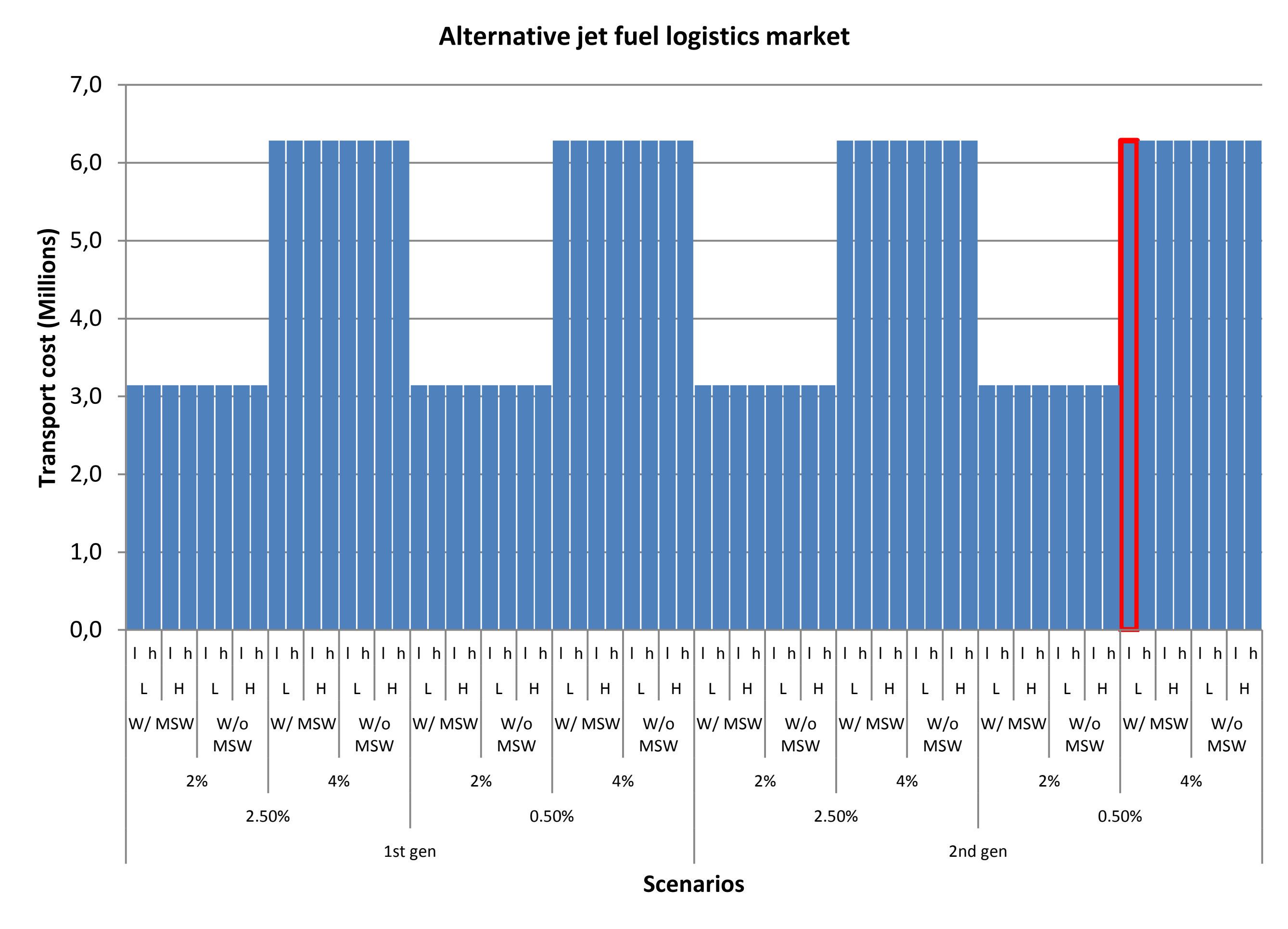

Figure 14 - Alternative jet fuel ton-km.

Since we assume that the facilities are located within 100km from the airport, the cost only depends on the amount of fuel transported, that is, on the mandate itself. Just above 3 M€ for the 2% mandate and about 6 M€ for the 4% mandate will be the costs related to alternative jet fuel logistics. Since the neat fuel is very sensible to logistics operations, it is possible that the transportation is needed to be accomplished with a 50% blend, which would double these costs.

Airport distribution

Figure 15 shows the distribution of alternative jet fuel to the airports throughout the years. This has been calculated using data of fuel consumption from 2013 and performing a traffic extrapolation per aerodrome based on traffic prediction increase per area. Eurocontrol, Airbus and Boeing forecasts have been used to perform these extrapolations.

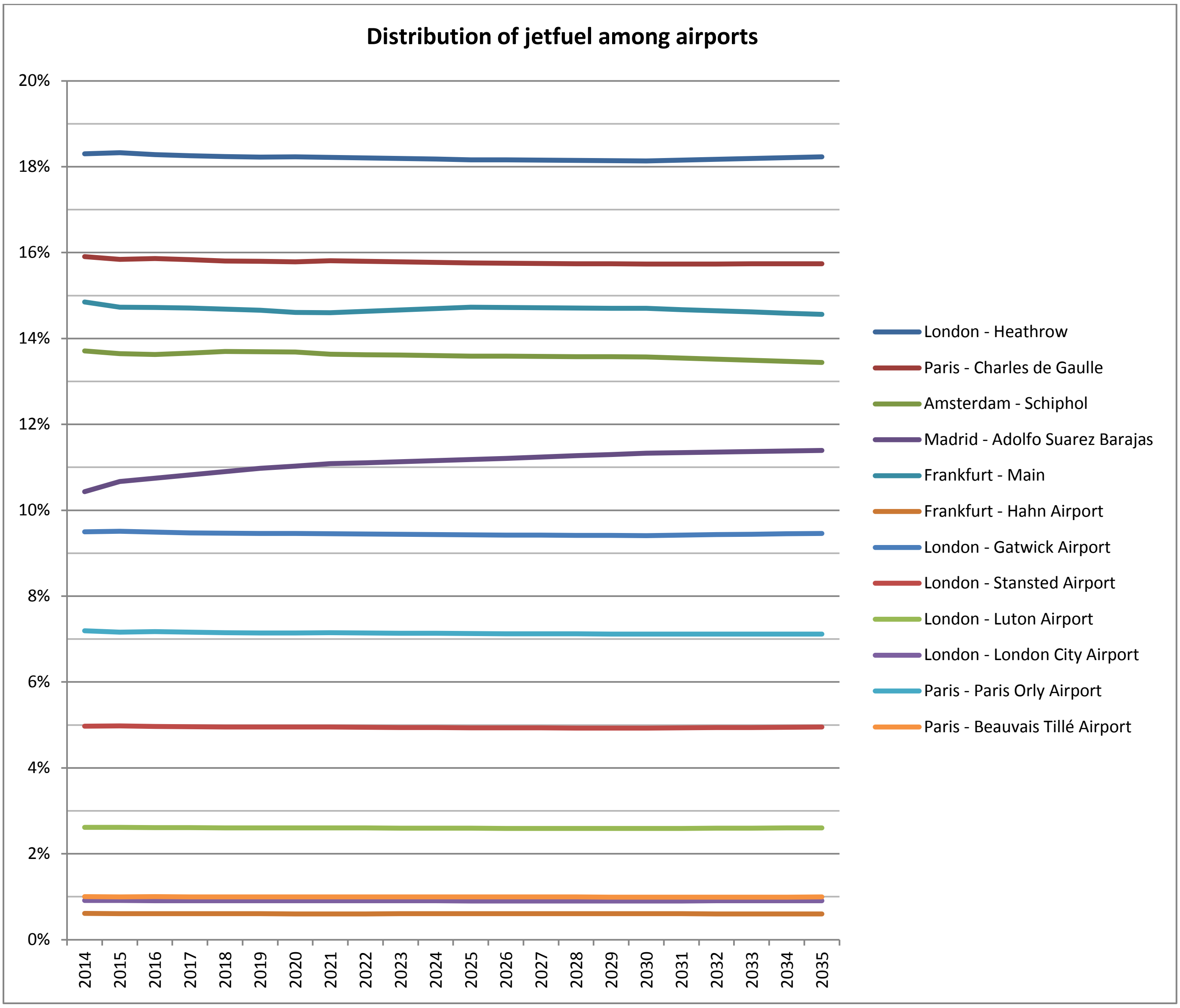

Figure 15 - Distribution of alternative jet fuel among airports.

The forecast of traffic growth in the different airports shows slight variations in the percentage of alternative jet fuel distribution among airports throughout the timeframe of the study. This is due to changes in traffic forecasting to different regions of the world.

3.5 Impact on airlines

Average premium in 2035

Figure 16 shows the average premium of the alternative jet fuel in 2035. This has been calculated by dividing the total cost of biofuel produced by what it would have costed if only fossil jet fuel was used.

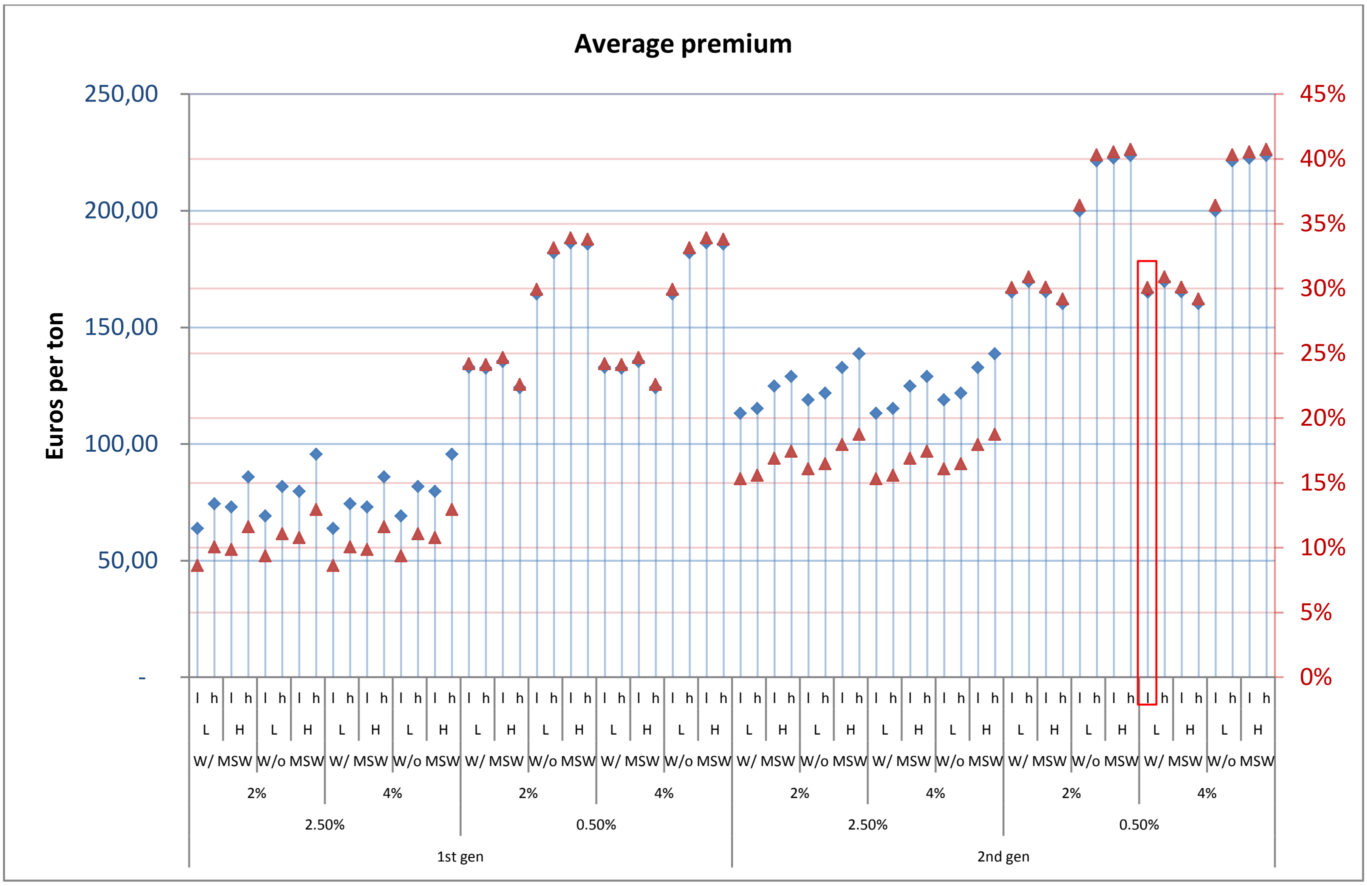

Figure 16 - Average premium in 2035.

The average premium is calculated in a top-down approach: the total cost of alternative fuel produced is divided by the quantity produced to reach average €/t. This is then divided by expected fossil jet fuel price in 2035 to reach the average premium.

The following observations can be made:

- The average premium will obviously depend on the fossil jet fuel growth scenario. With a growth of 2.5%, the premium will stay below 35% for 1st generation scenarios, and below 40% for second-generation scenarios.
- The model does not distinguish differences between the different mandate scenarios mainly because no limits on feedstocks have been established in the model. Establishing these limits would change the price of the pathways depending on the quantities required, generating differences between mandate scenarios.
- For high fossil jet prices, the premium stays below 42% (220 €). For low fossil jet prices, the premium stays below 20% (139 €).
- The base scenario shows a premium of 30% (162 €).

Cost efficiency

Figure 17 shows the cost efficiency in terms of euros per ton of CO_2 saved. The cost efficiency was calculated by dividing the over cost of producing alternative fuel (total alternative jet fuel cost minus the respective fossil jet fuel cost) and dividing it by the total amount of CO_2 tons saved. This means the average cost that the industry is spending to save a ton of CO_2.

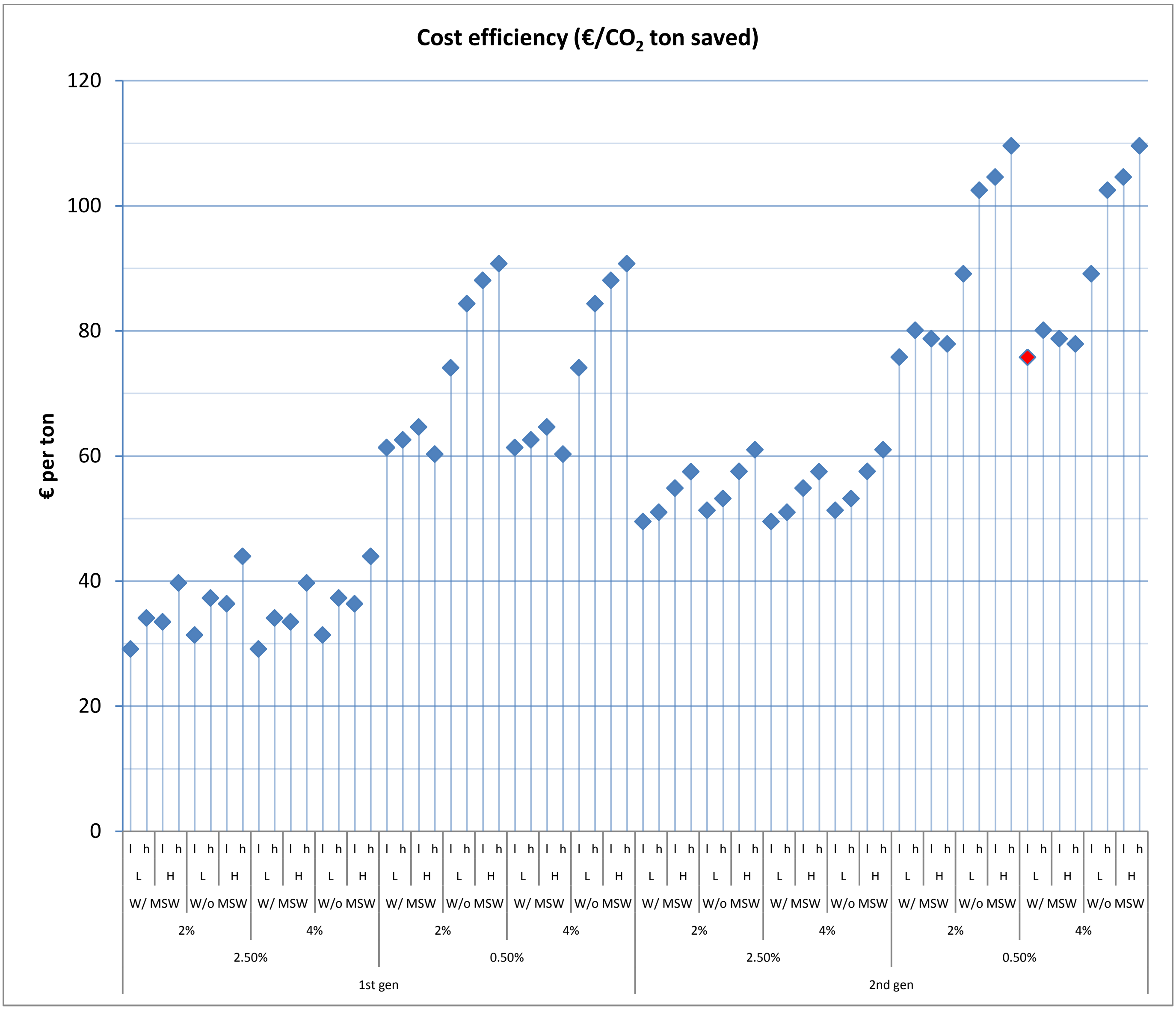

Figure 17 - Cost efficiency.

The following observations were obtained:

- As in the premium, there is no difference regarding the mandate percentage in the results.
- Scenarios with high fossil jet fuel price have lower cost efficiency, the ranges are from 29€ to 44€ for 1st generation, and from 49€ to 61€ for second-generation scenario.
- For low fossil jet fuel price, there is higher variability, ranging from 60€ to 90€ for 1st generation and from 78€ to 110€ for 2nd generation.
- The base scenario shows a cost efficiency of 76 €/CO_2 ton

Airlines market share

Figure 18 shows the alternative jet fuel share per airline. Based on the hypotheses of alternative jet fuel distribution, the airlines would save emissions based on their amount of movements in the selected "green" airports. The market share of the top-3 airlines for the selected airports has been calculated to estimate the amount of alternative jet fuel they would consume.

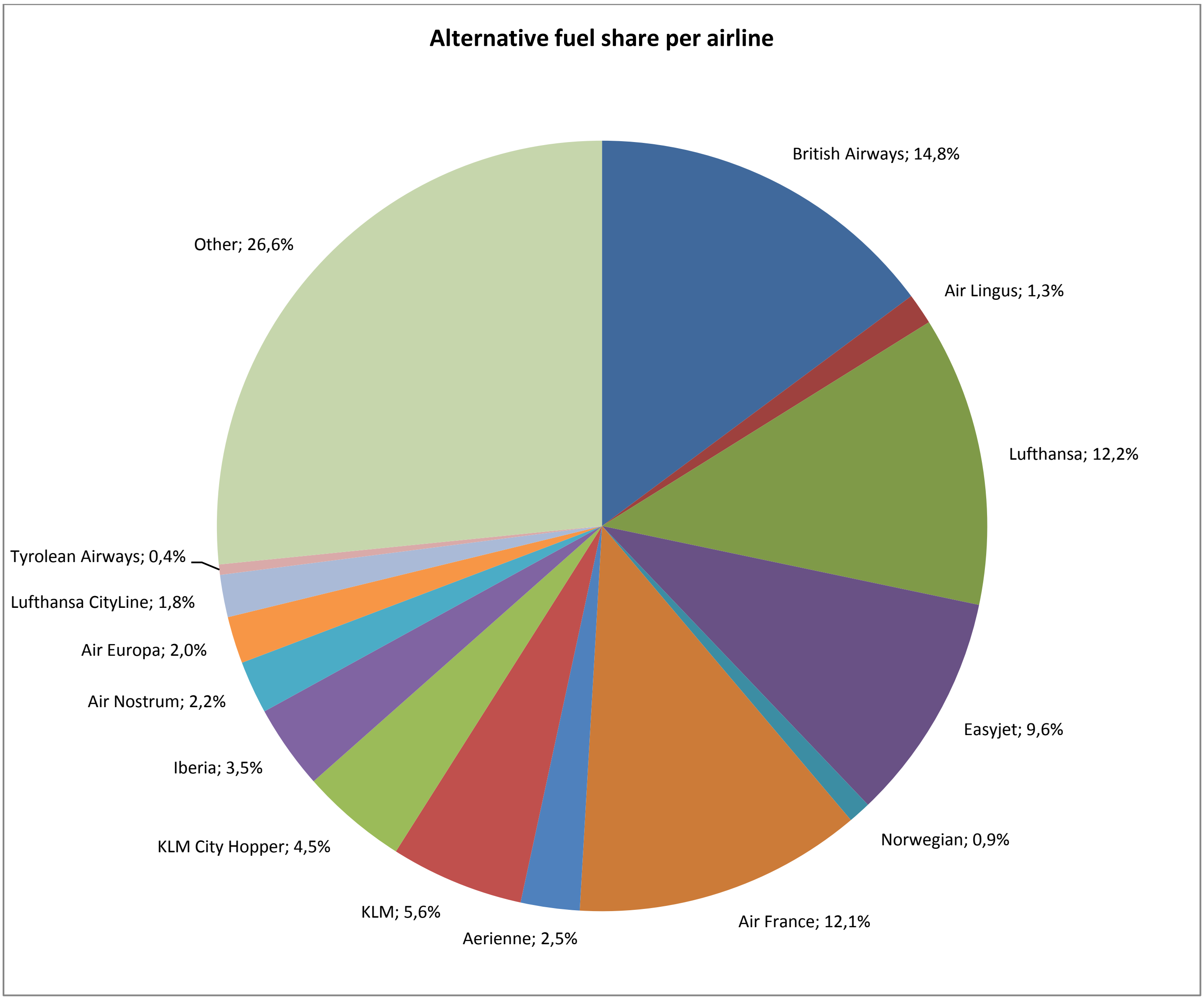

Figure 18 - Alternative fuel share per airline

In 2035, with the distribution of fuel to the selected cities, and the traffic growth expected in the selected airports, maintaining a similar share of operations among operators, British Airways would consume 14.8% of the alternative jet fuel produced in Europe, while Lufthansa and Air France would load about 12.1% as shown in Figure 18.

Depending on the scenario, the costs for each airline will vary as shown in Figure 19.

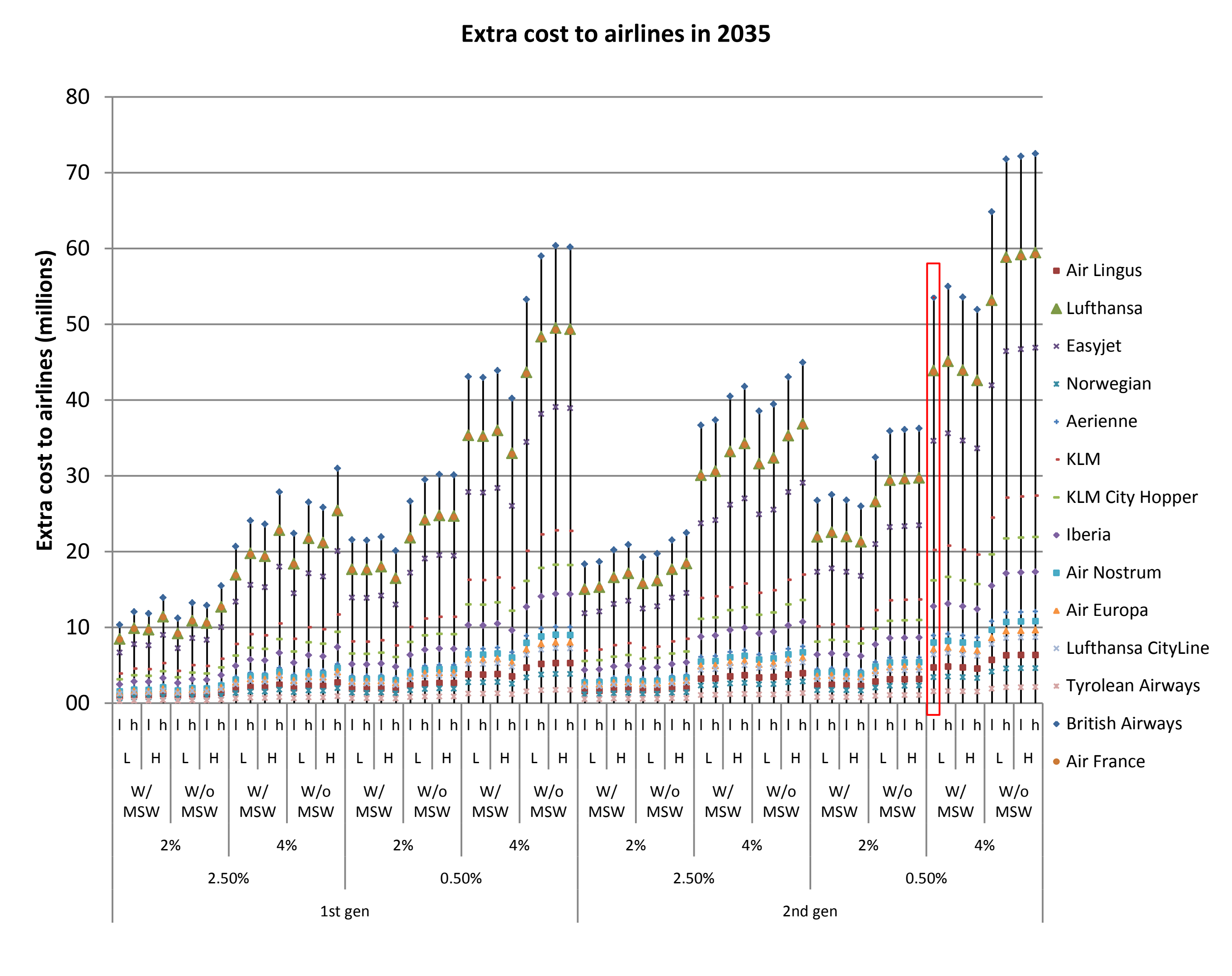

Figure 19 - Extra cost to airlines in 2035.

The extra cost to airlines is calculated by establishing the share of alternative jet fuel per airport. The airports considered and the hypotheses used can be found in *Annex I. Demand*. British Airways, Lufthansa, EasyJet and Air France would be most affected, when looking at single airline results. If we consider airline groups, we can see that the major airlines in Europe would be affected by this distribution of alternative fuel.

The ratio for each airline is the same regardless of the scenarios; the only thing that changes is the over-cost to produce the alternative fuel. This section of the model allocates the costs to the airlines flying the alternative jet fuel. However, it is expected that these airlines will receive certain type of "bio checks" similar to ETS allowances, which they can sell in the future CORSIA or ETS markets to receive income.

The main conclusion that can be reached is the importance of having the MSW pathway available, since worst case scenarios would be avoided for the industry and overall costs for alternative fuels would be lower.

Emissions saved per airline

Figure 20 shows the emissions saved by each airline depending on the mandate considered.

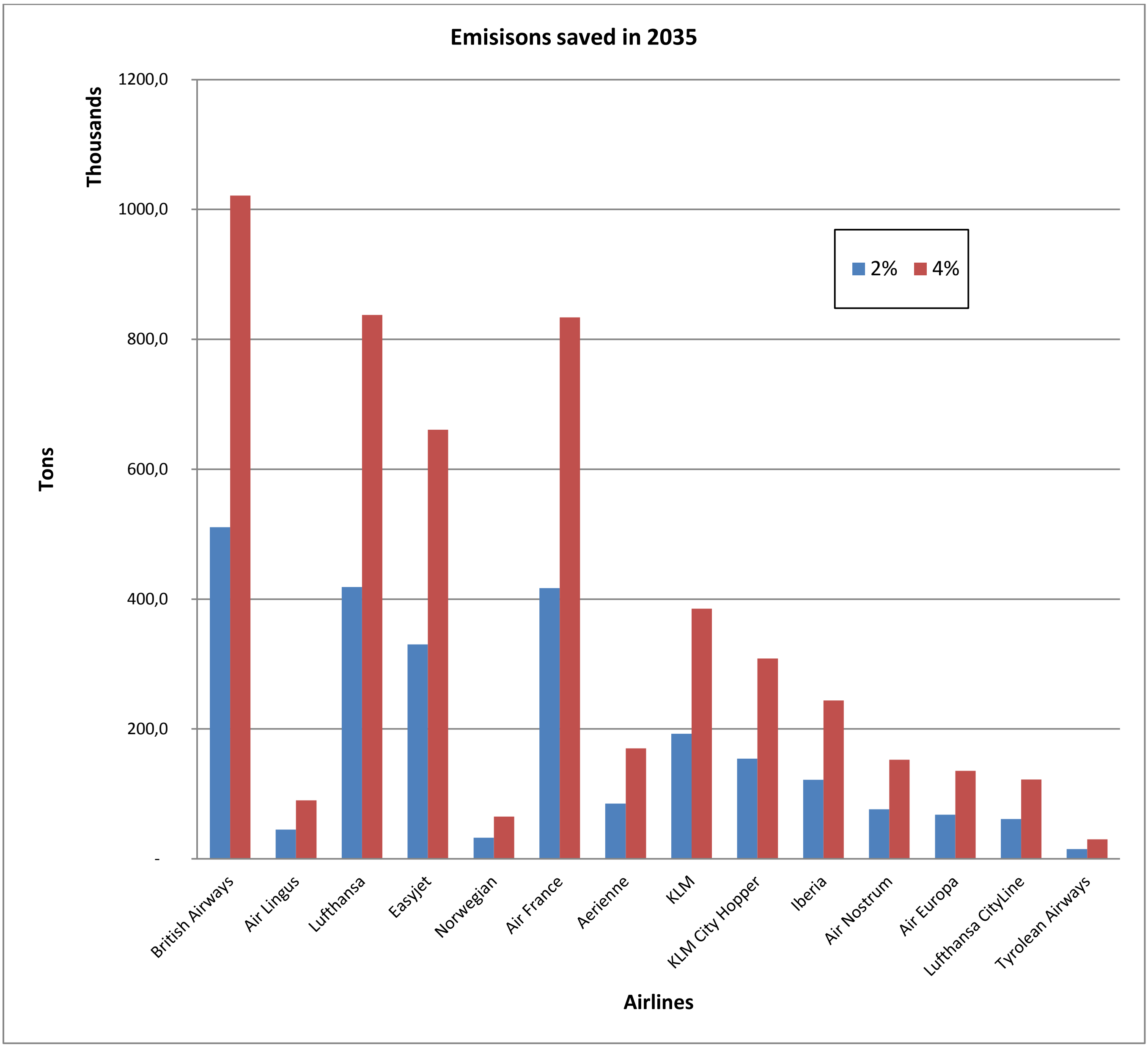

Figure 20 - Emissions saved in 2035.

The emissions saved will also be proportional to the biofuel consumed. The top 14 airlines will consume more than 73% of the alternative fuel consumed in Europe with the hypotheses established. With the cities selected, British Airways, Lufthansa, EasyJet and KLM would be the Airlines most affected, saving more than 600 000 tons of CO_2 each of them in 2035 (in the 4% mandate scenario). This information would be taken into advantage by these airlines, although the cost to buy would be distributed among all the airlines in Europe. This matter would need to be tackled in the future, since all the industry is making an effort and they all should take credit for it, even though they may not be loading the alternative fuel themselves.

3.6 Social impact

Direct employment

Figure 21 shows the direct employment for each scenario and depicting the distribution of these factors through the value-chain.

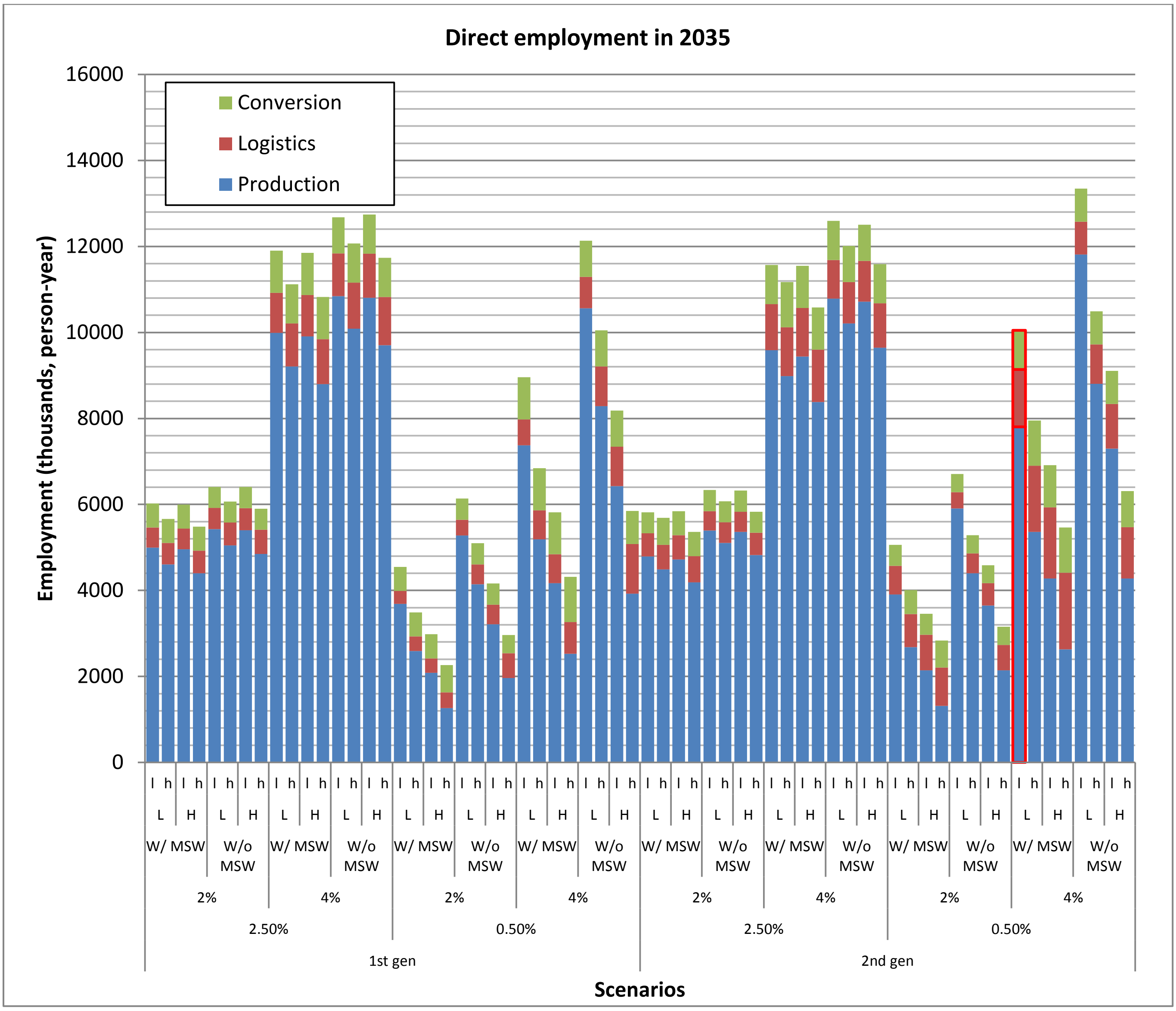

Figure 21 - Direct employment.

From the simulations we can observe that for 2% mandate scenarios, the range of direct employment produced goes from 2 000 to 7 000 jobs, while for the 4% scenarios; it ranges from 4 000 to 14 000 jobs. For the base scenario, 10 000 direct jobs are expected to be created, out of which almost 8 000 are due to production.

Indirect and induced employment has not been calculated in the model, or employment shifting. However, most social studies use factors of more than 50% to increase direct employment.

3.7 Environmental impact

Emissions saved

Figure 22 shows the emissions saved through the years to meet the base scenario of 4% alternative jet fuel demand.

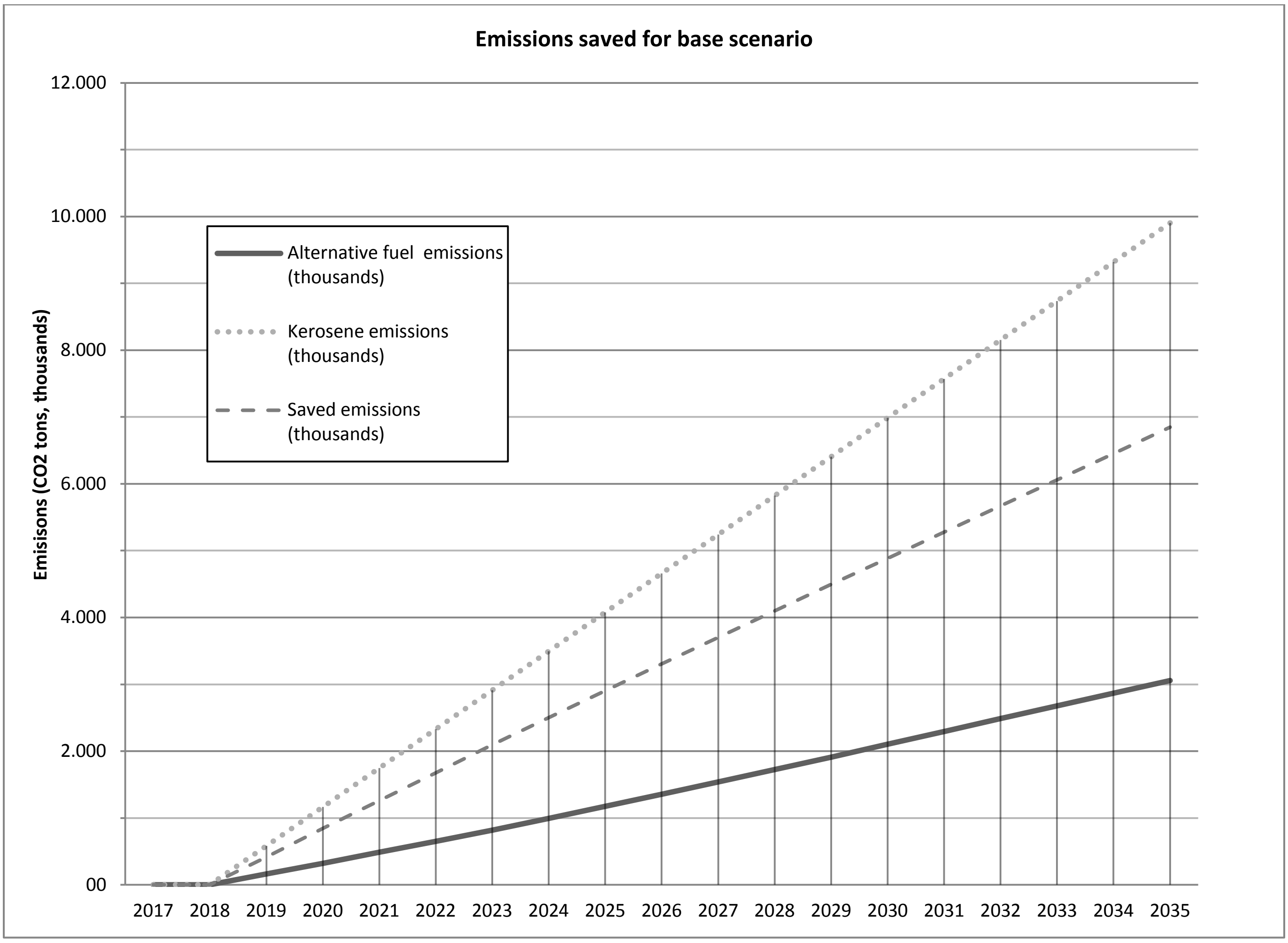

Figure 22 - Emissions saved for base scenario.

The emissions saved for the base scenario shows a linear implementation, which is due to a hypothesis considered in the model. This could have been designed in another way, but the difference is not deemed important for the researchers.

With the estimation of traffic growth considered by Eurocontrol, the fuel consumed in 2035 will be more than double the fuel consumed in 2015. 4% of the jet fuel consumption represents about 3.14 Million tons. The average reduction of emissions per ton using alternative fuels in the base scenario is 69% leading to total emissions of 3.0 Mt instead of 9.9 Mt if kerosene was burnt[3]. This leaves us savings in 2035 of about 6.8 Mt of CO_2.

[3] A reference value of 3.16 tons of CO_2 per ton of fuel burnt has been used.

3.8 Camelina results

Camelina oil and hectares required

Figure 23 shows the camelina oil and the relative hectares required for each scenario.

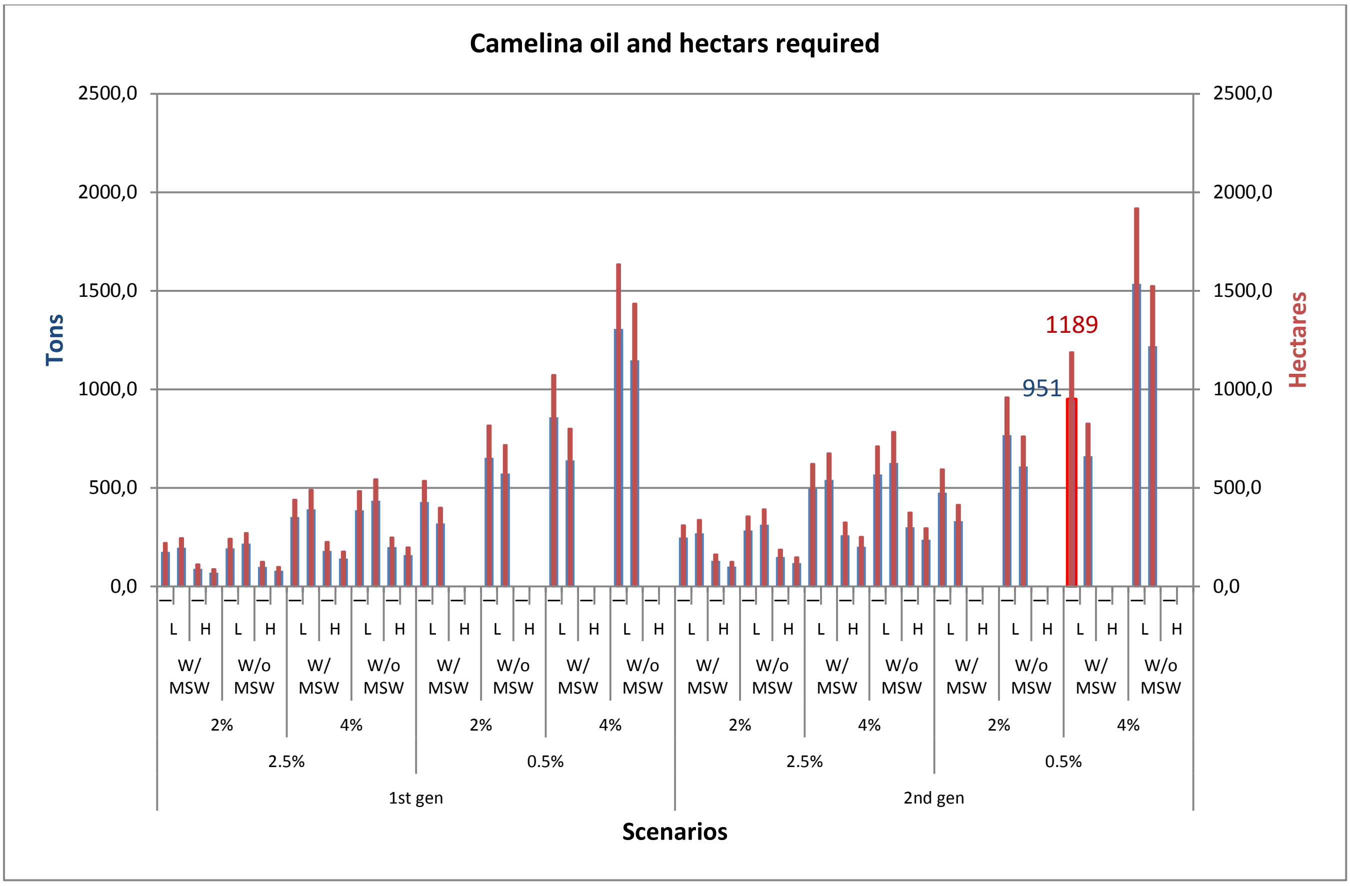

Figure 23 - Camelina oil and hectares required for 2035.

The following observations were made from the results:

- Camelina related results show that if the fossil fuel price growth is low and the camelina price is high, the premium will be too high and it will not meet the 60% requirement.
- As expected, the scenarios with first generation feedstocks will compete with camelina, making camelina market penetration lower.
- For low fossil fuel price growth, and where camelina meets the premium requirement, it finds itself with great demand, because less competition meets the premium requirement.
- No capacity limits have been implemented in the model; therefore, there is no effect on the mandate, other than the obvious direct relationship.
- The base scenario shows that 951 000 tons of camelina oil would be required in the market by 2035. This amount of oil would require 1 189 000 hectares, calculated using 800kg/ha as the average production yield of camelina.
- If MSW is not a viable pathway, camelina will absorb more market, reaching in some scenarios up to 1.5 Million tons per year of oil, which would require at least 1.9 Million hectares.

Camelina production direct employment

Figure 24 shows the estimated employment generated in the growth of camelina.

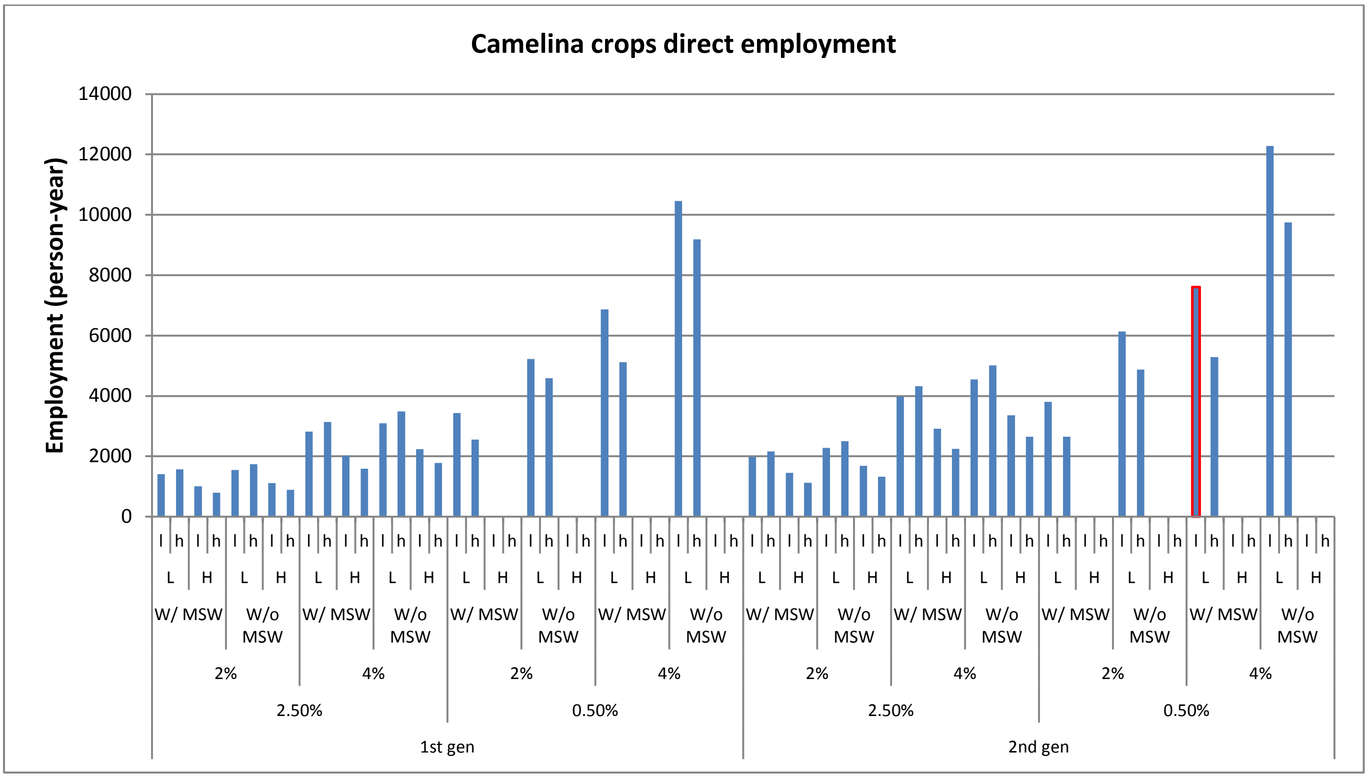

Figure 24 - Camelina oil production direct employment

The model considers that 80% of the camelina oil cost is due to direct labour costs. The total labour costs are divided by 50 000€ considered to be the standard annual salary costs for each employer. The following was observed from the results:

- The results show a direct relationship to the amount of camelina oil required in each scenario.
- The base scenario shows that about 7 608 direct jobs will be generated by 2035.
- Depending on the scenario, the direct employment may reach 12 000 direct jobs.

Employment shifting from other crops has not been considered since, in order to meet Renewable Energy Directives, camelina oil for fuel must be grown in fallow land or marginal land where no previous income was generated.

Base scenario alternative jet fuel distribution by source

Figure 25 shows the distribution of jet fuel based on its source. For the base scenario, about 761,000 tons of alternative jet fuel would need to be sourced from camelina.

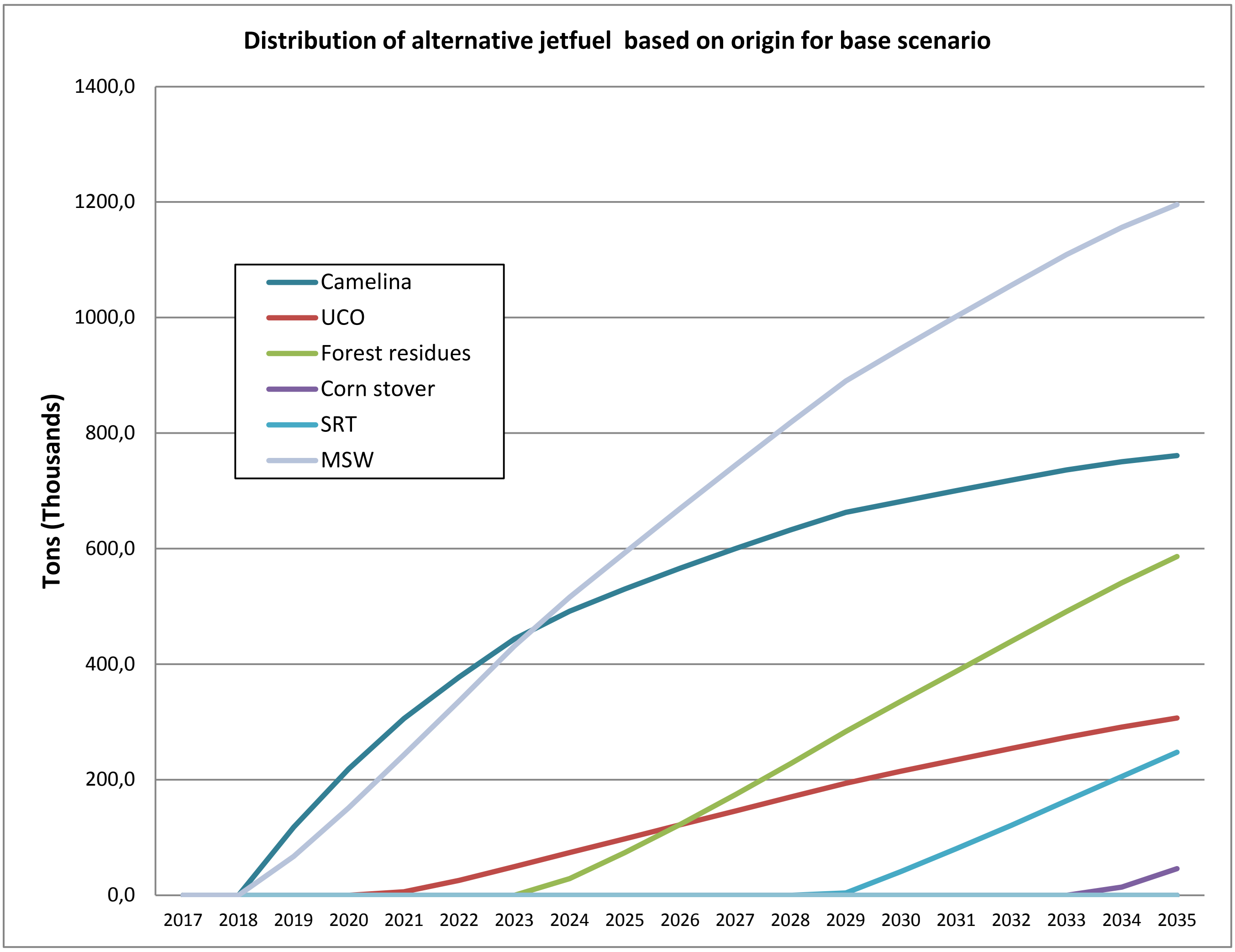

Figure 25 - Alternative jet fuel based on source.

The following can be observed from the results:

- The base scenario shows that at the beginning MSW and camelina are the main feedstocks; however, UCO and forest residues start having significant penetration in the mid '20s.
- Short rotation trees and corn stover have promising results at the end of the timeframe.

Based on the information above, the quantities of camelina oil can be calculated as shown in Figure 26.

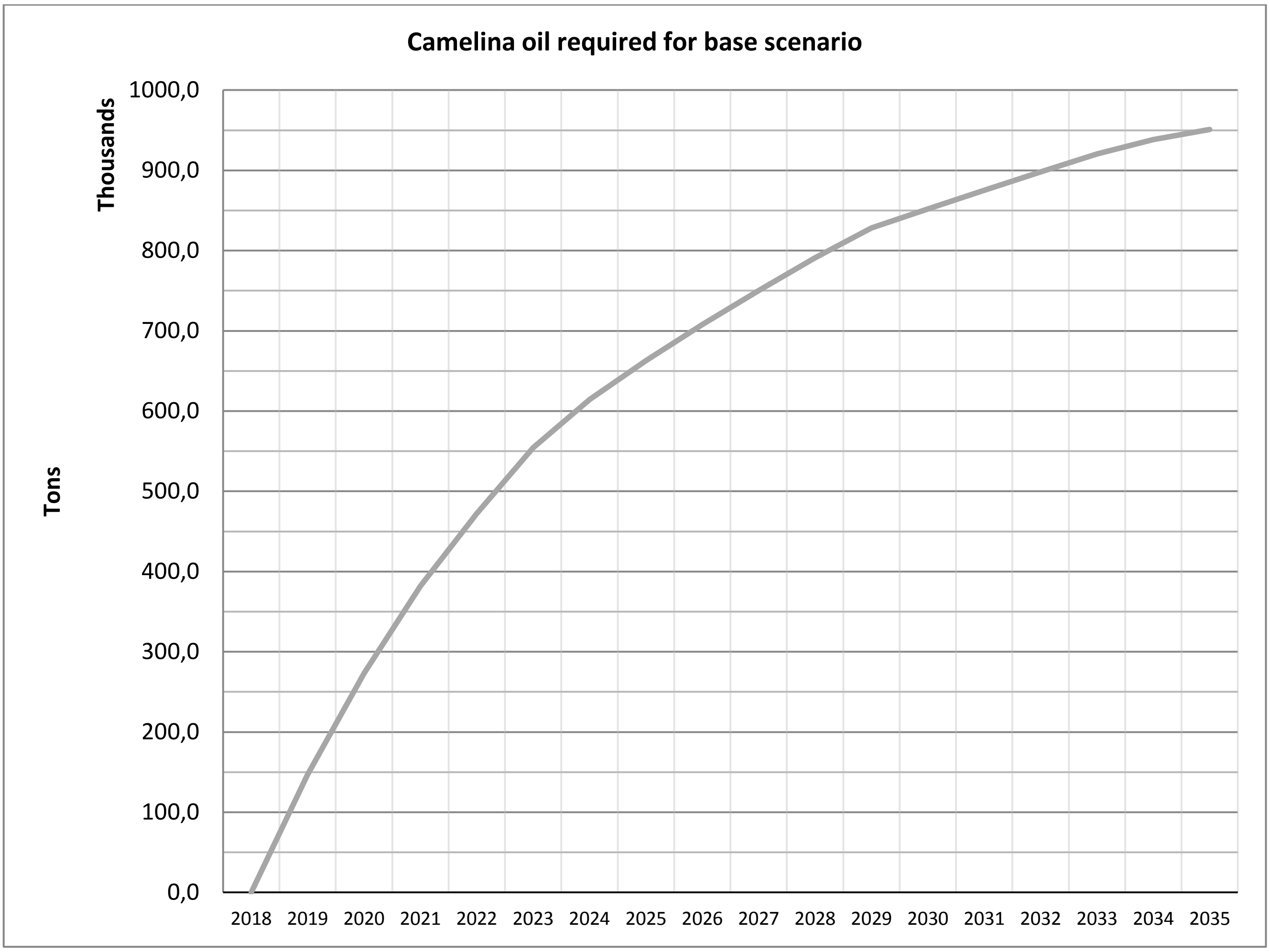

Figure 26 - Camelina oil required for base scenario

In order to calculate the amount of oil required to meet market demand, a ratio of 80% has been used for the HEFA process. The model shows continuous growth in camelina oil production; however, in the mid 20's its production is reduced due to the entry into market of competitive products. For the base scenario, about 950,000 tons of camelina oil are expected to be required in 2035.

4 Conclusions

4.1 Revision of hypotheses

This section revises the hypotheses the researchers expected at the beginning of the project and identifies if the model has proven them valid or invalid.

4.1.1 Feedstock production

FP.H1: Residues are expected to be much cheaper that other sources, therefore those feedstock-pathway combinations using residues are expected to become more viable and extended than other alternatives.

For the base scenario, the feedstocks that show market penetration include various residues: MSW, forest residues, UCO and corn stover. Camelina and SRTs are expected to enter the market although they are crops (if camelina HEFA maintains a low price).

Tall oil and yellow grease are too expensive in some scenarios to be competitive in the HEFA process.

MSW, in case it is a viable pathway, is expected to be the most used feedstock due to its cheap cost. Its market penetration will take advantage of the low amount of pathways with competitive prices, until the last years of the scope, where its market share decreases due to the cost reduction of other pathways.

From the results of the simulation, this hypothesis can be validated for all scenarios.

FP.H2: Camelina is expected to become the most used feedstock if considered 2nd generation feedstock if MSW-FT is not feasible and if its price is less than 700€/ton of oil.

Actually, from the simulations we obtained results that show that forest residues have a higher share of the alternative jet fuel market than camelina oil whenever the MSW is not available. Therefore, this hypothesis is disavowed.

FP.H3: MSW will be the most used feedstock if available due to its low cost.

This is only true in the case that fossil fuel price growth is low. If the fossil fuel growth price is high, there will be several pathways competing with fossil fuel and it is unsure that MSW will be the most used feedstock. Therefore, the hypothesis cannot be validated for all scenarios.

4.1.2 Conversion Technology

CT.H1: Due to efficiency gains, as time passes more technologies will be able to compete with fossil fuels.

The model shows that constant improvement of the cost efficiency of the value chains will reach fossil jet fuel prices if the latter has high growth. In that case, several pathways will be able to compete with fossil fuel in the late 2020s. Therefore, this hypothesis can be validated.

CT.H2: Some alternative fuels will suffer a bubble effect, covering large parts of the market while other alternatives are not competitive. However, with time, other alternatives will enter the market, increasing the distribution among the alternatives.

This happens as the different alternatives reach the premium of 10%, considered the minimum difference at which alternative jet fuel will sell over fossil jet fuel due to its advantages and preference for airlines. The first alternative jet fuel pathway to reach this limit in the base scenario will be FT with MSW. This alternative will cover large part of the market until other alternatives reach that limit, at which the market share of the FT-MSW will be reduced. This hypothesis can be validated with the model.

4.1.3 Impact on airlines

IA.H1: Hub airlines will be greatly affected because the alternative fuel will be distributed to main cities' airports.

As can be observed in the results of the model, the airlines most affected are those that have hubs in the selected airports. There is however, a low cost airline, EasyJet, which has a base at London Gatwick. It is a point-to-point airline, but Gatwick can be considered its hub. Therefore, this hypothesis can be validated by the model.

4.2 Conclusions

The model has provided valuable information in many aspects of the value chain. In this section, we will provide the main conclusions reached in each step of the value chain.

4.2.1 Feedstock

The market share capability of a given feedstock will be largely determined by its in relation to the fossil fuel price. The limits imposed in the model regarding the premium required to be in the market is key when trying to determine the potential of each pathway. Currently this limit is set to 10% to 60%, while it may happen that in the future, when one pathway reaches a premium of 20%, the rest of pathways may not be competitive unless they are closer to that 20%, in which case the premium range could be something like 10% to 30%.

The hypothesis of a mandate to generate alternative fuels will drive the industry to increase its efficiency reducing costs to the point of competing with alternative fuels. Only if there is high growth of fossil jet fuel prices, can the alternative fuels be competitive in the market.

The uncertain price of camelina oil and of the HEFA process is the most important factor to determine its potential in the market. Likewise, the decision to consider camelina as first or 2nd generation crop will be key in making it the sole European crop feasible for HEFA pathway. If camelina oil is indexed in the future, it may follow other oil indexes which are already more expensive than fossil jet fuel. In this case, HEFA with camelina does not seem a very profitable pathway and other alternatives like UCO would have better potential in the market.

Camelina's biggest competitor, FT with MSW has not been produced at commercial scale until now. Some companies in the USA are expected to produce alternative fuels using this pathway in 2018.

4.2.2 Conversion facilities

The model does not consider the existing facilities and other factors such as the overall profitability of the facilities considering the overall products produced. This work is of a confidential nature and could not be consulted with the existing entities; however, from the output of the model, there is no doubt about the average production capacities of the facilities, and how many would be needed. Their quantity is a huge factor when determining the logistics costs at European level.

4.2.3 Impact on airlines

The selection of the cities has direct impact on the airlines with hubs on those cities. The model has assigned the cost of the alternative fuel to those airlines loading the fuel. However, a possibility to reduce costs would be to acquire EU-ETS or CORSIA allowances that could be sold in the market. However, as the cost efficiency shown in the model, allowances of about 90€ for a single CO_2 ton would be required. Possible solutions could be to have different types of environmental units for biofuels; this way, the emissions efficiency could be taken into account so airlines were able to distribute the cost among other airlines. Another method could be to charge a European green tax that would be distributed to those airlines buying the alternative fuel. At the end, the objective is to foster alternative fuels while distributing its cost as much as possible.

4.2.4 General views

It is widely accepted that the introduction of biofuels cannot be done using current market mechanisms because their high production and distribution cost, at least during the initial stage limit their competitiveness with fossil fuels. Then, all States interested in promoting the use of biofuels are going to use special incentives to gain public acceptance of these new products.

The application of blending obligations is more difficult in the air transport sector than in other activities, due to the international character of aviation. A mandate in some countries may imply fuel price differentiation and deviation of connecting traffic through airports not included in the mandate. In addition, the airlines themselves may have to pay different amounts for fuel depending on the practical implementation of the mandate (by airports, by regions, by countries, by continents). This rises the convenience of applying provisionally mandates by airlines until the biofuel market is stabilized, the use of tradable certificates, as the RINs in USA is other possibility to be considered.

The mechanism for introducing an incentive economic mechanism to compensate the higher price of the alternative jet fuel without creating competitive distortions among the different operators would require a general agreement at regulatory level by the EU administrative bodies. There are three basic possibilities that may be alternatively used with different small variations:

a. A charge at producer level: The cost increase due to the production of a certain amount of alternative jet fuel is distributed over the total production of aviation kerosene. In this way, the non-biofuel producers would bear a part of the extra cost of the biofuel makers. The practical mechanism might be an EU subsidy covering the additional cost, to be recovered through a general kerosene levy. This relative straightforward procedure might face legal challenges as taxes on international aviation fuel are prohibited by the Chicago Convention. A legal decision on whether that would be a tax or a charge would be needed.
b. A charge at distribution level: A similar mechanism but the additional cost would be included as an additional airport levy. As there are large differences among the total ground operation expenses in different airports, the additional cost of biofuel would be included in the airport fees and applied to all the operators in the airport, independently of the composition of the uploaded fuel.
c. A charge at airline level: The more expensive biofuel is charged to the airline fuel bill and the cost goes against the airline balance. This is very simple to administrate but may create unbalance among the airlines uplifting more or less alternative jet fuel. A possible compensation might take the format of bio-credits to be used against income taxes or other fiscal instruments.

In order to avoid a monopoly of whichever pathway becomes the most profitable in the near future, the EU should find the best way to foster the different pathways considering their potential in emissions reductions, since while all of them would be validated according to the relevant LCA, their potential in emissions savings may be quite different. It seems sound to say that those pathways with greater potential in emissions savings should be able to receive more funds from the EU to develop their pathway. However, other factors, such as cost efficiency, play an important role to maximise the emissions savings per euro spent.

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Annex I. Demand

I.I Scope

The section explains the methodology used to extrapolate the traffic and estimate the fuel consumption in the different airports to which the biofuel is expected to be delivered as explained in section

2.2.6 Alternative jet fuel logistics.

The necessary steps to accomplish these tasks were:

- Setting up a baseline of commercial flights and associated fuel consumptions in the EU, based on the available EUROCONTROL data. Reference year is 2013.
- Selection of a representative sample of the flights program, normally two central weeks of June and September, which is generally accepted as an average of annual traffic in the Northern hemisphere.
- Definition of the cost structure of the different commercial operators in that baseline, according to their business model, particularly concerning fuel expenses percentage.
- Projection of the baseline up to 2035, based on published traffic growth forecast (ICAO, IATA, EUROCONTROL, aircraft manufacturers, etc.) and on the anticipated market share growth of each airline business model.
- Evolution of oil price and sensitivity analysis to different alternative jet fuel prices.
- Calculation of distribution to the different cities considered of alternative jet fuel based on 4% mandate.

A prerequisite for this analysis is the definition of the way in which the alternative jet fuel amount is introduced in the general air transport commercial fuel distribution system. A basic assumption is that the added fuel will be “drop-in”, meaning that it will be similar to the fossil origin kerosene and, therefore, certified for blending and using the same logistics facilities, without any special arrangement. At this moment, ASTM D7566 qualified biofuel can be mixed up to 50% with the standard kerosene to be consumed by any aviation turbine engine. For the purposes of this study, that is the maximum level of blending allowed.

The second important feature is how the alternative jet fuel would be mixed with the standard fuel. This is important because the geographical distribution of the mixing will translate in an unequal utilisation by different airlines and may have consequences in the individual cost repercussions as well. In addition, the present Emissions Trading System enforced by the European Union gives the biofuel a zero emission factor, providing an economic incentive to its use, but making necessary to carry a detailed accountability of the quantity use in intra-EU flights.

There are a number of possibilities going between two extreme cases:

1. The total amount of alternative jet fuel being produced is delivered to the fuel distributors to be mixed with the total amount of fossil origin kerosene sold to the operators. In this way, the percentage of biofuel in the fuel burned by the airlines will be constant. This creates some distribution problems if the production rate of alternative jet fuel is not constant or it is a one-time fixed amount. In the case of the ground transport, it is mandatory to have a minimum percentage of biodiesel in the fuel delivered by the EU[4] territory petrol stations but, unlike air transport, there is no need of computing the actual consumed bio quantity.
2. The total amount of alternative jet fuel being produced is delivered to a few points or distributors who mix it with standard kerosene in a previously fixed proportion, never higher than 50%. This is delivered in parallel with the fossil origin fuel and the operators may uplift one or the other

[4] Loading more fuel tan needed for performing the flight in order to reduce the amount of fuel upload in the destination airport for doing the next flight

according to either established rules or a system of market incentives. The enforcement of a scheme like that would need a strong EU regulatory action and might produce undesirable market distortions among airlines and airports.

An intermediate system, which is used for this analysis, delivers the alternative jet fuel production to a reduced number of airports selected among the most dense European traffic areas, distributing the biofuel proportionally to the total amount of fuel uplifted for commercial flights in those areas. In that way, the level of blend would be equal for all the flights operating out of the selected airports.

The consequences would be more important for the airlines having a base in those airports; however, being the ones with the highest traffic, there will be many operators using the blended fuel. This is a very general approach and no detailed operational practices that might change the framework conditions, like tankering, have been taken into account.

It is logical to think that this type of operation would not be viable unless certain types of economic measures are introduced in order to compensate the higher cost of the alternative jet fuel.

I.II Commercial air traffic and fuel consumption

This section provides an estimation of the uplifted fuel for commercial services in the five areas with most commercial air traffic in the European Union:

- London (Airports of Heathrow, Gatwick, Stansted, Luton and London City)
- Paris (Charles de Gaulle, Orly and Beauvais)
- Frankfurt (Frankfurt Main and Hahn)
- Amsterdam (Schiphol)
- Madrid (Barajas)

The airport selection is based on the present situation of commercial air services, including some facilities (Beauvais, Hahn) with relatively distant location, but being true alternate option for travelling to the selected city, mainly with low cost carriers. Airports close to the city with a sizeable number of general aviation movements but with very little commercial traffic (Le Bourget in Paris, Torrejón in Madrid) have been omitted.

The following table gives an estimation of the amount of fuel loaded at each airport in the whole year 2013. Data have been obtained from EUROCONTROL Data Demand Repository (DDR), where information on all flights in EUROCONTROL countries is stored (with information from the flights plans). In particular, it is possible to retrieve data from all flights of a specific day. The huge amount of flights (about 10 million per year) makes retrieving data for the 365 days of a year unfeasible. Therefore, a sample of data from two weeks (central week of June and central week of September) is downloaded and then averaged for the overall year. This is a standard practice in the airline industry to evaluate yearly data, considering the variation in flight schedules between the high peak (July-August in the North Hemisphere) and the bottom, usually marked by February. The detailed methodology is shown in (Alonso, et al., 2014).

Reference year for the database is 2013. Data extracted consists of, for each flight, the following information:

- Departure airport
- Arrival airport

- Type of aircraft
- Type of flight

Data collected have been processed and segmented. First, the distance between airports pairs have been evaluated using a distance calculator, computing the orthodromic distance from the airports geographical coordinates.

Flights have been filtered per type of activity, only scheduled and non-scheduled commercial flights are kept, i.e. military, customs or police flights, general aviation flights, and others are eliminated.

Then the fuel consumption for every flight is evaluated. To do that, the latest version of the Corinair database giving the fuel consumption (as a function of the distance flown) per aircraft type and per flight phase is used.

Data are segmented per aircraft type, taking into account the MTOW (Maximum Certified Take-off Weight) and the propulsion type (turboprops or turbofans). The following types have been considered:

- MTOW less than 7 tons (aircraft typically turboprops up to 19 seats, like Dornier 228, Fairchild Metro or Pilatus PC-7)
- Very limited number of these flights are operated from the dense traffic selected airports and the total quantity of fuel uplifted is negligible when compared with the other categories
- MTOW between 7 and 136 tons (short and medium range commercial transports, going from 30-seater regional aircraft up to sizeable jets like Airbus A321 or Boeing B757)
    - Turboprops
      While the number of movements in this 30 to 80-seat category is not small, most services are short range and the total fuel consumption is below 1% of each airport-uplifted quantity
    - Turbofans
      The majority of the movements are concentrated here (single aisle, medium range jets as Airbus A320 and Boeing B737 families, and regional jets, as Embraer RJ and Bombardier CRJ families) although in terms of fuel, the global load is smaller than for the heavy aircraft group
- MTOW larger than 136 tons (aircraft larger than 240 seats, including all long range passenger models and heavy freighters)
- This is the group with the largest fuel upload in the entire five cities group, although some individual airports (all London airports but Heathrow, or Paris' Orly) have higher figures for the medium range group or, like Beauvais, has only medium range aircraft flights.

Data are segmented per route distance bands in six different categories:

- Less than 500 km
- From 500 km to 1000 km
- From 1000 km to 1500 km
- From 1500 km to 2000 km
- From 2000 km to 2500 km
- More than 2500 km

The reason behind this division is to use the standard EU classification of transport distances, applicable to all transportation means. Less than 500 km is the basic car domain and the fuel consumption on those routes represents less than 3% of the total. The largest part of the fuel is in the longest routes approximately 75% of the total.

Table 16 - Total fuel loaded at airports studied

TOTAL FUEL LOADED (Mton)						
DEPARTURE AIRPORT	**DISTANCE BAND**	**Aircraft type**				**Total band**
		< 7	**7-136**		**> 136**	
		small	**turboprop**	**jet**	**wide**	
HEATHROW	< 500			0.077	0.002	0.079
	500 - 1000			0.199	0.014	0.213
	1000 - 1500			0.148	0.020	0.168
	1500 - 2000			0.049	0.001	0.050
	2000 - 2500			0.050	0.005	0.055
	> 2500			0.130	4682.000	4811.000
	total type			0.654	4723.000	**5377.000**
GATWICK	< 500		0.004	0.027	0.000	0.031
	500 - 1000		0.000	0.096	0.003	0.099
	1000 - 1500			0.151	0.004	0.155
	1500 - 2000			0.093	0.002	0.095
	2000 - 2500			0.073	0.002	0.075
	> 2500			0.150	0.486	0.636
	total type		0.004	0.590	0.497	**1091.000**
STANSTED	< 500	0.000	0.001	0.016	0.006	0.023
	500 - 1000		0.000	0.059	0.003	0.063
	1000 - 1500			0.100	0.002	0.101
	1500 - 2000			0.048	-	0.048
	2000 - 2500			0.011	-	0.011
	> 2500			0.039	0.040	0.078
	total type	0.000	0.001	0.272	0.051	**0.324**
CITY	< 500		0.006	0.008	-	0.015
	500 - 1000		0.002	0.035	-	0.037
	1000 - 1500			0.012	-	0.012
	1500 - 2000			0.001	-	0.001
	2000 - 2500			-	-	-
	> 2500			-	-	-
	total type		0.009	0.056	-	**0.065**
LUTON	< 500		0.001	0.012	0.000	0.013
	500 - 1000	0.000		0.021	0.003	0.024
	1000 - 1500			0.052	-	0.052
	1500 - 2000			0.036	0.001	0.036
	2000 - 2500			0.028	-	0.028
	> 2500			0.044	0.008	0.051
	total type	0.000	0.001	0.192	0.011	**0.204**
CHARLES DE GAULLE	< 500		0.002	0.071	0.008	0.081
	500 - 1000		0.002	0.165	0.007	0.174
	1000 - 1500		0.001	0.132	0.008	0.141
	1500 - 2000			0.069	0.001	0.070
	2000 - 2500			0.096	0.019	0.115
	> 2500			0.092	2939.000	3031.000
	total type		0.005	0.625	2982.000	**3612.000**
ORLY	< 500	0.000	0.004	0.016	0.000	0.021
	500 - 1000	0.000	0.001	0.115	0.001	0.117
	1000 - 1500			0.100	0.013	0.113
	1500 - 2000			0.042	0.001	0.043
	2000 - 2500			0.039	-	0.039
	> 2500			0.025	0.248	0.272
	total type	0.000	0.005	0.337	0.263	**0.605**
BEAUVAIS	< 500			-	-	-
	500 - 1000			0.014	-	0.014

	1000 - 1500			0.023	-	0.023
	1500 - 2000			0.014	-	0.014
	2000 - 2500			0.002	-	0.002
	> 2500			0.000	-	0.000
	total type			0.053	-	**0.053**
FRANKFURT MAIN	< 500	0.000	0.002	0.127	0.005	0.133
	500 - 1000		0.000	0.157	0.007	0.165
	1000 - 1500		0.000	0.134	0.003	0.137
	1500 - 2000			0.101	0.012	0.112
	2000 - 2500			0.069	0.011	0.080
	> 2500			0.112	2814.000	2926.000
	total type	0.000	0.002	0.699	2851.000	**3553.000**
HAHN	< 500			0.000	0.001	0.001
	500 - 1000	0.000		0.012	0.000	0.012
	1000 - 1500		0.000	0.015	-	0.015
	1500 - 2000			0.009	0.001	0.010
	2000 - 2500			0.004	0.005	0.008
	> 2500			0.002	0.041	0.044
	total type	0.000	0.000	0.043	0.047	**0.090**
MADRID	< 500	0.000	0.002	0.073	0.000	0.075
	500 - 1000	0.000	0.001	0.047	0.002	0.050
	1000 - 1500		0.000	0.202	0.021	0.223
	1500 - 2000			0.079	0.022	0.100
	2000 - 2500			0.029	0.003	0.032
	> 2500			0.088	1099.000	1188.000
	total type	0.000	0.003	0.519	1147.000	**1669.000**
AMSTERDAM	< 500	0.000	0.002	0.088	0.002	0.092
	500 - 1000		0.001	0.193	0.007	0.201
	1000 - 1500	0.000	0.001	0.102	0.001	0.104
	1500 - 2000			0.084	-	0.084
	2000 - 2500			0.099	0.008	0.107
	> 2500			0.093	2117.000	2210.000
	total type	0.000	0.004	0.660	2134.000	**2798.000**

The same information for each one of the five large traffic-capturing areas of the five urban conglomerates, aggregating data for those airports serving the same city, is given in the following table:

Table 17 - Total fuel loaded by city

TOTAL FUEL LOADED (Mton)						
DEPARTURE AIRPORT	**DISTANCE BAND**	**Aircraft type**				**Total band**
		< 7	**7-136**		**> 136**	
		small	**turboprop**	**jet**	**wide**	
TOTAL LONDON	< 500	0	0.012	0.14	0.008	0.161
	500 - 1000	0	0.003	0.411	0.023	0.437
	1000 - 1500		-	0.462	0.025	0.488
	1500 - 2000		-	0.227	0.004	0.23
	2000 - 2500		-	0.161	0.007	0.168
	> 2500		-	0.362	5.215	5.577
	total type	0	0.015	1.763	5.282	**7.06**
TOTAL PARIS	< 500	0	0.006	0.087	0.008	0.102
	500 - 1000	0	0.003	0.294	0.008	0.305
	1000 - 1500		0.001	0.256	0.021	0.277
	1500 - 2000		-	0.125	0.002	0.127
	2000 - 2500		-	0.137	0.019	0.156
	> 2500		-	0.117	3.187	3.303
	total type	0	0.01	1.015	3.245	**4.27**
TOTAL FRANKFURT	< 500	0	0.002	0.127	0.005	0.134
	500 - 1000	0	0	0.169	0.007	0.177
	1000 - 1500		0	0.149	0.003	0.152
	1500 - 2000		-	0.11	0.012	0.122

	2000 - 2500		-	0.073	0.016	0.089
	> 2500		-	0.114	2.856	2.97
	total type	0	0.003	0.742	2.899	**3.643**
MADRID	< 500	0	0.002	0.073	0	0.075
	500 - 1000	0	0.001	0.047	0.002	0.05
	1000 - 1500		0	0.202	0.021	0.223
	1500 - 2000			0.079	0.022	0.1
	2000 - 2500			0.029	0.003	0.032
	> 2500			0.088	1.099	1.188
	total type	0	0.003	0.519	1.147	**1.669**
AMSTERDAM	< 500	0	0.002	0.088	0.002	0.092
	500 - 1000		0.001	0.193	0.007	0.201
	1000 - 1500	0	0.001	0.102	0.001	0.104
	1500 - 2000			0.084		0.084
	2000 - 2500			0.099	0.008	0.107
	> 2500			0.093	2.117	2.21
	total type	0	0.004	0.66	2.134	**2.798**

The type of predominant traffic in those airports dictates the kind of airline with the majority of services. While it is not easy to determine a passenger or cargo ranking, including the length of the flights for calculating PKTs or TKTs, a first approach can be done using the number of scheduled flights of the dominant airlines in each airport.

The following table shows the EU airports ranking in 2013 by number of passengers, but giving also the number of flights, expressed in frequencies per week, and indicating the share of the leading three carriers:

Table 18 - Airports ranking

Airport	Passengers (thousands)	Frequencies per week	Proportion of flights by lead three carriers (%)					
			Carrier 1		Carrier 2		Carrier 3	
LHR	72 368	9 620	British Airways	51.1	Aer Lingus	5.3	Lufthansa	3.6
CDG	62 053	8 952	Air France	43.1	EasyJet	7.4	Aerienne Europeene[(1)]	7.4
FRA	58 037	9 360	Lufthansa	57.1	Lufthansa[(2)] CityLine	9.0	Tyrolean Airways	2.2
AMS	52 369	8 430	KLM	30.7	KLM City Hopper[(3)]	24.6	EasyJet	6.7
MAD	39 718	6 430	Iberia	23.0	Air Nostrum[(4)]	14.4	Air Europa	12.8
MUC	38 673	7 372	Lufthansa	32.8	Lufthansa CityLine[(2)]	25.9	Air Berlin	8.7
FCO	36 166	6 142	Alitalia	37.1	EasyJet	7.8	Alitalia Cityliner[(5)]	7.5
LGW	35 463	5 248	EasyJet	46.3	British Airways	17.5	Norwegian	7.4
BCN	35 197	5 638	Vueling[(6)]	38.4	Ryanair	11.7	EasyJet	7.8
ORY	28 274	4 354	Air France	30.4	Aerienne Europeene[(1)]	9.3	EasyJet	9.1

(1) Aerienne Europeene is owned by Air France
(2) Lufthansa City Line is owned by Lufthansa
(3) KLM City Hopper is owned by KLM
(4) Air Nostrum operates exclusively for Iberia, under a franchise agreement
(5) Alitalia Cityliner is owned by Alitalia
(6) Vueling is a member of the International Airlines Group (IAG) with British Airways e Iberia

Ref: (Airline Business, 2014)

I.III Cost structure of commercial operators

Primary objective is the construction and development of a methodology suitable for calculating the economic impact of airline use of alternative jet fuel, replacing partially the standard kerosene. This methodology will be able to identify:

- The typology of different airline business models
- The cost structure of each one of those airline types
- How the financial mechanisms related to alternative jet fuel introduction affect to costs and revenues
- The cost modelling of the flights

As a first step, the goal is to determine preliminary cost structures and key cost factors for generating an airline cost model based on airline type with the capability of simulating alternative jet fuel introduction cost impact, once fixed boundary conditions from different regulations and traffic scenarios.

The alternative jet fuel feasible blend percentages from operational costs perspective under different boundary conditions will be the most representative output of the developed methodology. As it has been previously indicated, the present 50% mix certification maximum is taken as a limiting value. Up to now, there is no evidence against future use of a higher blend as experience in service is accumulated.

Data area was covered by industry databases and US airlines traffic. Cost and financial reports were extrapolated to present European market analysis and 2035 foreseeable conditions through airline type and operated network correlation.

The existing airlines were classified in five categories, according with their business type, a key element to determine the relative importance of the fuel cost in their cost structure. This classification (Doganis, 2009) is based on the predominant features of network and type of service in the most economically important part of each airline activity, recognizing that in some cases there may exist some features corresponding to other category.

Airlines were classification in:

- Charter: Airlines operating most of their services on demand, with no published schedule, generally serving holiday markets.
- Freighter: Airlines carrying different types of freight and mail but not passengers.
- Legacy carriers: Traditional airlines operating scheduled service with a variety of fleets and short and long-range destinations. In general, they actively look for optimizing connections through airport hubs or limit their services to specific niche markets.
- Low cost. Airlines operating point to point services with very basic amenities and high density interior layouts, generally in the short/medium range with a very homogeneous fleet, high aircraft utilization and short turnaround times. Most of them do not carry freight.
- Regional. Airlines flying low density short range routes with aircraft smaller than 100 passengers. Most are affiliated to some legacy carriers in different ways like ownership, partial ownership, franchising or wide wet leasing agreements.

The most important parameters for allocation of airlines to each of one of these groups are fleet size and composition, aircraft utilization, type of demand, average stage length and annual revenue (IATA, 2010).

The economic structure for each airline type (Mayer & Scholz, 2012), based on operational costs and aircraft dependency, is divided in:

- Direct Operating Costs (DOC)
  - Fixed: Those related to the operating aircraft but difficult to modify once the flight program has been established.
  - Variable in the short-term: Those related to the operated aircraft that can be modified without great changes in the planned schedule
- Indirect Operating Cost (IOC)
  - Route-specific: Independent of the dimension of the operating program, but linked to the company network.
  - Non route-specific: General company cost.

Such structure will lead to get the avoidable costs on each term strategy: short, medium or long, arise of the planned alternative jet fuel introduction.

The following high-level operational cost structure will be the basis for aggregating cost factors impacts and scenarios boundary conditions when simulating cost model after alternative jet fuel introduction in specified blend percentages:

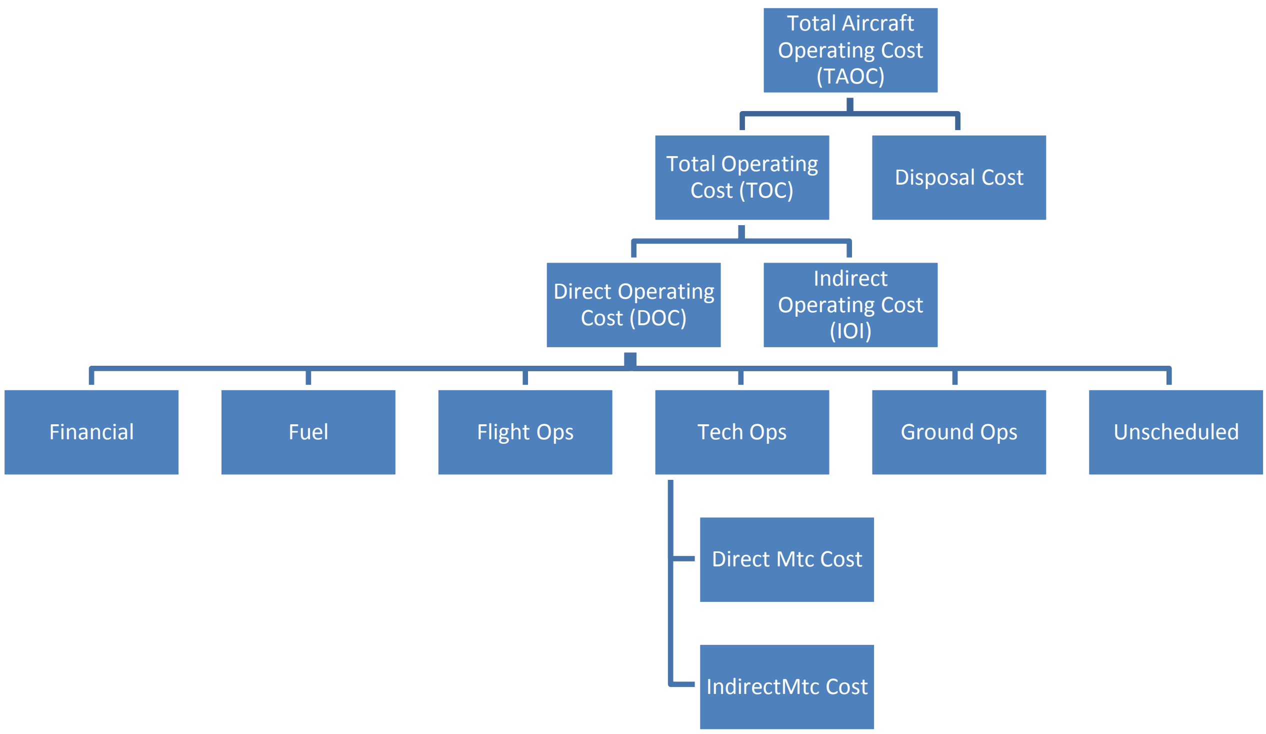

Figure 27 - Cost structure for airlines

The fuel cost share of the total airline expenses has changed substantially, following the oil price evolution. The figures corresponding to the last decade can be seen in the following table ((IATA, 2014) and (IATA, 2014b)**):**

Table 19 - Evolution of fuel cost share of airlines.

	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Expenses ($billion)	376	409	450	490	571	474	536	604	667	686	713
Fuel ($billion)	65	91	116	133	187	123	138	174	208	208	204
Fuel share (%)	17	22	26	27	33	26	26	29	31	30	29

The direct impact of the oil price on the airlines economy has been around 30% during the last four years. Recent short-term forecast, incorporating the oil price decline in the October-December 2014 period, give figures of 26-27% for 2015, keeping this percentage constant for 2016 and 2017.

Passing from global figures to type of business numbers introduces a wide dispersion in the results. Those airlines offering a wide range of services, like legacy carriers, show lower values while low cost carriers, charter airlines and freighter companies have much higher figures. The case of regional airlines moves between both groups: those operating a majority of regional jet aircraft are closer to low cost carriers due to the high consumption per RTK of that class of airplanes; on the contrary, the turboprop operators show low fuel burned figures and the results are closer or even better than the legacy carriers.

A wide survey of different data sources ((Hoon Lim & Hong, 2013), (IATA, 2011), (ICAO, 2014), (Morrell, 2007), (Wei & Hansen, 2003)) has been performed and the results are included in the following table:

Table 20 - Fuel share per type of carrier

Type of carrier	**Fuel as % of total expenses** (range of values)	**Fuel as % of total expenses** (mode value)
Legacy	22-33	27
Charter	31-38	34
Low cost	32-39	35
Regional	20-42	31
Freighter	34-40	37

As an example of this magnitude variation with the type of operation, a sample has been taken in the US market, a geographical market with very low change in fuel prices from one area to other (IATA, 2011).

US Department of Transportation financial data (Form 41) from US carries has been reviewed, and the information of the cost structure of the major airlines is shown in the table in next page. These data correspond to the domestic US market, being very homogeneous and providing accurate information about the different cost structure of legacy or network carriers and the so-called low cost carriers (LCC).

Table 21 - US DoT Form 41 financial data.

2013						
	fuel expenses (M$)	total operating expenses (M$)	percentage	total operating expenses per ASM ($ cents/ASM)	ASM (x10^8)	fuel expenses /ASM ($ cents/ASM)
American	7 415	24 270	31%	13.74	1 766	4.20
Continental						
Delta	9 379	33 980	28%	13.66	2 488	3.77
Northwest						
United	9 744	37 030	26%	13.87	2 670	3.65
US Airways	3 390	13 930	24%	13.43	1 037	3.27
America West						
sub-Network	**29 928**	**109 210**	**27%**	**13.72**	**7 960**	**3.76**
Southwest	5 539	16 420	34%	12.55	1 308	4.23
JetBlue	1 846	5 030	37%	11.64	432	4.27
AirTran						
Frontier	462	1 300	36%	11.93	109	4.24
Virgin America	471	1 340	35%	10.86	123	3.82
sub-LCC	**8 319**	**24 080**	**35%**	**12.21**	**1 972**	**4.22**

I.IV Projection of the baseline up to 2035

Data have been projected year by year up to 2035, using 2013 as a reference. Different growth scenarios have been used, as described hereafter.

After World War II, air transport has experienced a fast and continuous growth in every geographical area, at rates dictated by the prevalent socioeconomic conditions in each country. In the 50s and 60s decades, growth rates were double digit, fuelled by technological advances in the design of the commercial aircraft and the provision of larger and better-equipped infrastructures. Consequently, airfares went down and flying became affordable for people other than the affluent classes of the society.

The oil price shocks of the 70s and 80s tempered air transport increase and aligned it to the cyclic fluctuations of the World economy, with a typical elasticity (Air transport growth/world GDP growth) between 1.5 and 2. This figure represents an average relatively stable during the last two decades of the 20th Century but it cannot be taken as a solid data for specific regions or for individual years. Isolated events like the Gulf War, the September 11, 2001 terrorist attacks or the 2008 financial crisis may have had heavy repercussions on the traffic demand, far away of the elasticity values in steady conditions.

In spite of everything that happened, all the different specialized forecast extrapolate the idea of a growing industry in the coming years, based in a number of related socioeconomic trends well visible in our society:

- Direct relationship between air transport and economy, both in the international commerce and in the leisure travel sectors.
- Increased globalization of the world societies, with production more and more specialized in centres of excellence and extended links among political and cultural entities.
- The undeniable appeal of leisure travel, either for tourism or for visiting relatives and friends. An increased share of the families' available income is spent in travel every year.

There are negative factors as well, that are taking bigger size as the dimension and repercussions of commercial aviation gain importance. The most relevant ones might be:

- **The cost of the kerosene fuelling commercial aircraft:** Historically kerosene price has moved in parallel to the oil price, with a limited spread, reflecting the distillation and distribution cost. This trend is being kept even during the most turbulent periods for the oil price, as the recent financial crisis and oil price downturn, happened in the last years (see Figure 28, (IATA, 2014b)). Fifty years ago airlines fuel expenses were about 10% of their total costs; in 2013, it counted for 25-35% of that quantity. Until alternative fuels are fully introduced in the market, air transport suffers a strong dependence on the oil price that will be likely increased in the near future. The relatively small participation (about 7%) of the kerosene in the total oil distillation products gives little leverage to airlines in the global oil market.
- **The maturation of the air travel market in the most developed countries**. Paradigmatic example is the situation in the domestic market of United States, where the average air trip number per inhabitant is stabilized around 2.5 in the last 10 years and the volume of traffic climbs up with the population number.
- **Public opinion worries about life environmental conditions** have a great relevance on air transport development. Local noise and air quality emissions and the aviation contribution to climate change are becoming potential growth limiting factors for future growth. For instance, Frankfurt airport, one of the most crowded facilities in Europe, has decided to prohibit flights at night by noise disturbance reasons.

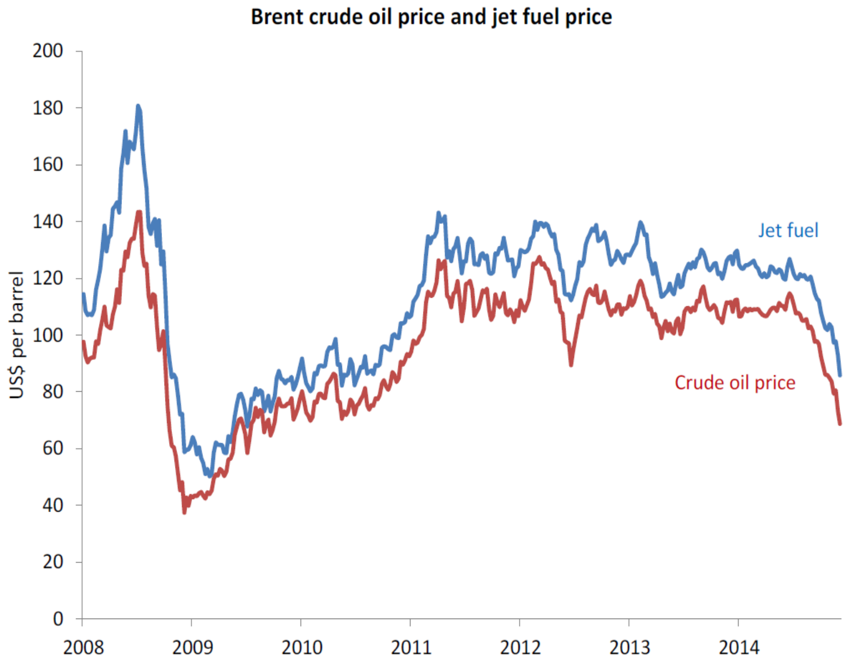

Figure 28 - Oil and aviation fuel price evolution (source Platts).

The different evolution of the above-mentioned factors in the European Union and in other parts of the World seems recommend using different growth scenarios for the traffic growth within European borders and the flights beyond them. This is the philosophy adopted in this study in order to evaluate the evolution of air transport in the European Union.

Long-term scenarios, covering the period 2011-2030, have been prepared. A central or most likely Scenario is followed by two additional ones, the first assuming a number of credible negative trends that may appear along that period and the second following the hypothesis of a more optimistic but equally credible conditions. The scheme is similar to the one used in the CONSAVE analysis (CONSAVE 2050, 2005).

The baseline of the central scenario considers an initial period (2013-2016) of slow economic growth within the European Union countries, followed by a gradual recuperation in the 2017-2020 and a steady growth in the next decade. At the same time, traffic to and from EU is supposed to have two different levels of development in each decade, but both higher than domestic EU demand as integrating the higher developing pace of emerging economies.

A survey of available forecast by specialized bodies has been performed, including international organizations: International Civil Aviation Organization (ICAO, 2010), (EUROCONTROL, 2010), (IATA, 2014) and (International, 2012): and some of the largest manufacturers of commercial aircraft ((Airbus, 2012), (Boeing, 2012), (Bombardier, 2012), (Embraer, 2012) and (Rolls-Royce, 2012)). The references of the consulted documents are listed in the last section of this document.

Most of the data are very similar, with slight variations due in most cases by different temporal calculation periods. The combination of them results in the following figures:

Table 22 - Central scenario traffic growth.

Period	**2013-2016**	**2017-2035**
EU traffic	2.8%	3.2%
Non EU traffic	4.0%	4.0%

The application of those values to the traffic is not immediately translated to the fuel consumption because there are several factors improving the energetic efficiency of air transport:

- Fleet replacement, substituting some aircraft models by new, more efficient ones as they enter into the market.
- Use of larger aircraft, as the average commercial aircraft size is continuously increasing. It is worth to note that, everything else being equal, a larger airplane is more efficient than a smaller one.
- Increased density seating inside aircraft: With the irruption of the low cost carriers, the number of seats is being risen up, not only by that type of airlines but also by the incumbents.
- Improvements in Air Traffic Management and navigation procedures, allowing the optimization of flight profiles and trajectories.

The calculation of the practical consequences of all those elements is complicated. During the last 15 years, IATA has been recording the values of the Revenue-Ton-Kilometre (RTK) of its affiliated companies, comparing them with the fuel consumption. The results show an average improved in efficiency, measured in ton of fuel per RTK, around 1.9% yearly. As the fuel is a very important part of the operating cost since many years ago, in the last years, the efficiency improvement trend is independent of the short-term variations of the oil price, as it can be seen in Figure 29 (IATA, 2014b).

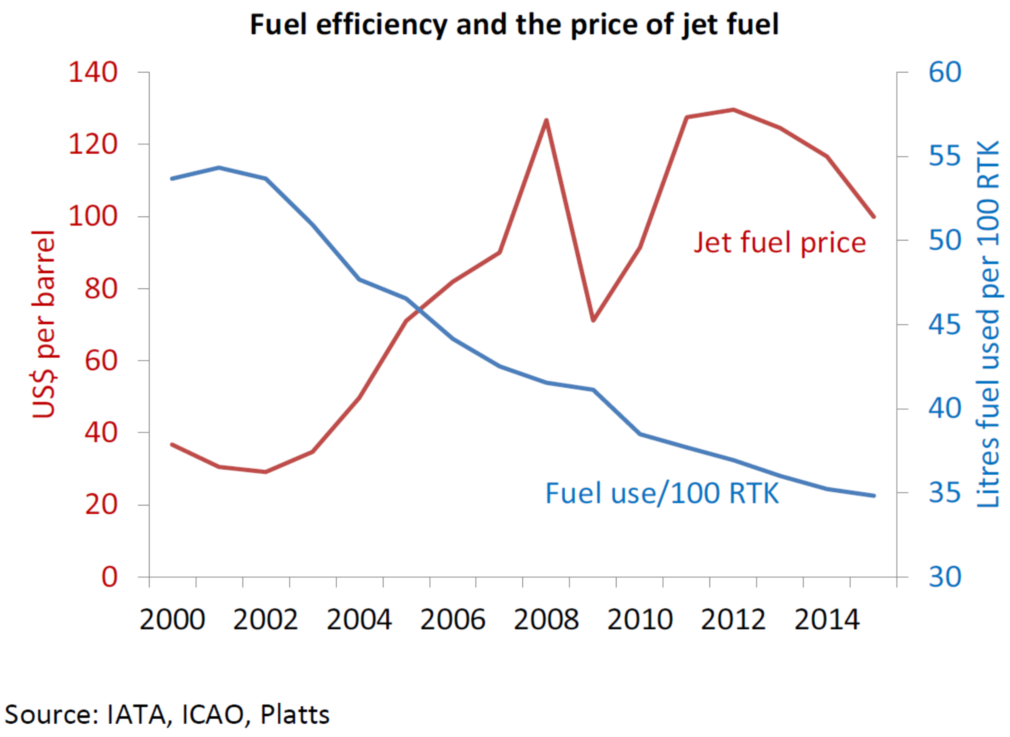

Figure 29 - Fuel efficiency and price of jet fuel evolution.

The efficiency is increasing in a steady way, only briefly disrupted by the traffic (and load factor) downturns of September 11 and 2008 financial crisis, recovered almost immediately.

The ICAO Council, in its climate change mitigation program, set an aspirational target for the World Air Transport sector of 2.0% yearly improvement until 2020, with a possible stretch until 2030 if the national Action Plans prepared by contracting States prove to be adequate. In addition, IATA considers possible an efficiency improvement of 1.5% per year, only due to airline operation, in the future years and adopted this magnitude as a voluntary commitment.

Considering that information, the annual figure of 1.5% efficiency improvement has been introduce in the Scenario for the full 2013-2030 period. The appearance of a number of new more efficient models in all size and range categories (A350, B777X, A320NEO, B737MAX, C919, MS21, C-Series, EJet and CRJ re-engined) in the next six years and the promised improvements in the use of the air space (SESAR, NextGen) seem to support the credibility of that number.

With respect to the biofuel usage, most of the specification and operational questions have been already answered and no technological showstopper is seen in the considered period. However, the economic viability is still far from being made secure. In this forecast, the introduction of a small quantity of biofuel is not supposed to have any influence on the traffic growth development during the studied period (SWAFEA, 2011).

The pessimistic scenario is based in the hypothesis of a prolongation of the EU financial crisis until the end of the present decade with a dual situation of high deficit countries sunk in the economic recession or its sequels, and better-off countries moving carefully their budget control with strong expenses limitation. This bleak forecast would be improving at a slow pace during the second decade. Moderate US economy recovery, inflationist pressures in China and fast rising oil prices, after the present downturn, would reduce a couple of percentage points the demand growth for the outside EU traffic.

Table 23 - Pessimistic scenario traffic growth

Period	**2013-2016**	**2017-2035**
EU traffic	0.8%	1.0%
Non EU traffic	2.0%	2.0%

The optimistic scenario assumes a fast and robust recovery of the EU economy, returning to before-the-crisis growth rates at the middle of the present decade, partially thanks to the stabilization of oil prices at lower levels than in the 2011-2013 period. International markets would gain from a high consumer expense increase in United States, an appreciation of the USD with respect to other currencies and a soft landing of the overheated Chinese economy. Intra EU demand will always rise up less than external traffic

Table 24 - Optimistic scenario traffic growth

Period	**2013-2016**	**2017-2035**
EU traffic	2.8 – 3.0	3.4 – 3.6
Non EU traffic	4.5%	5.0%

In both alternative scenarios, the efficiency improvement and the percentage of alternative jet fuel usage are kept at the same levels than in the central scenario.

The recent reduction of the oil price from about 105 USD per Brent barrel to close to 50 USD might support the optimistic scenario, as most forecasters are improving their 2015 figures for worldwide air traffic and airline economic profits. However, it is not clear if this trend corresponds to a stable movement of the market or to a mix of short-term future price speculation, mixed with a non-declared price war between established oil producers and new extraction technique users (shale oil, fracking). In the medium-long term, oil price is supposed to recover and continue its climb, at least until a competitive fuel is introduced at a scale big enough to have decisive influence on the market evolution.

I.V Analysis of potential consequences for the competitiveness of EU airlines and airports

The economic repercussions of the alternative jet fuel introduction would depend on the final specification of the product, price, quantity and regulatory conditions. Potentially it might be influential on the following magnitudes:

- Fuel price through the cost of the kerosene itself and the effect on the market price of the standard kerosene
- Climate change Market Based measures (MBMs) introduction by ICAO, the evolution of the European Emissions trading System (ETS) and the possible modification of some local environmental airport charges
- Performance depending on the Low calorific Value of the alternative jet fuel compared with the present fuel
- Marketing by providing a more environmentally minded image to the user airlines

According to recent EU estimations, aviation biofuel may cost above 2,000 euro per tonne, against 700 euro per tonne of fossil kerosene at average 2014 prices. Obviously, the European airline industry cannot afford trebling the price of an element representing between 25 and 35% of its total costs without losing competitiveness to other world areas airlines.

This relative position may change as the oil becomes scarce and its price goes up, but some experts suggest that feedstock prices are going up as well in not a very different way than oil.

A temporary reduction of the oil price as it is happening during the last quarter of 2014 has a dual effect on the alternative jet fuel demand: on one hand, the traffic grows as the transport cost decreases, incentivising demand. On the other hand, the kerosene price decreases and the relative difference between bio and fossil fuel becomes larger, making bio less attractive to the airlines.

It remains the evaluation of the three external effects above mentioned. The CO_2 reduction may be evaluated at first sight considering the European Emissions Trading System (ETS) that gives biofuels a zero emission factor. Then biofuel consumption is practically exempted of the emissions market. Burning a tonne of kerosene emits 3.16 tonne of CO_2 that if replaced by biofuel will not have to buy any emission allowance. Unfortunately, the low price of allowances would translate this in 25 € savings at a price of 8 euro per emitted ton (practically double than today's value).

Security of supply is more difficult to evaluate. Additional supplying sources may limit the price increase of the oil as more providers would enter into the market and get up the competition level, but aviation kerosene is taking around 7% of the oil production and the European part will be close to 2% of the total oil extraction, very low fraction to have an immediate price repercussion.

A more clear idea of the possible benefits comes from the analysis of the biofuels technical features (Kinder & Rahmes, 2009). A typical JetA1 net heat of combustion value is 42.8 MJ/kg. The corresponding figure for alternative jet fuel made out of camelina is around 44.2-44.3. It means that the same weight of fuel may save over 3% of fuel consumption. The experienced gained by a number of alternative jet fuel in flight tests are not very conclusive because were more orientated towards airworthiness and reliability issues and the used biofuel mix was not homogeneous, but the first results show an improvement of fuel efficiency in the order of 1.5%.

Finally, it remains to be seen the marketing appeal of introducing biofuels in normal service for the image of the airlines. A lot of publicity has been given to different flights operated with blended kerosene but it seems unlikely that all these activities can be translated into direct economic benefit in the short-term future.

With all these considerations in mind, the assumption that has been finally introduced is an annual traffic growth of 4.5 %, with a yearly improvement in fuel efficiency of 1.5 %. This hypothesis is kept the same for all considered airports and airlines.

Annex II. Results

II.I Feedstock production

Table 25 - Amounts to be produced in 2035 (1st generation scenario, Gtons)

	1st gen															
Feedstock required	2.50%															
Thousands	2%								4%							
	W/ MSW				W/o MSW				W/ MSW				W/o MSW			
	L		H		L		H		L		H		L		H	
	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h
Vegetable oil	656.0	594.1	593.1	497.2	720.7	659.9	654.7	556.6	1312.0	1188.1	1186.2	994.3	1441.3	1319.7	1309.4	1113.2
Tallow	125.6	104.0	131.6	111.3	138.0	115.5	145.3	124.7	251.2	208.0	263.2	222.7	275.9	231.0	290.6	249.3
MSW	176.3	195.9	184.7	209.8	0.0	0.0	0.0	0.0	352.5	391.9	369.5	419.6	0.0	0.0	0.0	0.0
UCO	176.3	171.2	184.7	183.3	193.7	190.2	203.9	205.2	352.5	342.4	369.5	366.6	387.3	380.4	407.8	410.5
Forest residues	803.8	893.5	842.4	956.7	883.0	992.5	929.9	1071.0	1607.6	1787.0	1684.9	1913.3	1766.1	1984.9	1859.8	2142.1
SRT	998.6	1110.1	1046.6	1188.5	1097.1	1233.0	1155.3	1330.6	1997.3	2220.1	2093.3	2377.1	2194.2	2466.1	2310.6	2661.3
Sugarcane	1444.3	1605.5	1513.7	1719.0	1586.7	1783.3	1670.9	1924.5	2888.7	3210.9	3027.5	3438.0	3173.4	3566.7	3341.8	3849.0
Switchgrass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corn grain	284.1	315.8	297.8	338.1	312.1	350.8	328.7	378.6	568.2	631.6	595.5	676.3	624.2	701.6	657.3	757.1
Corn stover	1360.4	1512.1	1425.8	1619.1	1494.5	1679.7	1573.8	1812.6	2720.8	3024.3	2851.5	3238.1	2989.0	3359.4	3147.5	3625.3
Tall oil + TCO	54.1	36.4	56.7	39.0	59.4	40.4	62.5	43.6	108.1	72.8	113.3	77.9	118.8	80.8	125.1	87.2

	1st gen															
Feedstock required	0.50%															
Thousands	2%								4%							
	W/ MSW				W/o MSW				W/ MSW				W/o MSW			
	L		H		L		H		L		H		L		H	
	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h
Vegetable oil	620.9	383.9	245.3	76.4	945.4	688.6	437.5	162.1	1241.7	767.8	490.6	152.8	1890.9	1377.2	875.0	324.2
Tallow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MSW	674.5	869.3	863.0	1038.4	0.0	0.0	0.0	0.0	1348.9	1738.6	1725.9	2076.8	0.0	0.0	0.0	0.0
UCO	173.1	71.9	221.5	85.9	263.6	129.0	395.0	182.2	346.2	143.8	443.0	171.8	527.2	258.0	790.0	364.4
Forest residues	1507.7	1943.2	1929.0	2321.2	2295.9	3485.4	3440.2	4923.7	3015.4	3886.4	3858.1	4642.4	4591.8	6970.9	6880.4	9847.4
SRT	482.1	621.3	616.8	742.2	734.1	1114.4	1100.0	1574.3	964.1	1242.6	1233.6	1484.3	1468.2	2228.9	2199.9	3148.6
Sugarcane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Switchgrass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corn grain	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corn stover	249.7	321.9	319.5	384.5	380.3	577.4	569.9	815.6	499.5	643.8	639.1	769.0	760.6	1154.7	1139.7	1631.2
Tall oil + TCO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 26 - Amounts to be produced in 2035 (2nd generation scenario, Gtons)

	2nd gen															
Feedstock required	2.50%															
Thousands	2%								4%							
	W/ MSW				W/o MSW				W/ MSW				W/o MSW			
	L		H		L		H		L		H		L		H	
	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h
Vegetable oil	271.1	234.8	63.9	23.4	342.2	309.8	85.3	33.0	542.1	469.7	127.8	46.8	684.4	619.6	170.7	66.0
Tallow	90.4	58.5	109.1	70.4	114.1	77.2	145.7	99.4	180.8	117.0	218.2	140.8	228.2	154.3	291.3	198.7
MSW	2143.3	2495.1	2587.2	3004.1	0.0	0.0	0.0	0.0	4286.6	4990.1	5174.5	6008.2	0.0	0.0	0.0	0.0
UCO	178.8	142.7	215.8	171.8	225.7	188.3	288.1	242.5	357.5	285.4	431.6	343.7	451.4	376.6	576.1	484.9
Forest residues	905.3	1053.8	1092.8	1268.8	1142.8	1390.2	1458.8	1790.4	1810.5	2107.7	2185.5	2537.6	2285.6	2780.4	2917.5	3580.8
SRT	607.7	707.4	733.6	851.8	767.2	933.3	979.3	1201.9	1215.4	1414.9	1467.2	1703.5	1534.3	1866.5	1958.6	2403.8
Sugarcane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Switchgrass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corn grain	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corn stover	756.7	880.9	913.5	1060.6	955.3	1162.1	1219.4	1496.6	1513.5	1761.8	1826.9	2121.3	1910.6	2324.2	2438.8	2993.3
Tall oil + TCO	13.6	0.0	16.4	0.0	17.1	0.0	21.8	0.0	27.1	0.0	32.7	0.0	34.2	0.0	43.7	0.0

	2nd gen															
Feedstock required	0.50%															
Thousands	2%								4%							
	W/ MSW				W/o MSW				W/ MSW				W/o MSW			
	L		H		L		H		L		H		L		H	
	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h
Vegetable oil	414.2	257.2	0.0	0.0	736.5	648.0	0.0	0.0	828.4	514.4	0.0	0.0	1473.1	1296.0	0.0	0.0
Tallow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MSW	4512.5	6218.8	6693.7	7796.2	0.0	0.0	0.0	0.0	9025.0	12437.5	13387.4	15592.5	0.0	0.0	0.0	0.0
UCO	121.2	0.0	179.8	0.0	215.5	0.0	512.4	0.0	242.4	0.0	359.5	0.0	431.0	0.0	1024.7	0.0
Forest residues	807.9	1113.4	1198.4	1395.8	1436.5	2805.0	3415.5	5721.6	1615.8	2226.7	2396.8	2791.6	2873.1	5609.9	6831.0	11443.3
SRT	8.0	11.1	11.9	13.9	14.3	27.8	33.9	56.8	16.0	22.1	23.8	27.7	28.5	55.7	67.8	113.6
Sugarcane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Switchgrass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corn grain	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corn stover	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tall oil + TCO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 27 - Market generated in 2035 (1st gen., G€)

Feedstock market	1st gen															
Millions	2.50%															
	2%								4%							
	W/ MSW				W/o MSW				W/ MSW				W/o MSW			
	L		H		L		H		L		H		L		H	
	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h
Vegetable oil	317.5	279.6	309.4	255.1	348.8	310.5	341.5	285.6	634.9	559.1	618.8	510.2	697.5	621.1	683.1	571.2
Tallow	63.6	52.7	66.6	56.4	69.9	58.5	73.6	63.1	127.2	105.3	133.3	112.8	139.7	117.0	147.1	126.2
MSW	4.8	5.3	5.0	5.7	0.0	0.0	0.0	0.0	9.6	10.7	10.1	11.4	0.0	0.0	0.0	0.0
UCO	80.4	78.1	84.2	83.6	88.3	86.7	93.0	93.6	160.8	156.1	168.5	167.2	176.6	173.4	186.0	187.2
Forest residues	8.5	9.4	8.9	10.1	9.3	10.4	9.8	11.3	16.9	18.8	17.7	20.1	18.6	20.9	19.6	22.5
SRT	15.1	16.8	15.9	18.0	16.6	18.7	17.5	20.2	30.3	33.7	31.7	36.1	33.3	37.4	35.0	40.4
Sugarcane	3.3	3.7	3.5	3.9	3.6	4.1	3.8	4.4	6.6	7.4	7.0	7.9	7.3	8.2	7.7	8.8
Switchgrass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corn grain	11.7	13.0	12.3	13.9	12.9	14.5	13.6	15.6	23.4	26.1	24.6	27.9	25.8	28.9	27.1	31.2
Corn stover	8.0	8.9	8.4	9.5	8.8	9.8	9.2	10.6	15.9	17.7	16.7	19.0	17.5	19.7	18.4	21.2
Tall oil + TCO	32.4	21.8	34.0	23.4	35.6	24.2	37.5	26.2	64.9	43.7	68.0	46.7	71.3	48.5	75.0	52.3

Feedstock market	1st gen															
Millions	0.50%															
	2%								4%							
	W/ MSW				W/o MSW				W/ MSW				W/o MSW			
	L		H		L		H		L		H		L		H	
	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h
Vegetable oil	260.1	157.1	113.2	34.8	396.1	281.8	201.9	73.8	520.3	314.2	226.4	69.6	792.3	563.6	403.8	147.6
Tallow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MSW	18.3	23.6	23.5	28.2	0.0	0.0	0.0	0.0	36.7	47.3	46.9	56.5	0.0	0.0	0.0	0.0
UCO	78.9	32.8	101.0	39.2	120.2	58.8	180.1	83.1	157.9	65.6	202.0	78.3	240.4	117.6	360.2	166.2
Forest residues	15.9	20.5	20.3	24.4	24.2	36.7	36.2	51.8	31.7	40.9	40.6	48.9	48.3	73.4	72.4	103.7
SRT	7.3	9.4	9.4	11.3	11.1	16.9	16.7	23.9	14.6	18.8	18.7	22.5	22.3	33.8	33.4	47.8
Sugarcane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Switchgrass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corn grain	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corn stover	1.5	1.9	1.9	2.3	2.2	3.4	3.3	4.8	2.9	3.8	3.7	4.5	4.5	6.8	6.7	9.6
Tall oil + TCO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 28 - Market generated in 2035 (2nd gen., G€)

Feedstock market	2nd gen															
Millions	2.50%															
	2%								4%							
	W/ MSW				W/o MSW				W/ MSW				W/o MSW			
	L		H		L		H		L		H		L		H	
	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h
Vegetable oil	168.3	147.8	146.4	99.9	192.6	171.4	169.3	117.7	336.6	295.6	292.8	199.9	385.3	342.7	338.6	235.5
Tallow	89.6	72.6	95.8	79.9	102.6	84.2	110.8	94.2	179.3	145.3	191.7	159.8	205.3	168.5	221.7	188.3
MSW	6.8	7.4	7.2	8.1	0.0	0.0	0.0	0.0	13.5	14.7	14.5	16.2	0.0	0.0	0.0	0.0
UCO	113.3	107.7	121.1	118.5	129.7	124.9	140.1	139.6	226.6	215.4	242.3	237.0	259.5	249.8	280.2	279.2
Forest residues	11.9	13.0	12.8	14.3	13.7	15.0	14.7	16.8	23.9	25.9	25.5	28.5	27.3	30.1	29.5	33.6
SRT	21.4	23.2	22.8	25.6	24.4	26.9	26.4	30.1	42.7	46.4	45.7	51.1	48.9	53.9	52.8	60.2
Sugarcane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Switchgrass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corn grain	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corn stover	11.2	12.2	12.0	13.4	12.9	14.2	13.9	15.8	22.5	24.4	24.0	26.9	25.7	28.3	27.8	31.7
Tall oil + TCO	45.7	30.1	48.9	33.1	52.3	34.9	56.5	39.0	91.5	60.2	97.8	66.3	104.7	69.8	113.1	78.1

Feedstock market	2nd gen															
Millions	0.50%															
	2%								4%							
	W/ MSW				W/o MSW				W/ MSW				W/o MSW			
	L		H		L		H		L		H		L		H	
	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h
Vegetable oil	190.2	132.3	0.0	0.0	307.0	243.8	0.0	0.0	380.4	264.6	0.0	0.0	614.0	487.6	0.0	0.0
Tallow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MSW	20.3	24.4	26.8	29.4	0.0	0.0	0.0	0.0	40.7	48.9	53.6	58.8	0.0	0.0	0.0	0.0
UCO	87.5	33.9	115.4	40.8	141.2	62.5	231.7	90.6	174.9	67.8	230.8	81.5	282.4	124.9	463.4	181.1
Forest residues	17.6	21.1	23.2	25.4	28.4	39.0	46.6	56.5	35.2	42.3	46.4	50.8	56.8	77.9	93.2	113.0
SRT	8.1	9.7	10.7	11.7	13.1	18.0	21.5	26.0	16.2	19.5	21.4	23.4	26.2	35.9	42.9	52.0
Sugarcane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Switchgrass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corn grain	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corn stover	1.6	1.9	2.1	2.3	2.6	3.6	4.3	5.2	3.2	3.9	4.3	4.7	5.2	7.2	8.6	10.4
Tall oil + TCO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

II.II Feedstock logistics

Table 29 - Tons-kilometres transported (1st gen., Gt)

	1st gen																															
	2.50%																0.50%															
	2%								4%								2%								4%							
	W/ MSW				W/o MSW				W/ MSW				W/o MSW				W/ MSW				W/o MSW				W/ MSW				W/o MSW			
	L		H		L		H		L		H		L		H		L		H		L		H		L		H		L		H	
	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h
Vegetable oil	8.8	8.0	7.9	6.7	9.7	8.8	8.8	7.5	17.6	15.9	15.9	13.3	19.3	17.7	17.5	14.9	8.3	5.1	3.3	1.0	12.7	9.2	5.9	2.2	16.6	10.3	6.6	2.0	25.3	18.5	11.7	4.3
Tallow	1.7	1.4	1.8	1.5	1.8	1.5	1.9	1.7	3.4	2.8	3.5	3.0	3.7	3.1	3.9	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MSW	2.4	2.6	2.5	2.8	0.0	0.0	0.0	0.0	4.7	5.3	5.0	5.6	0.0	0.0	0.0	0.0	9.0	11.6	11.6	13.9	0.0	0.0	0.0	0.0	18.1	23.3	23.1	27.8	0.0	0.0	0.0	0.0
UCO	2.4	2.3	2.5	2.5	2.6	2.5	2.7	2.8	4.7	4.6	5.0	4.9	5.2	5.1	5.5	5.5	2.3	1.0	3.0	1.2	3.5	1.7	5.3	2.4	4.6	1.9	5.9	2.3	7.1	3.5	10.6	4.9
Forest residues	10.8	12.0	11.3	12.8	11.8	13.3	12.5	14.4	21.5	23.9	22.6	25.6	23.7	26.6	24.9	28.7	20.2	26.0	25.8	31.1	30.8	46.7	46.1	66.0	40.4	52.1	51.7	62.2	61.5	93.4	92.2	132.0
SRT	13.4	14.9	14.0	15.9	14.7	16.5	15.5	17.8	26.8	29.7	28.0	31.9	29.4	33.0	31.0	35.7	6.5	8.3	8.3	9.9	9.8	14.9	14.7	21.1	12.9	16.7	16.5	19.9	19.7	29.9	29.5	42.2
Sugarcane	19.4	21.5	20.3	23.0	21.3	23.9	22.4	25.8	38.7	43.0	40.6	46.1	42.5	47.8	44.8	51.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Switchgrass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corn grain	3.8	4.2	4.0	4.5	4.2	4.7	4.4	5.1	7.6	8.5	8.0	9.1	8.4	9.4	8.8	10.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corn stover	18.2	20.3	19.1	21.7	20.0	22.5	21.1	24.3	36.5	40.5	38.2	43.4	40.1	45.0	42.2	48.6	3.3	4.3	4.3	5.2	5.1	7.7	7.6	10.9	6.7	8.6	8.6	10.3	10.2	15.5	15.3	21.9
Tall oil + TCO	0.7	0.5	0.8	0.5	0.8	0.5	0.8	0.6	1.4	1.0	1.5	1.0	1.6	1.1	1.7	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 30 - Tons-kilometres transported (2nd gen., Gt)

	2nd gen																															
	2.50%																0.50%															
	2%								4%								2%								4%							
	W/ MSW				W/o MSW				W/ MSW				W/o MSW				W/ MSW				W/o MSW				W/ MSW				W/o MSW			
	L		H		L		H		L		H		L		H		L		H		L		H		L		H		L		H	
	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h
Vegetable oil	4.8	4.5	3.3	2.3	5.5	5.2	3.8	2.7	9.6	8.9	6.6	4.6	11.0	10.4	7.7	5.4	6.4	4.4	0.0	0.0	10.3	8.2	0.0	0.0	12.7	8.9	0.0	0.0	20.6	16.3	0.0	0.0
Tallow	2.4	1.9	2.5	2.1	2.7	2.2	2.9	2.5	4.7	3.8	5.1	4.2	5.4	4.5	5.9	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MSW	27.0	29.4	28.9	32.3	0.0	0.0	0.0	0.0	54.0	58.8	57.8	64.6	0.0	0.0	0.0	0.0	81.2	97.7	107.2	117.4	0.0	0.0	0.0	0.0	162.5	195.3	214.4	234.9	0.0	0.0	0.0	0.0
UCO	3.3	3.2	3.6	3.5	3.8	3.7	4.1	4.1	6.7	6.3	7.1	7.0	7.6	7.3	8.2	8.2	2.6	1.0	3.4	1.2	4.1	1.8	6.8	2.7	5.1	2.0	6.8	2.4	8.3	3.7	13.6	5.3
Forest residues	15.2	16.5	16.2	18.2	17.4	19.1	18.8	21.4	30.4	33.0	32.5	36.3	34.8	38.3	37.5	42.8	22.4	26.9	29.5	32.4	36.1	49.6	59.3	71.9	44.8	53.8	59.1	64.7	72.3	99.2	118.6	143.8
SRT	18.9	20.5	20.2	22.6	21.6	23.8	23.3	26.6	37.7	41.0	40.3	45.1	43.2	47.6	46.6	53.2	7.2	8.6	9.4	10.3	11.6	15.9	19.0	23.0	14.3	17.2	18.9	20.7	23.1	31.7	37.9	46.0
Sugarcane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Switchgrass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corn grain	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corn stover	25.7	28.0	27.5	30.8	29.4	32.4	31.8	36.2	51.4	55.9	54.9	61.5	58.8	64.8	63.5	72.5	3.7	4.5	4.9	5.4	6.0	8.2	9.8	11.9	7.4	8.9	9.8	10.7	12.0	16.4	19.6	23.8
Tall oil + TCO	1.0	0.7	1.1	0.7	1.2	0.8	1.3	0.9	2.0	1.3	2.2	1.5	2.3	1.6	2.5	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

II.III Conversion technology

Table 31 - Conversion facilities

Generation	1st gen																															
Fossil increase	2.5%																0.5%															
Mandate	2.0%								4.0%								2.0%								4.0%							
MSW	W/ MSW				W/o MSW				W/ MSW				W/o MSW				W/ MSW				W/o MSW				W/ MSW				W/o MSW			
Camelina oil	L		H		L		H		L		H		L		H		L		H		L		H		L		H		L		H	
HEFA CAPEX	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h
HEFA	3	3	3	3	3	3	3	3	6	5	6	5	6	6	6	5	3	2	2	1	4	3	3	1	5	3	3	1	7	5	5	2
FT	1	1	1	1	0	0	0	0	2	2	2	2	0	0	0	0	3	4	4	5	0	0	0	0	6	7	7	9	0	0	0	0
DSHC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ATJ	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HDCJ	2	2	2	2	2	2	2	2	3	3	3	4	3	4	4	4	2	2	2	3	3	4	4	5	3	4	4	5	5	7	7	9

Generation	2nd gen																															
Fossil increase	2.5%																0.5%															
Mandate	2.0%								4.0%								2.0%								4.0%							
MSW	W/ MSW				W/o MSW				W/ MSW				W/o MSW				W/ MSW				W/o MSW				W/ MSW				W/o MSW			
Camelina oil	L		H		L		H		L		H		L		H		L		H		L		H		L		H		L		H	
HEFA CAPEX	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h
HEFA	3	3	3	2	3	3	3	3	5	5	5	4	6	5	5	5	2	2	1	1	3	2	2	1	4	3	2	1	6	4	3	2
FT	1	2	2	2	0	0	0	0	2	3	3	3	0	0	0	0	3	4	4	5	0	0	0	0	6	8	8	9	0	0	0	0
DSHC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ATJ	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HDCJ	2	3	2	3	3	3	3	3	4	5	4	5	5	5	5	6	2	2	2	3	3	4	4	5	3	4	4	5	5	7	8	10

II.IV Alternative jet fuel logistics

Table 32 - Tons-kilometres of alternative jet fuel to be transported (1st gen., Gt·km)

Generation	1st gen																															
Fossil increase	2.50%																0.50%															
Mandate	2%								4%								2%								4%							
MSW	W/ MSW				W/o MSW				W/ MSW				W/o MSW				W/ MSW				W/o MSW				W/ MSW				W/o MSW			
Camelina oil	L		H		L		H		L		H		L		H		L		H		L		H		L		H		L		H	
HEFA CAPEX	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h
Biojet logistics	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3

Table 33 - Tons-kilometres of alternative jet fuel to be transported (2nd gen., Gt·km)

Generation	2nd gen																															
Fossil increase	2.50%																0.50%															
Mandate	2%								4%								2%								4%							
MSW	W/ MSW				W/o MSW				W/ MSW				W/o MSW				W/ MSW				W/o MSW				W/ MSW				W/o MSW			
Camelina oil	L		H		L		H		L		H		L		H		L		H		L		H		L		H		L		H	
HEFA CAPEX	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h
Biojet logistics	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3

II.V Impact on airlines

Table 34 - Additional cost in 2035 (1st gen., G€)

Generation	1st gen																															
Fossil increase	2.50%																0.50%															
Mandate	2%								4%								2%								4%							
MSW	W/ MSW				W/o MSW				W/ MSW				W/o MSW				W/ MSW				W/o MSW				W/ MSW				W/o MSW			
Camelina oil	L		H		L		H		L		H		L		H		L		H		L		H		L		H		L		H	
HEFA CAPEX	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h
British Airways	10.3	12.0	11.8	13.9	11.2	13.3	12.9	15.5	20.7	24.1	23.6	27.9	22.4	26.5	25.8	31.0	21.5	21.5	21.9	20.1	26.6	29.5	30.2	30.1	43.1	43.0	43.9	40.2	53.3	59.0	60.4	60.2
Air Lingus	0.9	1.1	1.0	1.2	1.0	1.2	1.1	1.4	1.8	2.1	2.1	2.5	2.0	2.3	2.3	2.7	1.9	1.9	1.9	1.8	2.3	2.6	2.7	2.7	3.8	3.8	3.9	3.5	4.7	5.2	5.3	5.3
Lufthansa	8.5	9.9	9.7	11.4	9.2	10.9	10.6	12.7	17.0	19.8	19.4	22.8	18.4	21.7	21.2	25.4	17.7	17.6	18.0	16.5	21.8	24.2	24.8	24.7	35.3	35.2	36.0	33.0	43.7	48.4	49.5	49.4
EasyJet	6.7	7.8	7.6	9.0	7.3	8.6	8.4	10.0	13.4	15.6	15.3	18.0	14.5	17.2	16.7	20.1	13.9	13.9	14.2	13.0	17.2	19.1	19.5	19.5	27.9	27.8	28.4	26.0	34.5	38.2	39.1	38.9
Norwegian	0.7	0.8	0.8	0.9	0.7	0.8	0.8	1.0	1.3	1.5	1.5	1.8	1.4	1.7	1.6	2.0	1.4	1.4	1.4	1.3	1.7	1.9	1.9	1.9	2.7	2.7	2.8	2.6	3.4	3.8	3.9	3.8
Air France	8.4	9.8	9.6	11.4	9.1	10.8	10.5	12.7	16.9	19.7	19.3	22.7	18.3	21.6	21.1	25.3	17.6	17.5	17.9	16.4	21.7	24.1	24.6	24.6	35.2	35.1	35.8	32.8	43.5	48.2	49.3	49.1
Aerienne	1.7	2.0	2.0	2.3	1.9	2.2	2.2	2.6	3.4	4.0	3.9	4.6	3.7	4.4	4.3	5.2	3.6	3.6	3.7	3.4	4.4	4.9	5.0	5.0	7.2	7.2	7.3	6.7	8.9	9.8	10.1	10.0
KLM	3.9	4.5	4.5	5.3	4.2	5.0	4.9	5.8	7.8	9.1	8.9	10.5	8.5	10.0	9.7	11.7	8.1	8.1	8.3	7.6	10.0	11.1	11.4	11.4	16.3	16.2	16.6	15.2	20.1	22.3	22.8	22.7
KLM City Hopper	3.1	3.6	3.6	4.2	3.4	4.0	3.9	4.7	6.2	7.3	7.1	8.4	6.8	8.0	7.8	9.4	6.5	6.5	6.6	6.1	8.0	8.9	9.1	9.1	13.0	13.0	13.3	12.2	16.1	17.8	18.2	18.2
Iberia	2.5	2.9	2.8	3.3	2.7	3.2	3.1	3.7	4.9	5.8	5.6	6.7	5.4	6.3	6.2	7.4	5.1	5.1	5.2	4.8	6.4	7.0	7.2	7.2	10.3	10.3	10.5	9.6	12.7	14.1	14.4	14.4
Air Nostrum	1.5	1.8	1.8	2.1	1.7	2.0	1.9	2.3	3.1	3.6	3.5	4.2	3.4	4.0	3.9	4.6	3.2	3.2	3.3	3.0	4.0	4.4	4.5	4.5	6.4	6.4	6.6	6.0	8.0	8.8	9.0	9.0
Air Europa	1.4	1.6	1.6	1.9	1.5	1.8	1.7	2.1	2.7	3.2	3.1	3.7	3.0	3.5	3.4	4.1	2.9	2.9	2.9	2.7	3.5	3.9	4.0	4.0	5.7	5.7	5.8	5.3	7.1	7.8	8.0	8.0
Lufthansa CityLine	1.2	1.4	1.4	1.7	1.3	1.6	1.5	1.9	2.5	2.9	2.8	3.3	2.7	3.2	3.1	3.7	2.6	2.6	2.6	2.4	3.2	3.5	3.6	3.6	5.2	5.1	5.3	4.8	6.4	7.1	7.2	7.2
Tyrolean Airways	0.3	0.4	0.3	0.4	0.3	0.4	0.4	0.5	0.6	0.7	0.7	0.8	0.7	0.8	0.8	0.9	0.6	0.6	0.6	0.6	0.8	0.9	0.9	0.9	1.3	1.3	1.3	1.2	1.6	1.7	1.8	1.8

Table 35 - Additional cost in 2035 (2nd gen., G€)

Generation	2nd gen																															
Fossil increase	2.50%																0.50%															
Mandate	2%								4%								2%								4%							
MSW	W/ MSW				W/o MSW				W/ MSW				W/o MSW				W/ MSW				W/o MSW				W/ MSW				W/o MSW			
Camelina oil	L		H		L		H		L		H		L		H		L		H		L		H		L		H		L		H	
HEFA CAPEX	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h
British Airways	18.3	18.7	20.2	20.9	19.3	19.7	21.5	22.5	36.7	37.3	40.5	41.8	38.5	39.5	43.1	45.0	26.8	27.5	26.8	26.0	32.4	35.9	36.1	36.3	53.5	55.0	53.6	51.9	64.8	71.8	72.2	72.5
Air Lingus	1.6	1.6	1.8	1.8	1.7	1.7	1.9	2.0	3.2	3.3	3.6	3.7	3.4	3.5	3.8	4.0	2.4	2.4	2.4	2.3	2.9	3.2	3.2	3.2	4.7	4.8	4.7	4.6	5.7	6.3	6.4	6.4
Lufthansa	15.0	15.3	16.6	17.1	15.8	16.2	17.6	18.4	30.1	30.6	33.2	34.3	31.6	32.4	35.3	36.9	21.9	22.6	22.0	21.3	26.6	29.4	29.6	29.7	43.9	45.1	43.9	42.6	53.2	58.9	59.2	59.5
EasyJet	11.9	12.1	13.1	13.5	12.5	12.8	13.9	14.5	23.7	24.2	26.2	27.0	24.9	25.5	27.9	29.1	17.3	17.8	17.3	16.8	21.0	23.2	23.3	23.5	34.6	35.6	34.7	33.6	42.0	46.4	46.7	46.9
Norwegian	1.2	1.2	1.3	1.3	1.2	1.3	1.4	1.4	2.3	2.4	2.6	2.7	2.5	2.5	2.7	2.9	1.7	1.8	1.7	1.7	2.1	2.3	2.3	2.3	3.4	3.5	3.4	3.3	4.1	4.6	4.6	4.6
Air France	15.0	15.2	16.5	17.1	15.7	16.1	17.6	18.4	30.0	30.5	33.0	34.1	31.5	32.2	35.1	36.7	21.8	22.5	21.9	21.2	26.5	29.3	29.5	29.6	43.7	44.9	43.7	42.4	52.9	58.6	58.9	59.2
Aerienne	3.1	3.1	3.4	3.5	3.2	3.3	3.6	3.7	6.1	6.2	6.7	7.0	6.4	6.6	7.2	7.5	4.5	4.6	4.5	4.3	5.4	6.0	6.0	6.0	8.9	9.2	8.9	8.7	10.8	12.0	12.0	12.1
KLM	6.9	7.0	7.6	7.9	7.3	7.4	8.1	8.5	13.8	14.1	15.3	15.8	14.5	14.9	16.2	17.0	10.1	10.4	10.1	9.8	12.2	13.5	13.6	13.7	20.2	20.8	20.2	19.6	24.5	27.1	27.2	27.4
KLM City Hopper	5.5	5.6	6.1	6.3	5.8	6.0	6.5	6.8	11.1	11.3	12.2	12.6	11.6	11.9	13.0	13.6	8.1	8.3	8.1	7.8	9.8	10.8	10.9	11.0	16.2	16.6	16.2	15.7	19.6	21.7	21.8	21.9
Iberia	4.4	4.5	4.8	5.0	4.6	4.7	5.1	5.4	8.8	8.9	9.7	10.0	9.2	9.4	10.3	10.7	6.4	6.6	6.4	6.2	7.7	8.6	8.6	8.7	12.8	13.1	12.8	12.4	15.5	17.1	17.2	17.3
Air Nostrum	2.7	2.8	3.0	3.1	2.9	3.0	3.2	3.4	5.5	5.6	6.0	6.2	5.8	5.9	6.4	6.7	4.0	4.1	4.0	3.9	4.8	5.4	5.4	5.4	8.0	8.2	8.0	7.8	9.7	10.7	10.8	10.8
Air Europa	2.4	2.5	2.7	2.8	2.6	2.6	2.9	3.0	4.9	5.0	5.4	5.6	5.1	5.2	5.7	6.0	3.6	3.7	3.6	3.5	4.3	4.8	4.8	4.8	7.1	7.3	7.1	6.9	8.6	9.5	9.6	9.6
Lufthansa CityLine	2.2	2.2	2.4	2.5	2.3	2.4	2.6	2.7	4.4	4.5	4.8	5.0	4.6	4.7	5.2	5.4	3.2	3.3	3.2	3.1	3.9	4.3	4.3	4.3	6.4	6.6	6.4	6.2	7.8	8.6	8.6	8.7
Tyrolean Airways	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.7	1.1	1.1	1.2	1.2	1.1	1.2	1.3	1.3	0.8	0.8	0.8	0.8	0.9	1.1	1.1	1.1	1.6	1.6	1.6	1.5	1.9	2.1	2.1	2.1

Table 36 - Premium in 2035.

	1st gen																															
	2.50%																0.50%															
	2%								4%								2%								4%							
	W/ MSW				W/o MSW				W/ MSW				W/o MSW				W/ MSW				W/o MSW				W/ MSW				W/o MSW			
	L		H		L		H		L		H		L		H		L		H		L		H		L		H		L		H	
	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h
Premium (€)	63.76	74.31	72.90	85.90	69.13	81.76	79.64	95.61	63.76	74.31	72.90	85.90	69.13	81.76	79.64	95.61	132.88	132.51	135.38	124.08	164.26	181.93	186.20	185.62	132.88	132.51	135.38	124.08	164.26	181.93	186.20	185.62
Premium (%)	9%	10%	10%	12%	9%	11%	11%	13%	9%	10%	10%	12%	9%	11%	11%	13%	24%	24%	25%	23%	30%	33%	34%	34%	24%	24%	25%	23%	30%	33%	34%	34%
	2nd gen																															
	2.50%																0.50%															
	2%								4%								2%								4%							
	W/ MSW				W/o MSW				W/ MSW				W/o MSW				W/ MSW				W/o MSW				W/ MSW				W/o MSW			
	L		H		L		H		L		H		L		H		L		H		L		H		L		H		L		H	
	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h
Premium (€)	113.16	115.17	124.82	128.87	118.83	121.74	132.77	138.66	113.16	115.17	124.82	128.87	118.83	121.74	132.77	138.66	165.09	169.65	165.22	160.19	199.98	221.39	222.62	223.63	165.09	169.65	165.22	160.19	199.98	221.39	222.62	223.63
Premium (%)	15%	16%	17%	17%	16%	16%	18%	19%	15%	16%	17%	17%	16%	16%	18%	19%	30%	31%	30%	29%	36%	40%	41%	41%	30%	31%	30%	29%	36%	40%	41%	41%

II.VI Social impact

Table 37 - Employment in 2035

Generation	1st gen																															
Fossil increase	2.50%																0.50%															
Mandate	2%								4%								2%								4%							
MSW	W/ MSW				W/o MSW				W/ MSW				W/o MSW				W/ MSW				W/o MSW				W/ MSW				W/o MSW			
Camelina oil	L		H		L		H		L		H		L		H		L		H		L		H		L		H		L		H	
HEFA CAPEX	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h
Production	4994	4606	4955	4401	5423	5045	5402	4850	9989	9211	9909	8801	10847	10089	10805	9700	3688	2594	2083	1264	5281	4144	3213	1963	7376	5188	4166	2529	10561	8288	6425	3926
Logistics	468	500	481	522	496	535	513	563	935	999	963	1044	992	1070	1025	1126	302	337	336	368	366	462	458	578	605	675	673	736	732	923	916	1155
Conversion	560	560	560	560	490	490	490	490	980	910	980	980	840	910	910	910	560	560	560	630	490	490	490	420	980	980	980	1050	840	840	840	770
Generation	2nd gen																															
Fossil increase	2.50%																0.50%															
Mandate	2%								4%								2%								4%							
MSW	W/ MSW				W/o MSW				W/ MSW				W/o MSW				W/ MSW				W/o MSW				W/ MSW				W/o MSW			
Camelina oil	L		H		L		H		L		H		L		H		L		H		L		H		L		H		L		H	
HEFA CAPEX	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h	l	h
Production	4792	4492	4721	4190	5394	5106	5360	4823	9585	8984	9443	8380	10787	10212	10719	9646	3904	2681	2139	1315	5907	4401	3649	2139	7808	5363	4278	2631	11815	8802	7297	4279
Logistics	536	569	562	610	449	479	472	516	1073	1138	1124	1220	899	957	945	1032	667	769	828	892	379	460	519	594	1334	1538	1657	1784	759	921	1037	1189
Conversion	490	630	560	560	490	490	490	490	910	1050	980	980	910	840	840	910	490	560	490	630	420	420	420	420	910	1050	980	1050	770	770	770	840

II.VII Environmental impact

Table 38 - Emissions saved per airline in 2035 (t CO2)

Mandate	2%	4%
British Airways	510,689	1,021,378
Air Lingus	44,975	89,949
Lufthansa	418,738	837,475
EasyJet	330,383	660,766
Norwegian	32,588	65,175
Air France	416,891	833,782
Aerienne	85,112	170,223
KLM	192,641	385,282
KLM City Hopper	154,364	308,727
Iberia	121,929	243,858
Air Nostrum	76,338	152,677
Air Europa	67,856	135,712
Lufthansa CityLine	61,186	122,371
Tyrolean Airways	14,956	29,913