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Biomass based energy intermediates boosting biofuel production

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 282873

Deliverable 6.5

Market Implementation Plan

Workpackage:	WP6
Deliverable Nº:	D6.5
Due date of deliverable:	1-7-2015
Actual date of delivery:	1-7-2015
Version:	1.2
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Dissemination level:	PU-Public / ~~CO-Confidential~~

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1 Introduction

To increase the share of biobased, renewable energy in Europe conversion pathways are required which are economically feasible, flexible in feedstock utilization and energy efficient. The EU funded project BioBoost aims to facilitate the transition towards biobased, renewable energy by providing tools to optimize for logistics and biomass utilization. The project concentrates on dry and wet residual biomass and organic waste as feedstock for local conversion by **fast pyrolysis (FP)**, **catalytic pyrolysis (CP)** and **hydrothermal carbonization** (HTC) to the intermediate energy carriers biosyncrude, bio-oil and biocoal, respectively.

In this document TNO presents a Market Implementation Plan (MIP) based on the results of techno-economic, environmental and social assessments following logistics optimization. Main mechanisms which either positively or negatively influence implementation of the described pathways in Europe will be identified and discussed. This MIP is a Deliverable (6.5) of Work Package 6 and consists of two parts: an executive summary with the main conclusions and a PowerPoint presentation with the results in detail.

The logistics optimizations were performed using an optimization tool developed by FHOÖ within the Bioboost project and based on HeuristicLab. Details on the logistics model have previously been reported in “D4.1 Logistics Concept” and “D4.3 Logistics Model”. Details on the methodology of the techno-economic, environmental and sustainability assessments and their results have been reported earlier in “D6.4 LCA Report”.

2 Market implementation for biofuel production in Europe

2.1 Introduction

Under which conditions does it make sense to produce biofuels? How is the feedstock potential spread over Europe? What would be an ideal location to start up a new production facility? What is the preferred capacity? What are the consequences for social and environmental aspects? And how do they differ from region to region? Many questions, in addition to the technical feasibility of biofuel production, can be asked. The answers to these questions reveal the main mechanisms that affect, positively or negatively, the implementation of biofuel production in Europe.

The logistics optimization tool has been used to explore biofuel production scenario's for implementation in Europe. The following biofuel pathways are being assessed in this report: fast pyrolysis (FP) and catalytic pyrolysis (CP). Logistics optimization of the HTC pathway on European level is not relevant to study.

2.2 Fast pyrolysis

In the fast pyrolysis pathway reference case, wheat straw is converted in a local processing plant into an energy dense biosyncrude, which is subsequently converted into biofuel in a central gasification plant. Conversion of wheat straw at the local processing plant occurs in three steps: biomass preparation, fast pyrolysis reaction and product recovery or conversion.

In the biomass preparation step, the biomass is cut, milled, and dried. The subsequent fast pyrolysis reaction takes a few seconds after which the pyrolysis products are recovered.

Product recovery consists out of several steps starting with the separation of the char from the aqueous and organic vapors. The organic and aqueous vapors are separated in two condensation steps. The remaining gas phase is transferred to a gas burner for process energy generation. Finally, the char and the organic phase are mixed to form the biosyncrude.

Figure 1 illustrates the value chain for the fast pyrolysis reference pathway including transportation of wheat straw to the local fast pyrolysis plant by truck and transport of biosyncrude to the central gasification plant by train.

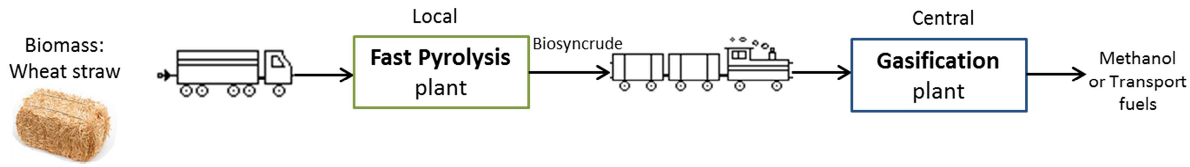


Figure 1. Fast pyrolysis pathway diagram.

2.3 Catalytic pyrolysis

In the catalytic pyrolysis reference pathway, beechwood is converted in a local processing plant into bio-oil, which is subsequently converted into gasoline and diesel in a central refinery plant. Conversion of biomass by catalytic pyrolysis at the local processing plant occurs in three steps: biomass preparation, catalytic pyrolysis and product recovery.

In the biomass preparation step beechwood is milled and dried. Subsequently, the beechwood is converted by means of catalytic pyrolysis. While the solid co-products, coke and char, are burned to provide process energy, the pyrolysis vapor produced in the pyrolysis process is retrieved and led into a fractionation system. In the fractionation system the organic vapors are cooled down in several steps to separate the light gas fraction from the organic liquid which is known as bio-oil.

The bio-oil is upgraded in a central refinery plant. Here the oxygen content of bio-oil is further reduced upon reaction with hydrogen gas in a hydrotreater. By means of cracking and hydrogenation the upgraded bio-oil is separated in final products with chain lengths from 6 to 20 carbons.

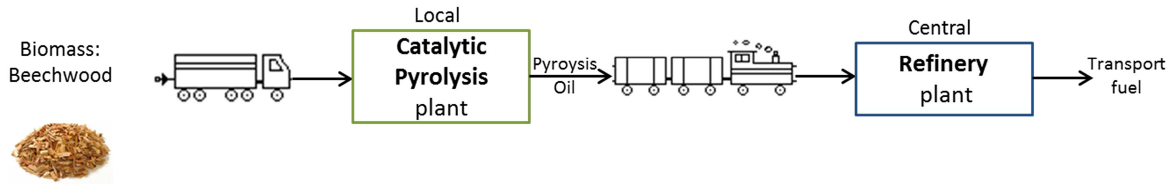


Figure 2. Catalytic pyrolysis reference pathway diagram

3 Logistics optimization

3.1 Introduction

The optimization tool, which is developed by FHOÖ, allows optimizing the implementation of FP and CP pathway through simulations. In these simulations feedstock utilization, price and transport distance and location and capacities of local (CP and FP) and central (Refineries and Gasification) are optimized for a given NUTS3 region, as considered in the WP1 biomass potential studies. For this Market Implementaion Plan different scenarios were simulated and their results analyzed. The scenarios are discussed in the subsequent three sections.

3.2 Europe wide FP and CP pathway implementation

Europe wide simulations were performed for both the FP and CP pathway. These simulations reveal Europe's straw and forestry residue potentials. The simulations also identified the optimal plant capacities for local and central production plants and their locations (section 4.1). From these results the main mechanisms that influence the biofuel business case were identified.

Finally, the techno-economical results of simulations were used to calculate and identify social and environmental impacts of an EU wide FP and CP implementation (section 4.2).

3.3 Fluctuation of market prices

The impact of fluctuating energy prices on the biofuel business case has been made visible by studying the assumed market price trends for 2015, 2020 and 2050.

In addition, a scenario with different feedstock prices was analyzed for straw and forestry residue. The impact of a fluctuating feedstock price on the biofuel business case has been made visible by applying feedstock prices of 50%, 100% and 150% of the current feedstock prices.

Both studies were performed for France and surrounding countries for both the FP and CP pathways.

3.4 Implementation region

To analyze implementation strategies from a regional and a continental perspective local and EU wide implementations were simulated exemplary and their outcomes compared. Three different regional perspectives were considered for biofuel production: I) an optimization considering only Austria, II) Austria as part of a region including its surrounding countries, and III) Austria as part of the whole of Europe. The impact on the biofuel business case in Austria was assessed.

4 Results

4.1 Techno-economic impacts of EU wide implementation

4.1.1 Feedstock potentials

Two Europe-wide biofuel production simulations were performed to identify Europe's feedstock potentials. A FP pathway simulation revealed Europe's straw potential and a CP pathway simulation revealed Europe's forestry residue potential.

Straw

The total straw potential for Europe is 149.7 Mton/year[1]. EU wide simulation showed a straw utilization of 52 Mton/year for biofuel production. This means that the average utilization per region is 35%. With the current state of the art this would result in the production of 5.5 Mton biofuel per year, which is 1.25% of the total transport fuel requirement for Europe.

The regions with the highest straw production can be found in France, Spain and in the East of Europe in general (Figure 3).

Forestry residue

The total forestry residue potential for Europe is 117.9 Mton/year[1]. EU wide simulation showed a forestry residue utilization of 23.2 Mton/year for biofuel production. This means an average utilization per region of 20%. With the current state of the art this would result in the production of 4 Mton biofuel per year which is 0.9% of the total transport fuel requirement for Europe.

The regions with the highest forestry residue production can be found in the Scandinavian countries, the East of Europe and France (Figure 6).

[1] D1.2 BioBoost IUNG feedstock potential

4.1.2 Plant capacities and locations

Europe-wide simulations for both the FP and CP pathway were performed with the aim to identify the optimal plant locations and capacities for local and central production plants. From these results the main mechanisms that influence plant capacity and location were identified.

Fast pyrolysis

The optimization tool has been used to determine the optimal locations for local and central conversion plants in Europe. Feedstock potentials are depicted in Figure 3a, local plant capacities and locations in Figure 3b and central plant capacities and locations in Figure 3c.

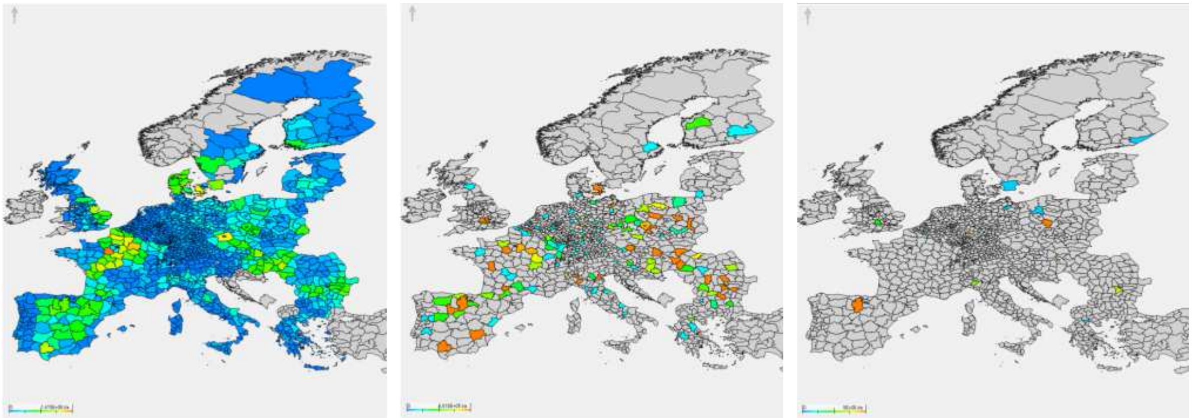


Figure 3. a) Straw potential in Europe, b) locations and capacities of local (FP) plants and c) locations and capacities of central plants in Europe. Colors indicate volumes or size of the respective parameter: red is high/large, green is medium, blue is small and grey is zero.

Simulation of EU-wide biofuel production from straw returned an optimal solution in which 137 straw conversion plants are constructed. The conversion plant capacities were overall either small (< 200,000 ton/year) or very large (> 350,000 ton/year) for the conversion of straw.

Approximately 10 times less biosyncrude plants are built with 5-10 times larger capacities when compared to straw conversion plants. This is in line with the local/central principle, where an intermediate is locally produced and centrally converted. The plant capacity distribution of local and central conversion plant is presented in Figure 4.

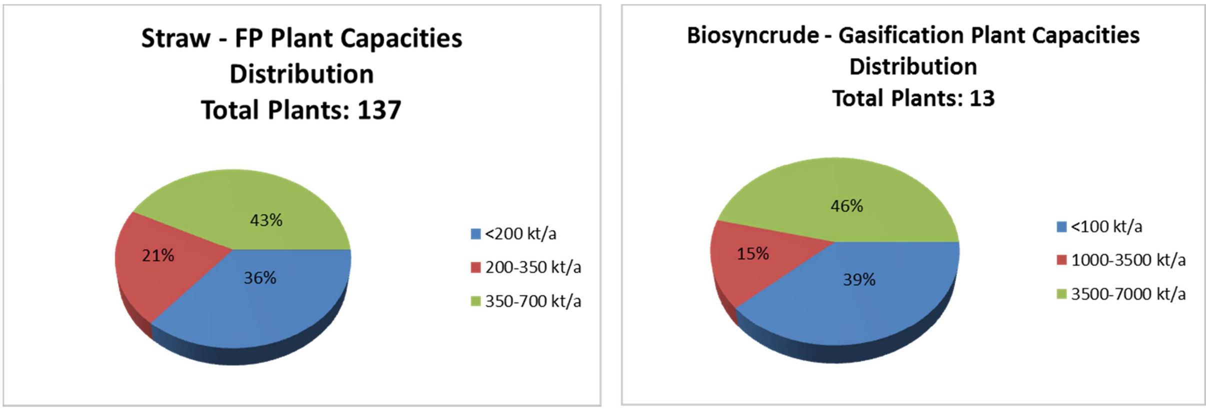


Figure 4. a) Plant capacity distribution expressed in ton feedstock per year and b) gasification plant capacity distribution expressed in ton biofuel per year.

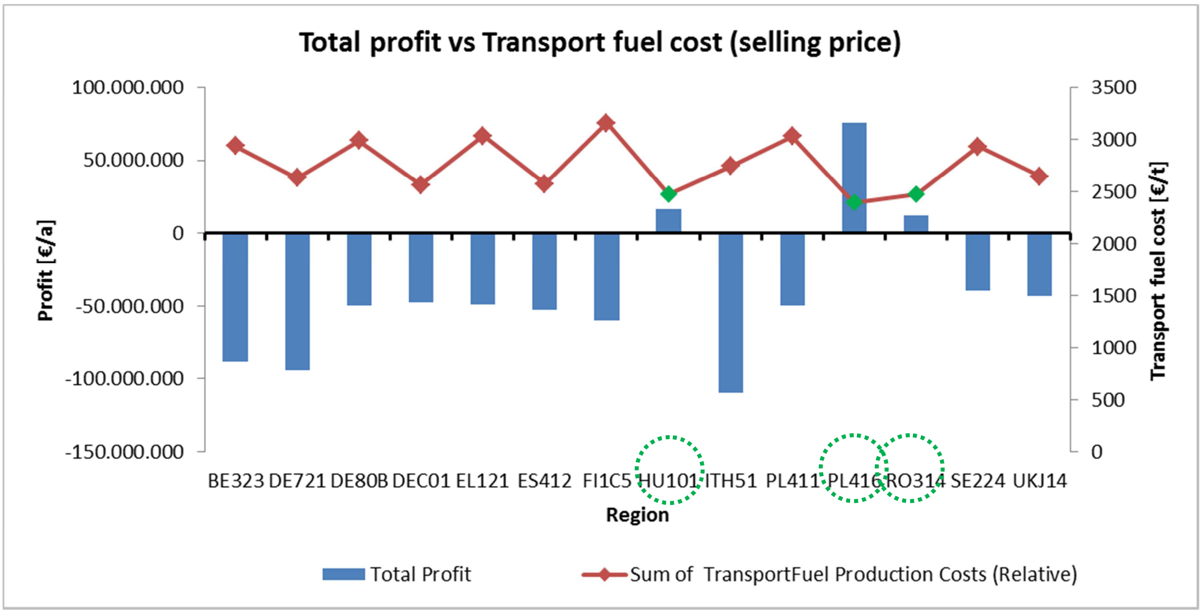


Figure 5. Biofuel production costs and annual, absolute profits per region. In Hungary, Poland and Romania are the regions with the lowest production costs.

High biofuel production costs via FP limit the optimization to find more profitable regions. The regions with the lowest production costs are in Hungary, Poland and Romania, see Figure 5. These are also the regions were profits are being made with a biofuel selling price of 2500 €/ton. From an economic perspective these are the regions where biofuel production should be first implemented.

Catalytic pyrolysis

The optimization tool has been used to determine the optimal locations for local and central conversion plants in Europe. Feedstock potentials are depicted in Figure 6a, local plant capacities and locations in Figure 6b and central plant capacities and locations in Figure 6c.

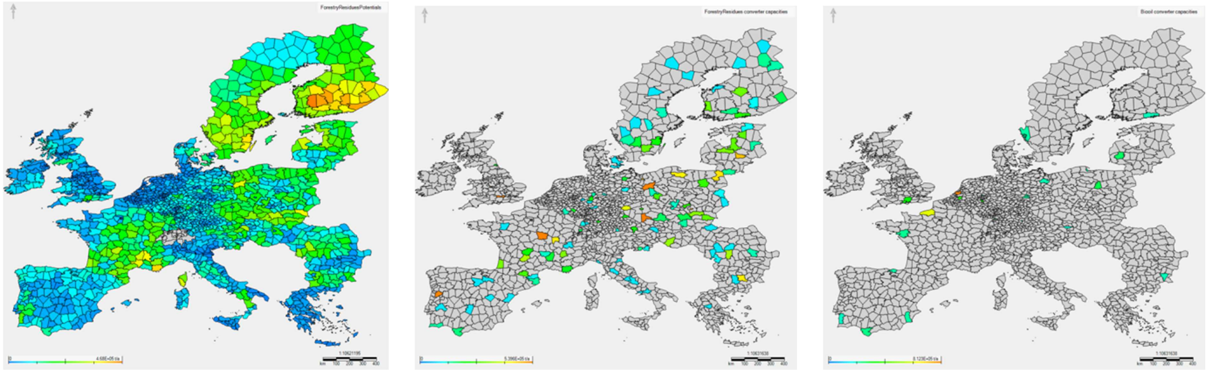


Figure 6. a) Forestry residue potentials in Europe, b) locations and capacities of local (CP) plants and c) capacities and locations of central plants in Europe. Colors indicate volumes or size of the respective parameter: red is high/large, green is medium, blue is small and grey is zero.

Simulation of EU-wide biofuel production from forestry residues returned an optimal solution in which 120 forestry residue conversion plants are constructed. The local conversion plant capacities were overall either small (< 100,000 ton/annum) or very large (> 500,000 ton/annum).

Approximately 6 times less central conversion plants are built when compared to the number of local plants. However, in contrast with the FP pathway, the capacities are in the same range. This is the results of the assumption that bio-oil conversion plants are limited by the on-site availability of hydrogen gas from existing refineries. Therefore, in this case the availability of H_2 production in existing refineries is in this case the limiting factor. The plant capacity distribution of local and central conversion plant is presented in Figure 7.

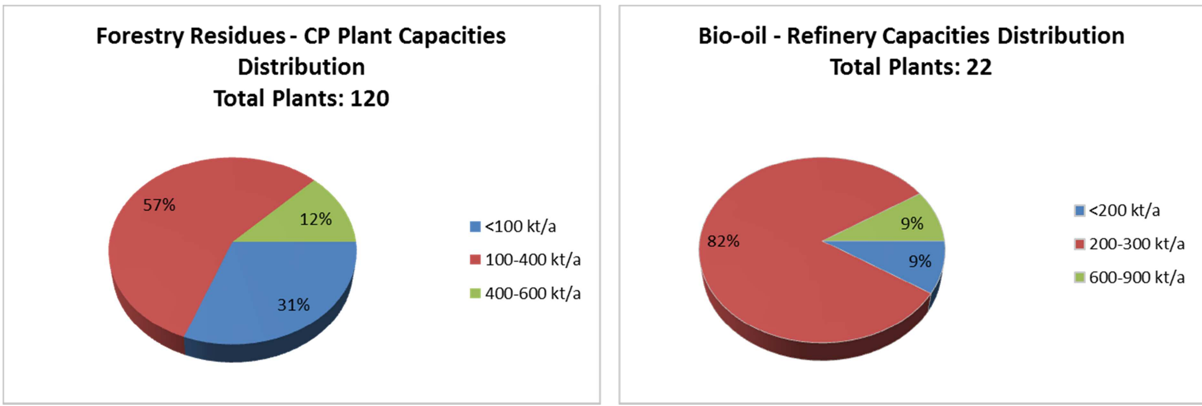


Figure 7. a) Local plant capacity distribution expressed in ton feedstock per year and b) refinery capacity distribution expressed in ton biofuel per year.

The biofuel production costs are quite comparable for all the production regions. The highest capacities can be found in France and the Netherlands, which is related to the presence of large refineries. As a result the highest absolute profit will be achieved in these countries. Existing industrial infrastructure is of great importance to the CP pathway.

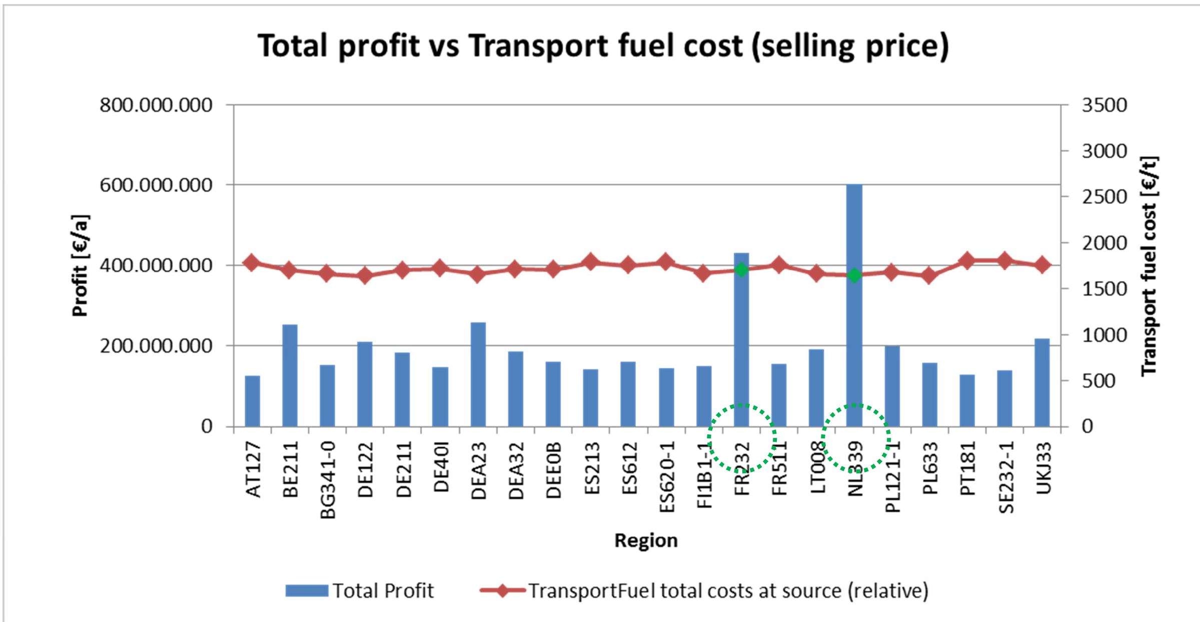


Figure 8. Biofuel production costs and annual, absolute profits per region. In France and the Netherlands the regions with the highest net profit can be found, which is related to the presence of large refineries.

4.1.3 Conclusions

- The simulation model allows to optimize for feedstock availability, price and transport distance to efficiently distribute local (FP and CP) and central (Gasification and Refinery) plants over Europe.
- Optimization of the FP pathway results in a clear local/central distribution in terms of plant numbers and capacities with around 10 FP plants per central conversion facility. In case of the CP pathway, there are approximately 6 times less central plants, but the conversion capacities are similar, which is related to limited hydrogen gas availability at existing refineries.
- For the FP pathway, biofuel production appears to be profitable in only three regions (see Figure 7). On the other hand, biofuel production via the CP pathway is more promising, since simulations show profitable production regions on the short- and mid-term.
- For FP, the regions with the lowest production costs are in Hungary, Poland and Romania. Due to the relative high contribution of transport costs to the biofuel production costs for the FP central conversion plants, production locations should be built close to feedstock production locations.
- For CP, the biofuel production costs are quite comparable for all the production regions. The highest capacities can be found in France and the Netherlands, which is related to the presence of large refineries. Existing and available industrial infrastructure is of great importance to the CP pathway.

4.2 Socio-economic and environmental impacts of EU wide implementation

4.2.1 Introduction

Socio-economic and environmental impacts of the implementation of biofuel production via the FP and CP pathway were determined based on the outcome of the techno-economic results of the EU wide simulations (section 4.1). The impacts were evaluated based on the social indicators identified by GBEP[2]. The following impacts were taken into account: change in income, number of jobs in the biobased sector and number of incidents of occupational injury.

Change in income

The change in value added due to the implementation of biofuel production is considered as an accurate and relevant indicator for the socio-economic impact, particularly if the change in distribution over countries is taken into account. The change in geographical distribution of impacts is in our opinion one of the major social aspects of introducing transitions to biobased energy systems.

Number of jobs in bioenergy sector

This indicator evaluated on the basis of statistical sector information. For Europe, we consider the change in the number jobs per member state as being particularly relevant.

Number of incidents of occupational injury

The number of fatal and non-fatal accidents is assessed on the basis of statistical sector information. These numbers are allocated to member states on the basis of sector activities in these states.

4.2.2 Fast pyrolysis

Setting

For the evaluation of the impact of the EU wide implementation of biofuel production via the FP pathway the following assumptions were made:

- The EU wide transport fuel demand is 400 Mton.
- In the EU wide implementation 5 Mton biofuel is produced via the FP pathway.
- In the EU 1.25% of fossil transport fuel is replaced by biofuel.
- 30% of the total wheat straw potential used.

[2] GBEP (2011) The global bioenergy partnership sustainability indicators for bioenergy are Change in Income

Indicators

Value added

Over the whole of Europe approximately 2.5 billion euro value added will be created. This is comparable to the value added created in the fossil fuel value chain. Most of the value added will be generated in Germany.

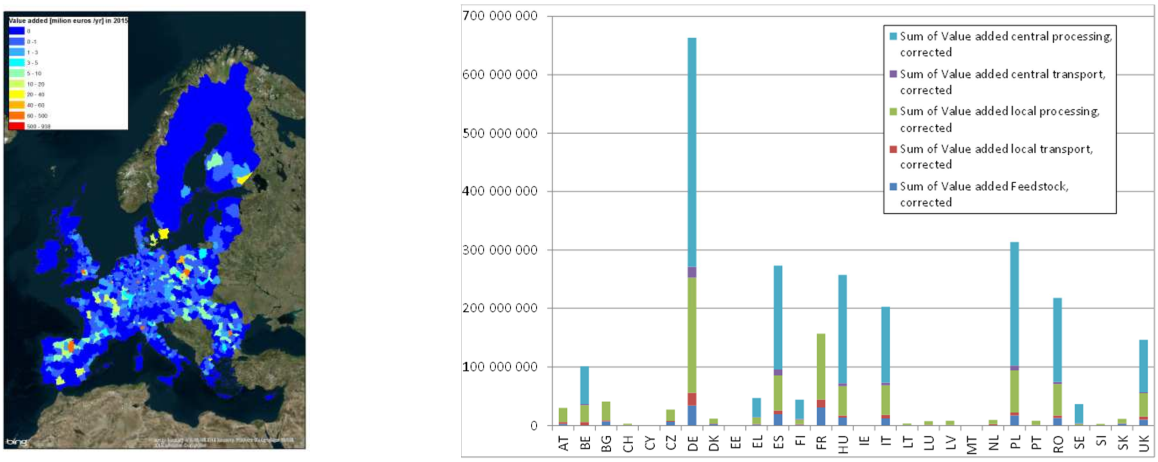


Figure 9. a) Value added for the FP pathway, presented in a map of the EU and b) per country.

Number of jobs

Upon implementation of biofuel production via the FP pathway a large number of jobs will be created in the agricultural sector, especially in the East of Europe (based on country statistics). The relatively higher number of jobs in the East of Europe is related to the more labor intensive farming practices in this region. A total of approximately 25,000 jobs will be created. Most likely, oil industry would lose jobs (but less since it is less labor intensive), this is not included in this analysis.

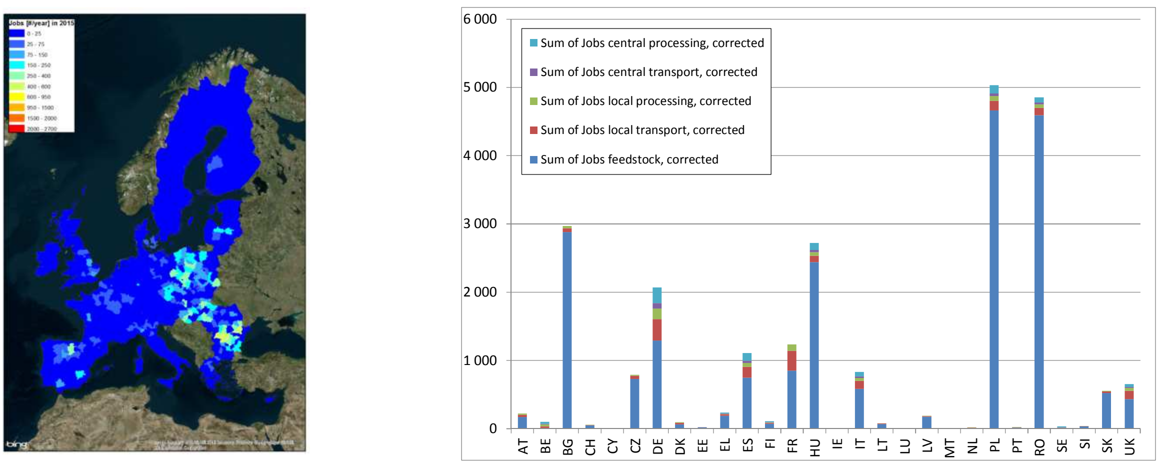
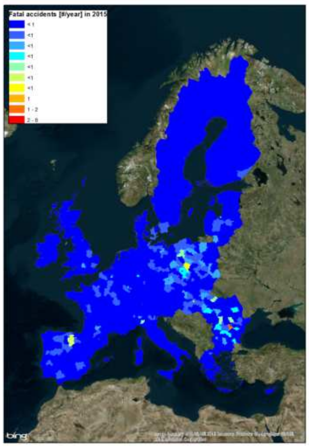


Figure 10. a) Number of jobs related to the implementation of the FP pathway presented in a map of the EU and b) per country.

Number of fatal accidents

Most fatal accidents as a result of the EU wide implementation of biofuel production via the FP pathway will occur in plants in the East of Europe. Based upon statistical information from agricultural and industrial practice, the total number of fatal accidents will add up to approximately 6 per year.



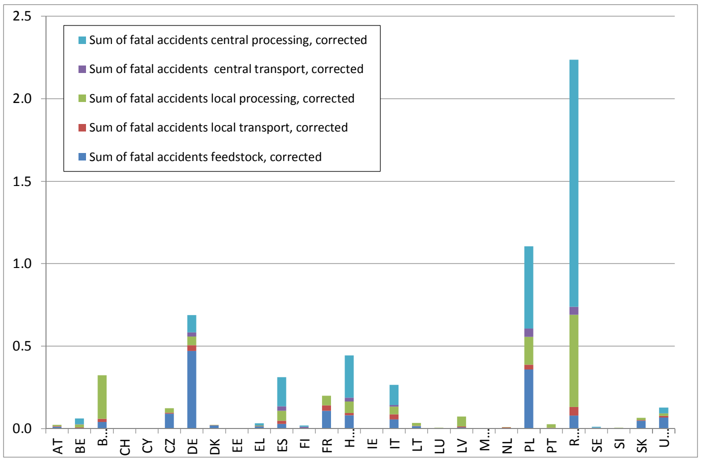
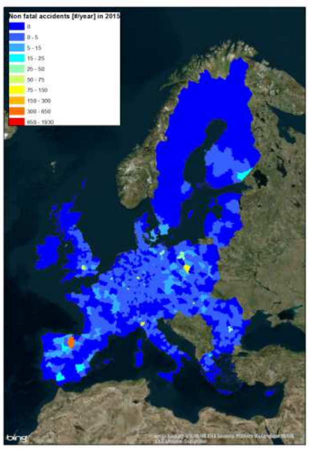


Figure 11. a) Number of fatal accidents related to the implementation of the FP pathway presented in a map of the EU and b) per country.

Number of non-fatal accidents

It is remarkable that despite the large number of jobs that are created with the implementation of biofuel production via the FP pathway, the country statistics show a low number of non-fatal accidents. This is probably due to poor quality of the statistics. In total approximately 2,500 non-fatal accidents per year are occurring due to the implementation of the biofuel production via the FP pathway.



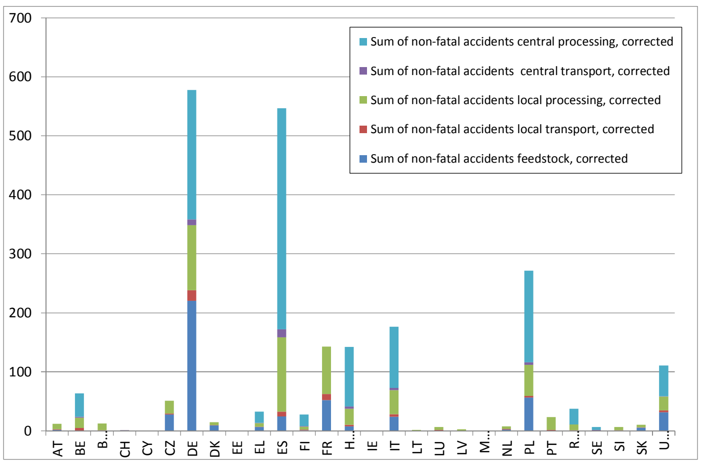
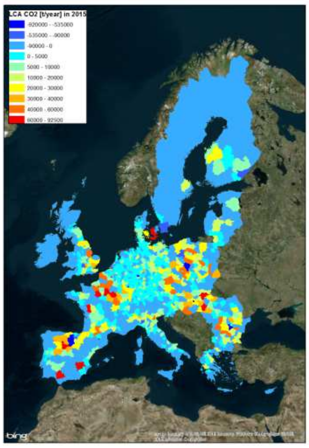


Figure 12. a) Number of non-fatal accidents related to the implementation of the FP pathway presented in a map of the EU and b) per country.

CO2 emissions

Biofuel production via the FP pathway is almost CO_2 neutral (net 0.2 Mton CO_2). The prevented emissions from fossil fuel production (2.8 Mton CO_2) and the use phase (16.6 Mton CO_2) amount 19.4 Mton CO_2, based on a production of 5 Mton biofuel. This results in a net CO_2 reduction of 19.2 Mton CO_2 (total annual EU transport emissions are in the order of 1000 Mton).



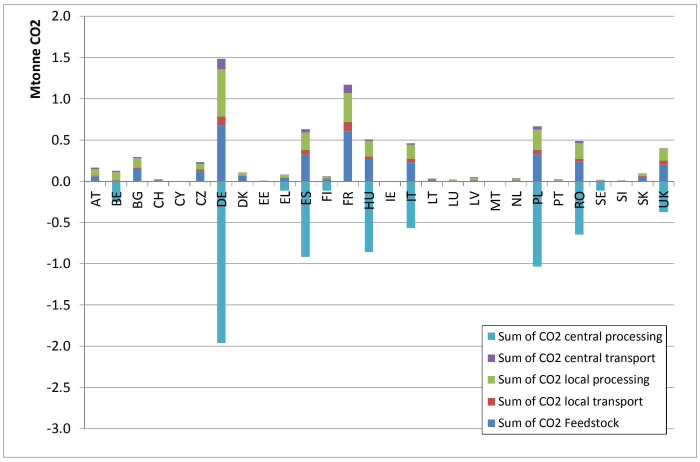


Figure 13. a) CO_2 emissions related to the implementation of the FP pathway presented in a map of the EU and b) per country.

Conclusions

- Straw utilization would generate value added and jobs
- The considerable CO_2 mitigation, emissions and reductions are unevenly distributed over the value chain and thus Europe.
- All in all, the biofuel production potential is limited with 1% fossil fuel replacement when only FP pathway on wheat straw is taken into account.
- The gasification process has a high value added and as a result a relative important share in the socio-economic indicators of the FP pathway as a whole.
- Within Europe Germany Poland and Poland are key players in the implementation of the FP pathway, followed by Spain and France.

4.2.3 Catalytic pyrolysis

Setting

For the evaluation of the impact of the EU wide implementation of biofuel via the CP pathway the following assumptions were made:

- The EU wide transport fuel demand is 400 Mton;
- In the EU wide implementation 4 Mton biofuel is produced via the CP pathway;
- In the EU 1% of fossil transport fuel is replaced by biofuel;
- 20% of the total forestry residue potential used.

Indicators

Value added

Over the whole of Europe approximately 1.5 billion euro value added will be created. This is comparable to the value added created in the fossil fuel value chain. Most of the value added will be generated in Germany.

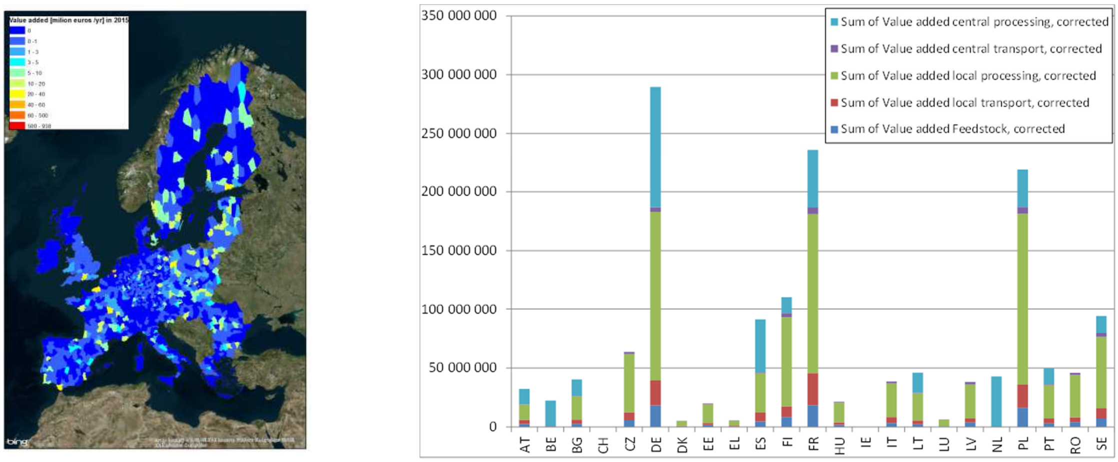


Figure 14. a) Value added for the CP pathway presented in a map of the EU and b) per country.

Number of jobs

Upon implementation of biofuel production via the CP pathway a large number of jobs will be created in the forestry sector, especially in the East of Europe (based on country statistics). The relatively high number of jobs in the East of Europe is related to the more labor intensive forestry practice relative to other regions of Europe. A total of approximately 18,000 jobs will be created. Most likely, oil industry would lose jobs (but less since it is less labor intensive), this is not included in this analysis.

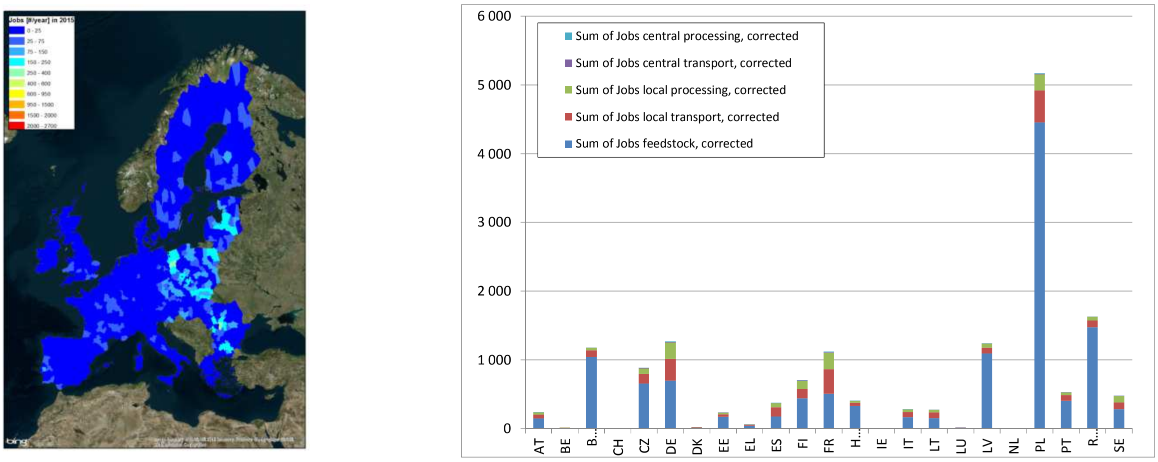


Figure 15. a) Number of jobs related to the implementation of the CP pathway presented in a map of the EU and b) per country.

Number of fatal accidents

As a result of the implementation of EU wide biofuel production via CP pathway a total number of fatal accidents will add up to approximately 4 per year. This value is based on statistical information from agricultural and industrial practice.

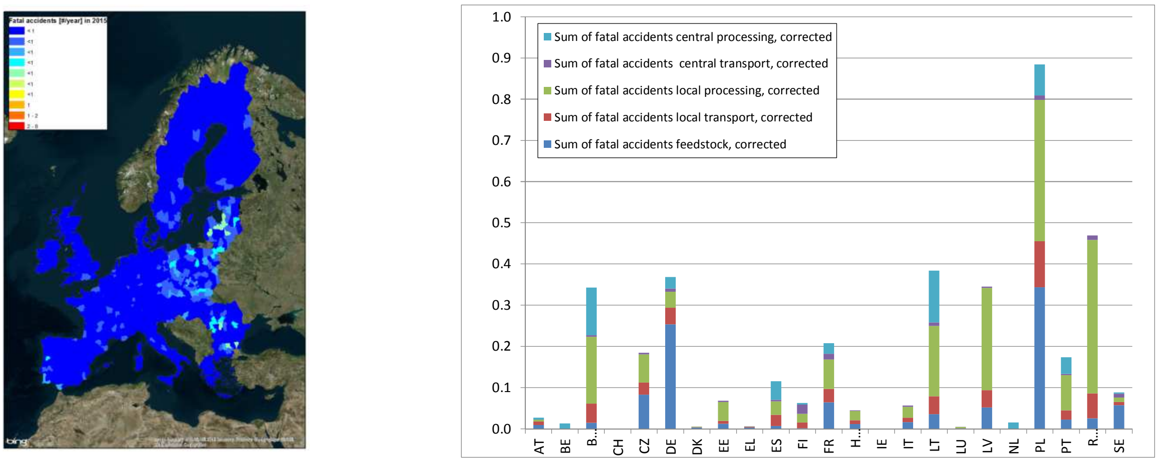


Figure 16. a) Number of fatal accidents related to the implementation of the CP pathway presented in a map of the EU and b) per country.

Number of non-fatal accidents

In total approximately 1,500 non-fatal accidents will occur per year due the implementation of EU wide biofuel production via the CP pathway.

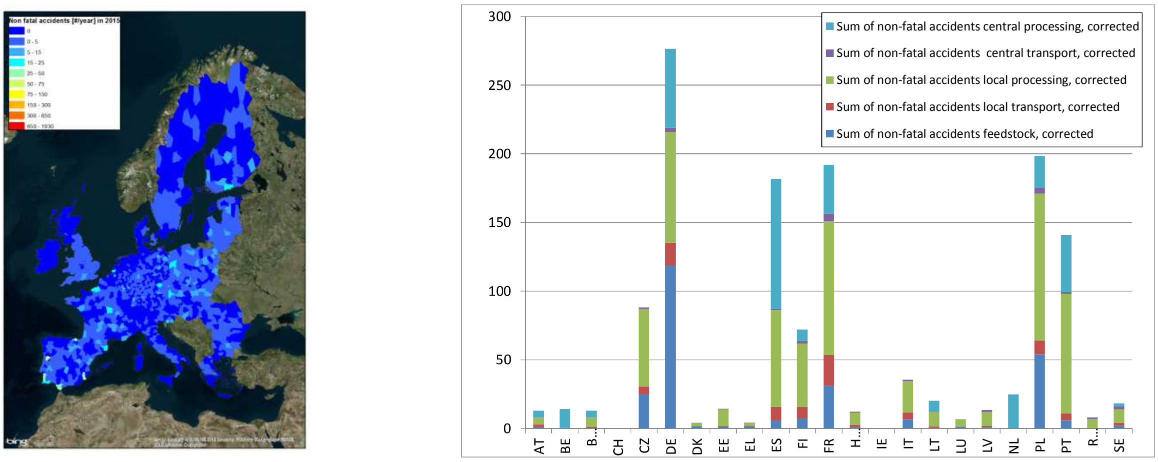


Figure 17. a) Number of non-fatal accidents related to the implementation of the CP pathway presented in a map of the EU and b) per country. `

CO2 emissions

Biofuel production via the CP pathway is almost CO_2 neutral (net 0.3 Mton CO_2). The prevented emissions from fossil fuel production (2 Mton CO_2) and the use phase (12 Mton CO_2) are 14 Mton CO_2, based on a production of 4 Mton biofuel. This results in a net CO_2 reduction of 14 Mton CO_2 (total annual EU transport emissions are in the order of 1000 Mton).

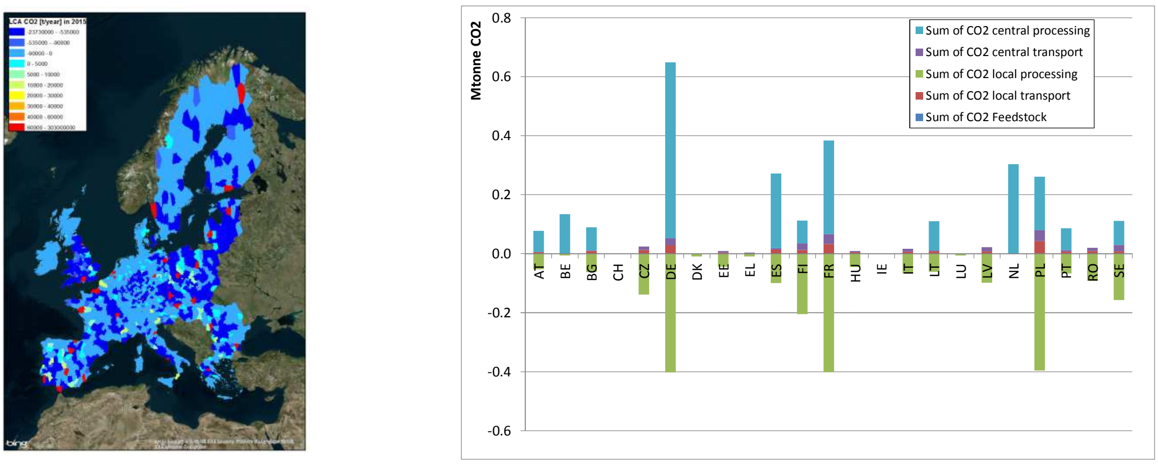


Figure 18. a) CO_2 emissions related to the implementation of the CP pathway presented in a map of the EU map and b) per country.

Conclusions

- Forestry residue utilization would generate value added and jobs.
- Considerable CO_2 mitigation, emissions and reductions are unevenly distributed over the value chain and thus Europe.
- All in all, the biofuel production potential is limited with 1% fossil fuel replacement when only the CP pathway on wheat straw is taken into account.
- The catalytic pyrolysis process has a high value added and as a result a relative important share in the socio-economic indicators of the CP pathway as a whole.
- Within Europe Germany, France, Poland and Romania are key players in the implementation of the CP pathway.

4.3 Fluctuation of market prices

4.3.1 Introduction

The impact of fluctuating energy prices on the biofuel business case has been analyzed by simulating the assumed market price trends for 2015, 2020 and 2050.

In addition, a scenario with different feedstock prices was performed for straw and forestry residue. The impact of a fluctuating feedstock price on the biomass utilization has been analyzed by simulating feedstock prices of 50%, 100% and 150% of the current feedstock prices.

Both studies were performed exemplary for France and surrounding countries (FR+) for both the FP and CP pathways.

4.3.2 Energy prices

To simulate the effect of different energy price levels European energy price projections for 2015, 2020, and 2050 were simulated in the optimization tool. The following price levels were applied: for 2020 of 104%, 114%, and 106% of the 2015 price values for respectively fuel, gas and electricity. For 2050, a similar approach was followed considering levels of 126%, 116% and 90%, for respectively fuel, gas and electricity.

The simulation was performed for both the FP and CP pathway for a region that comprised France, Spain, Portugal, Luxemburg, Belgium and The Netherlands. A minimum biofuel selling price of 1.60 €/kg was used in all simulations. The main conclusions for this scenario are:

- In general, fossil energy price fluctuations directly influence biofuel production costs via, for example, increasing transport and handling costs. In case of the CP pathway the effect of increasing fossil fuel price was reduced by optimization of forestry residue transport distance, which resulted in decreasing transport costs (Forestry Residues Transport Costs Sum, Figure 19).

- On the overall biofuel production costs the energy related costs are relatively low, while on the other hand an increase in energy market prices has an overall positive effect on the biofuel business case due to increasing biofuel selling price (Figure 19). An increase in fossil fuel market prices allows biofuels to be sold at higher selling prices without significant increase of biofuel production cost prices. This mechanism benefits the biofuel business case in the scenario of increasing energy market prices.
- In the future, when biofuel production technologies are further evolved and as a results construction and operational costs are lowered, the share of fossil energy related production costs might increase and thereby become a significant factor.

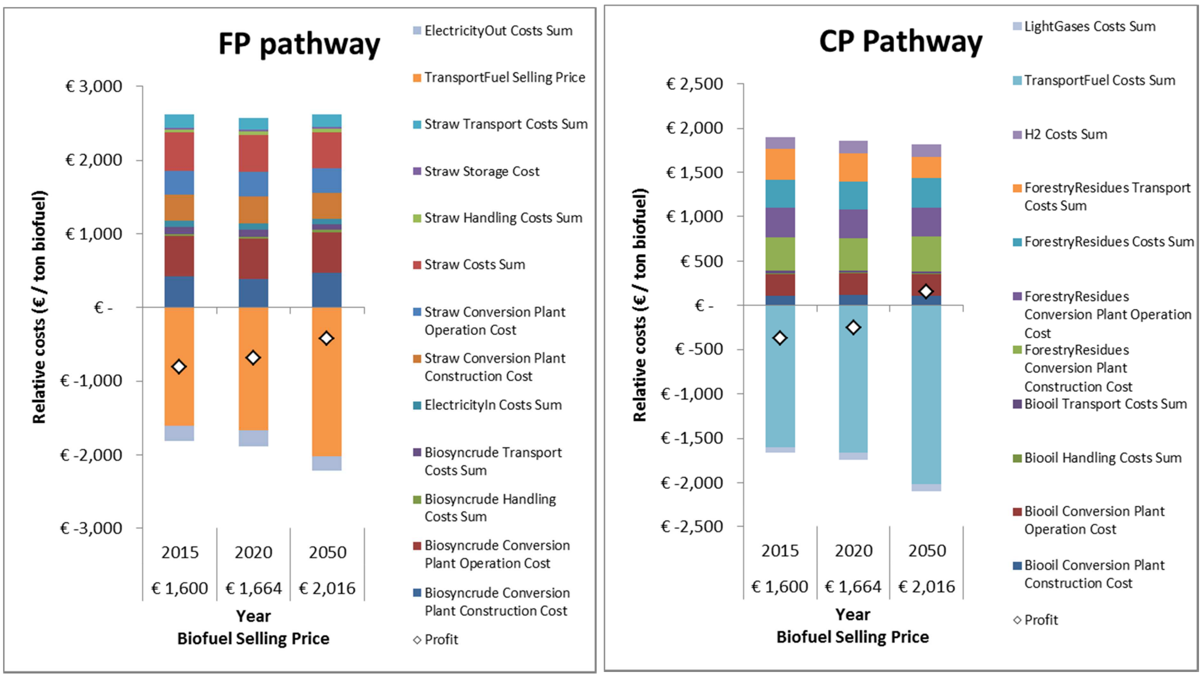


Figure 19. Overview of production costs and revenues for both the FP and CP pathway, expressed in euro per ton of biofuel produced in 2015 and projected to 2020 and 2050.

4.3.3 Feedstock prices

In the 2015 scenario (100% feedstock price) straw prices of 23-50 €/t, 46-100 €/t and 69-150 €/t and forestry residue prices of 24-60 €/t, 48-120 €/t and 72-179 €/t were applied. The effect of the different feedstock prices was studied for a region comprising France, Spain, Portugal, Luxemburg, Belgium and The Netherlands. In both cases, a minimum biofuel selling price of 2.5 €/kg was used in the simulation to allow profitable conditions. The main findings of this scenario are:

- In case of the FP pathway simulation the increasing feedstock price was tempered by reducing straw utilization. The higher the straw utilization, the higher the feedstock price and vice versa. The degree of utilization was reduced by obtaining straw from regions further away. Despite increasing transport costs, net costs were reduced as compared to the non-optimized situation.

- Also in case of the CP pathway simulation the increasing feedstock price was tempered by reducing utilization (**Error! Reference source not found.**, right). This time both the degree of utilization (feedstock price) and the transport costs were reduced by building more local plants.
- Although cost reduction by optimization of utilization can be achieved, the effect of these optimizations is not strong enough to overcome the negative effect of feedstock price increase on the overall production costs (Figure 20).
- In general, feedstock price has a significant effect on the profitability of the biofuel business case, an effect that cannot be nullified by means of logistics optimization.

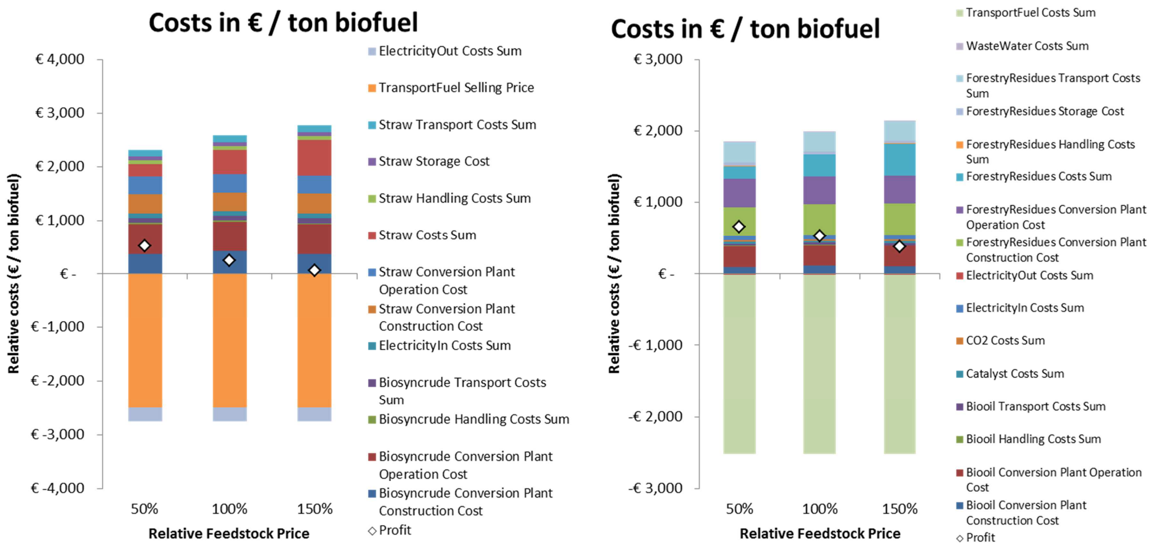


Figure 20. Overview of production costs and revenues for both the FP and CP pathway, expressed in euro per ton of biofuel produced.

4.4 Implementation region

4.4.1 Introduction

To analyze an implementation strategy from a regional and a continental perspective local and EU wide implementation was simulated for the FP and CP pathway and the outcomes compared. Three different regions were considered for implementation of biofuel production: I) Austria (AT), II) Austria as part of a region including its surrounding countries (AT+), and III) Austria as part of Europe (EU) (Figure 21). The impact on the biofuel business case in Austria was assessed. In all scenarios a biofuel selling price of 2.50 €/kg was applied.

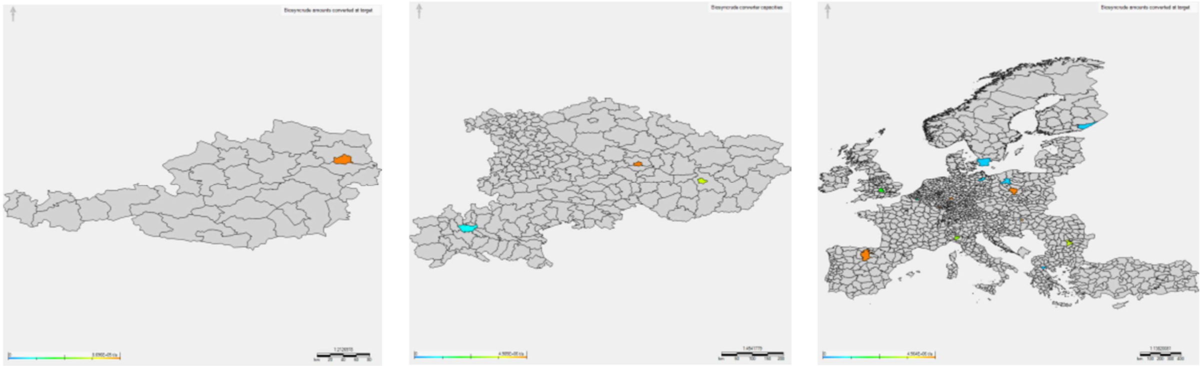


Figure 21. Distribution of central conversions plants in case of AU, AU+ and EU wide implementation of the FP pathway.

4.4.2 Fast pyrolysis

For the FP pathway simulations the main findings are:

- Biofuel production is not profitable when its implementation is limited to the borders of Austria. It is possible to convert straw to biofuel by building three FP plants and one gasification plant, but no profit will be generated under the assumptions that are made. This is mainly due to the mismatch between the capacities of local and central plants.
- When an implementation region of Austria including surrounding countries is applied in the simulation, a profit is generated. In- and export of feedstock and (intermediate) products takes place, resulting in the construction of 5 FP plants and 1 gasification plant with 5x the size of the one built for Austria alone.
- However, when EU wide implementation is simulated, no gasification plants are built in Austria.

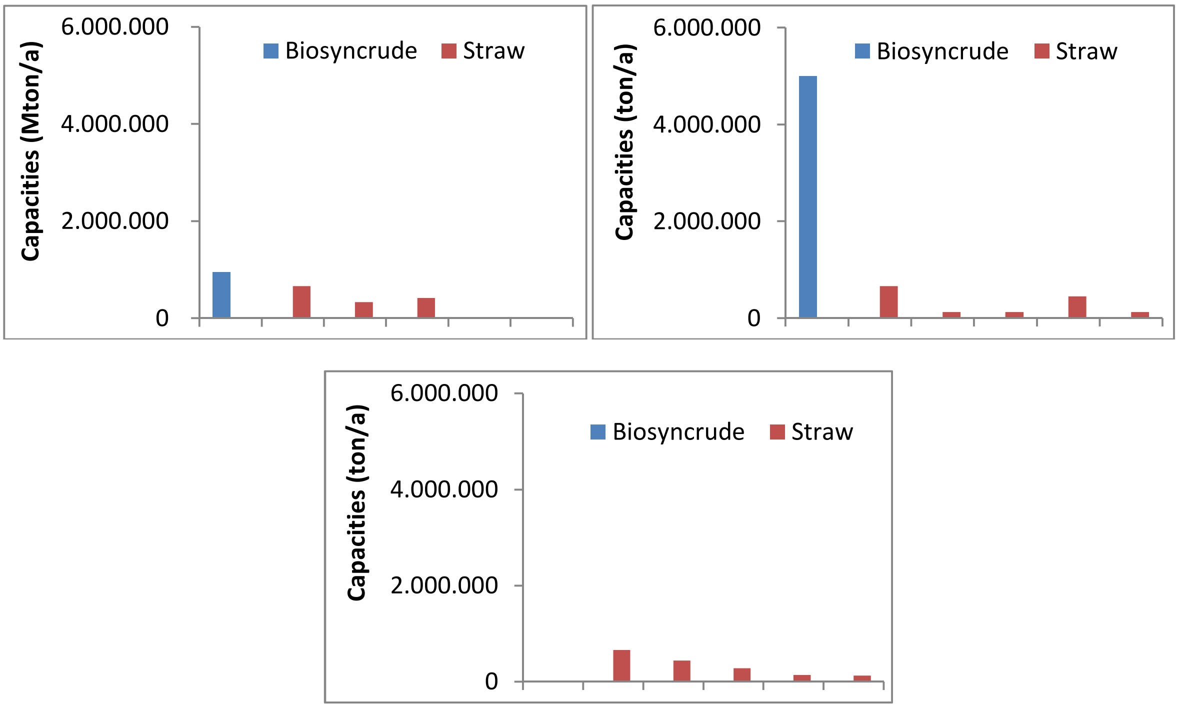


Figure 22. Capacities of local and central conversion plants in the county Austria for a) AU case, b) AU+ case and c) EU case, where no biofuel production facility in located in Austria.

4.4.3 Catalytic pyrolysis

For the CP pathway simulations the main findings are:

- In case of the CP pathway, simulation of all implementation region sizes resulted in the construction of profitable central conversion plants in Austria.
- With expansion of the implementation region the biofuel production costs are significantly reduced for the central conversion plant constructed in Austria (Figure 23).

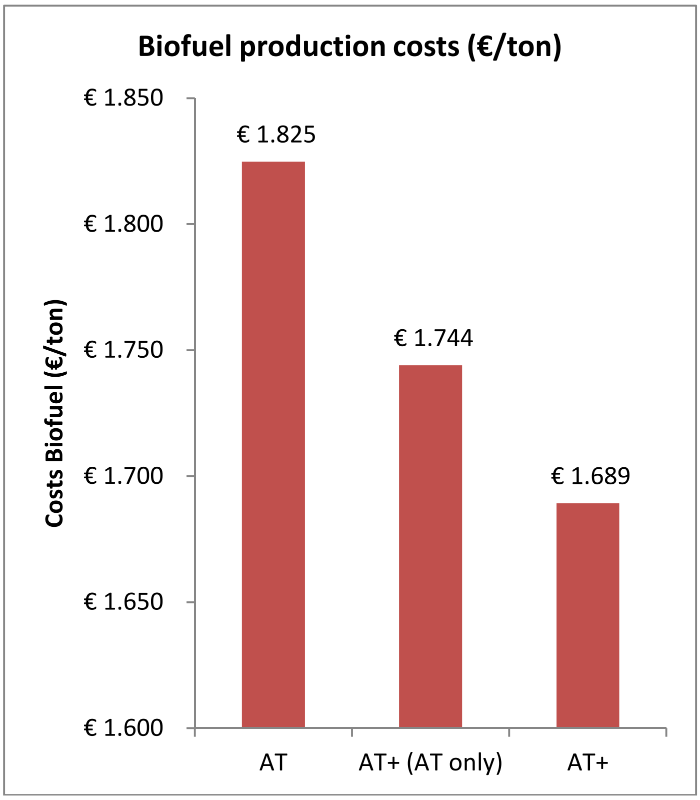


Figure 23. Biofuel production costs €/ton, for the implementation regions AU, AU+ and EU wide implementation. The biofuel production costs decrease with increasing implantation region size.

4.4.4 Conclusions

In general, it can be concluded that optimization of logistics should be optimized between neighboring country states and under some conditions it might be beneficial to optimize continentally. Generation of value and economic growth has to be sought from a European perspective to gain the most value out of residual biomass.

5 Conclusions

5.1 Logistics optimization model

- The logistics model is a valuable tool to optimize different biofuel implementation scenarios and to investigate and visualize the influence of relevand impact parameters on the simulation outcome.
- The Logistics model can be used as business decision supportive tool to identify suitable implementation regions. However, much more detailed information of the local conditions is required for a reliable business decision.

5.2 Techno-economic impacts

- All in all, the produced biofuel volumes are limited with 2% of the transportation fuel demand in EU, when taking both the fast pyrolysis (straw) and catalytic pyrolysis (forestry residues) pathways into account.
- The regions with the highest straw production can be found in France, Spain and in the East of Europe in general, while the regions with the highest forestry residue production can be found in the Scandinavian countries, the East of Europe and France.
- Optimization of the FP pathway results in a clear local/central distribution in terms of plant numbers and capacities with around 10 FP plants per central conversion facility. In case of the CP pathway, there are approximately 6 times less central plants, but the conversion capacities are similar, which is related to limited hydrogen gas availability at existing refineries.

5.3 Socio-economic and environmental impacts

- The biobased feedstock production related to biofuel production would generate value added and jobs.
- Considerable CO_2 mitigation, emissions and reductions are unevenly distributed over the value chain and thus Europe.
- In the fast pyrolysis pathway most value added is generated in the centralized gasification process, while in the catalytic pyrolysis pathway most value added is generated locally in the catalytic pyrolysis process. Both these steps have a significant share in the socio-economic indicators of the total pathways.
- Germany, Poland and Romania are key players in the implementation of the fast pyrolysis pathway, followed by Spain and France. Again Germany, Poland, Romania and France are key players in the implementation of the catalytic pyrolysis pathway.

5.4 Market prices

- In general, fossil energy price fluctuations directly influence biofuel production costs via, for example, increasing transport and handling costs. In case of the catalytic pyrolysis pathway the effect of increasing fossil fuel prices can be reduced by optimization of forestry residue transport distance, which results in decreasing transport costs.
- An increase in fossil fuel market prices allows biofuels to be sold at higher selling prices without significant increase of biofuel production cost prices. This mechanism benefits the biofuel business case in the scenario of increasing energy market prices.
- In the future, when biofuel production technologies are further evolved and construction and operational costs are reduced, the share of fossil energy related production costs might increase and thereby become relatively more significant.
- For both pathways, the effect of increasing feedstock prices can be tempered by optimization of feedstock utilization. While the net costs are reduced as compared to the non-optimized situation, optimization cannot nullify the negative effect of feedstock price increase on the overall production costs.
- In general, feedstock price has a significant effect on the profitability of the biofuel business case, an effect that cannot be nullified by means of logistics optimization.

5.5 Implementation region

- When an implementation region is relatively small, there is no balance between feedstock availability and optimal plant size, which results in relatively high production costs. Especially the FP pathway is affected by this mechanism.
- In general, with increasing region size the effect of logistics optimization becomes more significant due to the higher degree of freedom.

6 Recommendations

For the mid and long term utilization and valorization of residual biomass one has to consider a dynamic economic environment with high feedstock demand and fluctuating feedstock prices. Under these conditions logistic optimization is necessary.

The conclusions in the Market Implementation Plan have been based on simulations with the logistics optimization model. In some cases the available data was limited and therefore assumptions had to be made, e.g. by taking averages or using approximations. Any business or investment decision should be based on recent local data.

Biofuel produced from residual biomass is an alternative, carbon neutral energy source. However, to accomplish economically feasible, non-subsidized biofuel production from residual biomass an integrated production process in which higher value co-products are produced is required.

EU wide implementation of biofuel production from residual biomass would not only bring environmental benefits through CO_2 mitigation, but would also bring positive socio-economic effects through creation of jobs in the agricultural, transport and energy sectors. These jobs create economic growth and social wealth.

The logistics optimization tool created within Bioboost would be very suitable to investigate the techno- and socio-economic and environmental impacts and mechanism behind the implementation of other biobased technologies such as the production of biobased plastics.