www.BioBoost.eu

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

Energy Carrier online tool

Workpackage:	WP7
Deliverable Nº:	D7.2
Due date of deliverable:	31/12/14
Actual date of delivery:	11/09/15
Version:	v.1.2
Responsible:	SYNCOM
Authors:	Simon Kühner
Contact:	s.kuehner@syn-com.com
Dissemination level:	PU-Public
Nature:	Other

Table of Content

Inhalt

1. Introduction

The Energy Carrier Online Tool (BioBoost Navigator) is a mean of dissemination to spread the project results on e.g. the conversion technologies, the energy carriers and their utilisation, the residue biomass pathways and especially their eventual implementation in Europe to stakeholders, scientists and citizens.

This information gateway leads to the results of the dynamic logistic/economic optimisation model, which is at the core of the Navigator as it interprets and projects the BioBoost results to Europe: A transportation network is established between biomass collection areas for different feedstocks, decentralised conversion plants and central upgrading or utilization facilities. The output of the pathways is then optimised in terms of amount and return on invest. The user finds summarised information about the pathways (with links to the respective deliverables for further details) and key results like plant capacities, costs of the single steps of the considered pathway and the total production costs and capacities. The results are generated by an heuristic algorithm and thus approximations to the one and only optimal solution. Displayed are the results of the best of three parallel runs.

It is not possible to run the optimisation model online, because a typical desktop-PC achieves about 80,000 calculation cycles per day of an EU-wide optimisation problem but a rough optimisation over the whole EU needs about 300,000 generations, for good results even 1.5 million generations are required. Thus, a set of optimisation runs was prepared from which the data to be displayed will be selected according to the interests of the online user. The variables are:

- Technology pathway:
  - FP/straw/synthetic transport fuel
  - CP/forest residues/refinery upgrading to transport fuel
  - HTC/organic waste/heat&power
- Biomass feedstock provision: EU-28 or one of 7 regions
- Biomass feedstock price: low, medium or high
- Implementation phase: Early (first plants), medium, broad (conversion of a high share of the available biomass)

The Navigator is accessible via the project homepage. The entry page is a quick guide on the operation of the navigator under
http://www.bioboost.eu/results/bioboost_navigator.php

2. Conversion pathways

Information displayed in the Navigator:
The following paragraphs show some text to explain the available pathways to the online user; he can select biomass price and implementation phase for each of them. The pathways are denoted by the feedstock used, the conversion technology applied and the product obtained. These texts were edited from deliverables and presentations of the BioBoost project.

2.1 Pathway 1/3 in biomass and conversion technology: Straw-Fast Pyrolysis-synthetic transportation fuel

This pathway is based on bioliq-technology developed by the KIT (Karlsruhe Institute for Technology). Detailed information available under www.bioliq.de

Straw
Straw is a residue from the harvest of cereals as e.g. wheat, barley or rye. Depending on the soil demand for organic carbon and other agricultural uses, the surplus straw can be used as feedstock for bioenergy generation. An efficient supply chain is based on large square bales of high density, collected in field-side stacks for truck transport. These bales have a density of about 200 kg/m^3 and enable to use the full payload of 120 m^3-large volume trucks.

Fast Pyrolysis
For Fast Pyrolysis (FP) straw is milled and pyrolysed at about 500 °C in the absence of oxygen. The biomass vapours formed are cooled down rapidly and mixed with the milled char to a pump- and transportable 'biosyncrude', the energy carrier. The non-condensable gases are used to fire the pyrolysis reactor. 1500 kg straw is converted to 1000 kg biosyncrude, which contains 85% of the straw energy. The FP plants are expected to have a capacity of 200,000 to 660,000 tonnes straw per year which relates to 28 to 82 truck loads per day. In regions of good straw availability transport distances would be between 50 and 100 km. Biomass from landscape management, lignocellulosic energy crops (e.g. Miscanthus, Switchgrass) or waste wood are alternative feedstocks for this process. Use of these biomasses as co-feedstock would shorten the average transport distance. The decentralised FP plant produces between 145,000 and 435,000 tonnes biosyncrude per year. The energy carrier has a heating value of 18 to 20 GJ/t.

Biosyncrude energy carrier transport
With regard to transportability, a truck load of 20 to 24 tonnes of straw in large square bales has a volume of 120 m^3 and would be converted to about 15 m^3 of a pumpable energy carrier. A freight train of 40 railway tank wagons with a payload of 65 tonnes each could transport the energy carrier produced from 170 truck loads straw. This is a very cost- and environmental efficient transport mean to bring the bioenergy from several rural areas to a central, industrial site for upgrading. The transportation vessels require corrosion resistant properties.

Upgrading to transportation fuel
The good transportability of the biosyncrude enables long distance railway transport of the output of 5 to 10 straw pyrolysis plants to a large synfuel plant. These are expected to have a feedstock demand between 1.3 and 4 million tonnes of biosyncrude, which relates to a thermal fuel capacity between 800 MW to 2.5 GW. The energy carrier is gasified at high pressure and temperatures of higher than 1200 °C to hydrogen and carbon monoxide for the production of transportation fuels via Methanol-to-Gasoline- or Fischer-Tropsch-synthesis. Both fuels purely consist of hydrocarbons, which guarantee drop-in blending. The fuels are

fully engine compatible and do not require changes in the distribution infrastructure, two points very important for consumer acceptance. Renewable power is a co-product, there are 2.5 MWh produced per tonne of transportation fuel which is by energy about 6 %. The transport fuels have a GHG-avoidance potential of 81 % compared to fossil fuels.

Figure 1: The bioliq pilot plant at the KIT in Karlsruhe, Germany, has a straw pyrolysis unit of 500 kg/h (2 MW) with bioslurry preparation, an high pressure, entrained flow gasifier with a capacity of 1 t/h bioslurry (5 MW) with hot gas cleaning and fuel synthesis unit operating at 55 bar.

2.2 Pathway 2/3 in biomass and conversion technology: Forestry residues-Catalytic Fast Pyrolysis-transportation fuels

This pathway is based on CatOil-technology developed by the CERTH (Center for Research and Technology Hellas), Royal DSM and Neste. Detailed information available under http://www.bioboost.eu/results/public_results.php

Forestry residues

Forestry residues are co-products of forest cultivation and wood harvest: Thinning wood occurs as whole tree or delimbed stems in the thinning of young stands: Final felling yields logs for the production of timber, wood pulp or boards; co-products are tree-tops, branches and off-spec logs (bent or rotten). In some countries stump excavation is allowed to prepare the ground for tree planting. Depending on the site conditions, soil fertility or ash return a certain share of forest residues can be taken from the forest without threatening its productivity. This sustainable amount is collected and stored at the forest road for chipping on trucks or transport in whole for chipping at the plant. Depending on site and duration of storage, the water content of forestry residues is between 30 and 50 %. The maximum allowable weight of forest trucks is between 40 and 76 tonnes in European countries.

Catalytic fast Pyrolysis

The Catalytic fast Pyrolysis (CFP) starts with the drying and milling of forestry residues (e.g. thinning wood, tree-tops, branches). The biomass is pyrolysed at about 500 °C in absence of oxygen in contact to a catalytic material. The catalyst splits off a high share of the oxygen which is contained in the biomass molecules (about 45 % by weight) as carbon dioxide, carbon monoxide or water. The pyrolysis vapours are rapidly cooled. The condensed biooil contains 50 % of the liquid biomass energy, is low in oxygen content (15 to 20 %) and has a heating value of about 30 GJ/t. CFP off-gases and the catalyst coke are combusted to supply the reaction heat for pyrolysis and produce power (0.83 MWh per tonne of biooil). Another co-product is crude acetic acid of which about 50 kg are produced per tonne of energy carrier. The decentralised CFP plants are erected in areas of high feedstock availability: They are expected to have a capacity of 160,000 to 520,000 tonnes forest residue dry matter per year which relates to 28 to 92 truck loads per day. In regions of good availability transport distances would be between 60 and 120 km. Straw, lignocellulosic energy crops (e.g. Miscanthus, Switchgrass) or waste wood are alternative feedstocks for this process. Use of these biomasses as co-feedstock would shorten the average transport distance. The decentral CFP plant produces between 45,000 and 147,000 tonnes biooil per year.

Biooil energy carrier transport
With regard to transportability, a truck load of 25 tonnes forest residue chips (14 to 17 tonnes wood dry matter, rest is water) is converted to 4 to 5 m^3 of a pumpable energy carrier. A freight train of 40 railway tank wagons with a payload of 65 tonnes each could transport the energy carrier produced from 570 truck loads forest residues. This is a very cost- and environmental efficient transport mean to bring the bioenergy from several rural areas to a central refinery for upgrading by co-processing with crude oil. The energy carrier is moderately corrosive and compatible to crude oil transport and storage vessels.

Upgrading to transportation fuels
The good transportability of the energy carrier enables long distance railway transport for upgrading in refineries with capacities between 50,000 and 850,000 tonnes of biooil in European countries. The energy carrier is stabilized in two hydrotreatment steps consuming about 70 kg hydrogen per tonne of transportation fuel. One co-product are light gases (180 kg per tonne fuel) another might be phenol(-ics) which have a higher market value for the chemical industry than for biofuel production. Due to changes in the European refining sector it is expected that the CP biooil may replace 2 % of fossil crude. This enables use of existing capacity for steam methane reforming and hydrotreatment for the deoxygenation of the biooil. The product is co-processed with the fossil streams and distilled to the conventional transportation fuels gasoline/kerosene/diesel according to the production slate of the refinery. All fuels purely consist of hydrocarbons which guarantee drop-in blending. The fuels are fully engine compatible and do not require changes in the distribution infrastructure, two points very important for consumer acceptance. The fuels have a GHG-avoidance potential of 81 % compared to fossil fuels.

2.3 Pathway 3/3 in biomass and conversion technology Organic municipal waste-Hydrothermal Carbonisation-heat&power

This pathway is based on technology developed by the AVA-CO2. Detailed information available under www.ava-co2.com.

Organic municipal waste
Organic municipal waste contains matter from kitchens and gardening and is collected from households or enterprises either in individual bins (source separated) or together with other waste and then separated at the waste yard. Depending on the composition it has a water content between 60 and 70 % and about 15 % ash related to dry matter. As landfilling of waste containing organic carbon was prohibited in Europe it has to be treated by e.g.

incineration, anaerobic digestion or composting. For bioenergy generation non-biogenic matter has to be removed.

Hydrothermal Carbonisation (HTC)

Hydrothermal Carbonisation starts with organic municipal waste received from a waste separation unit. The separated, wet organic matter is minced and heated with steam to about 180 to 250 °C under corresponding vapor pressure of around 10 bar. The process medium is liquid water allowing wet biomass as feedstock, which is converted to HTC biocoal by elimination of chemically bonded water from carbohydrates (dehydratisation). After several hours the pressure is released in an expansion vessel leading to a separation of wet biocoal and steam. The steam is used to start the exothermal reaction in the next reactor as the semi-continuous plant is operated in a multi-batch concept. It consists mainly of a biomass feeder, 7 HTC reactors and one expansion vessel. During HTC all soluble salts e.g. of potassium and chloride are solved and found to a high share in aqueous solution after the reaction. This lowers the potassium content of HTC coal which increases the ash melting temperatures from about 700 °C to 1200 °C for straw or organic waste based biocoal. Low K^+ and Cl^- content allow combustion of non-wood biomass in power plants because slagging and corrosion problems are avoided. The wet biocoal can be filter-pressed to a water content of 50 to 60 %. The HTC process has an energetic conversion efficiency of 75 % from organic waste to biocoal.

The HTC plants are expected to be operated on the waste yard, so there is no additional waste truck transport. The capacity will be between 40,000 and 480,000 t/a wet organic municipal waste and the rated firing power of the HTC plant is accordingly between 9 and 105 MW organic municipal waste. The energy carrier output is between 8,400 and 100,000 tonnes biocoal dry matter per year.

Figure 2: The world-wide first HTC-plant with commercial-scale reactors at AVA-CO2 with a nameplate capacity of 8400 t/a biomass residues from breweries, municipalities and agriculture.

HTC coal energy carrier transport and utilisation
If dried, biocoal has self-flammable properties and is categorised as hazardous material (ADR 4.2). At a water content of about 40 % it can be transported like ordinary waste material. Regarding improvement of transportability 2.8 tonnes wet organic waste are converted to 1 tonne of biocoal (at 60 % dry matter) which is a significant reduction of transport efforts. HTC coal has properties like lignite and can substitute brown coal (lignite), municipal waste or wood in respective heat & power plants.

3 Geographic area

The user can select between the EU-28 and 7 regions. The areas were composed on base of clustering results.

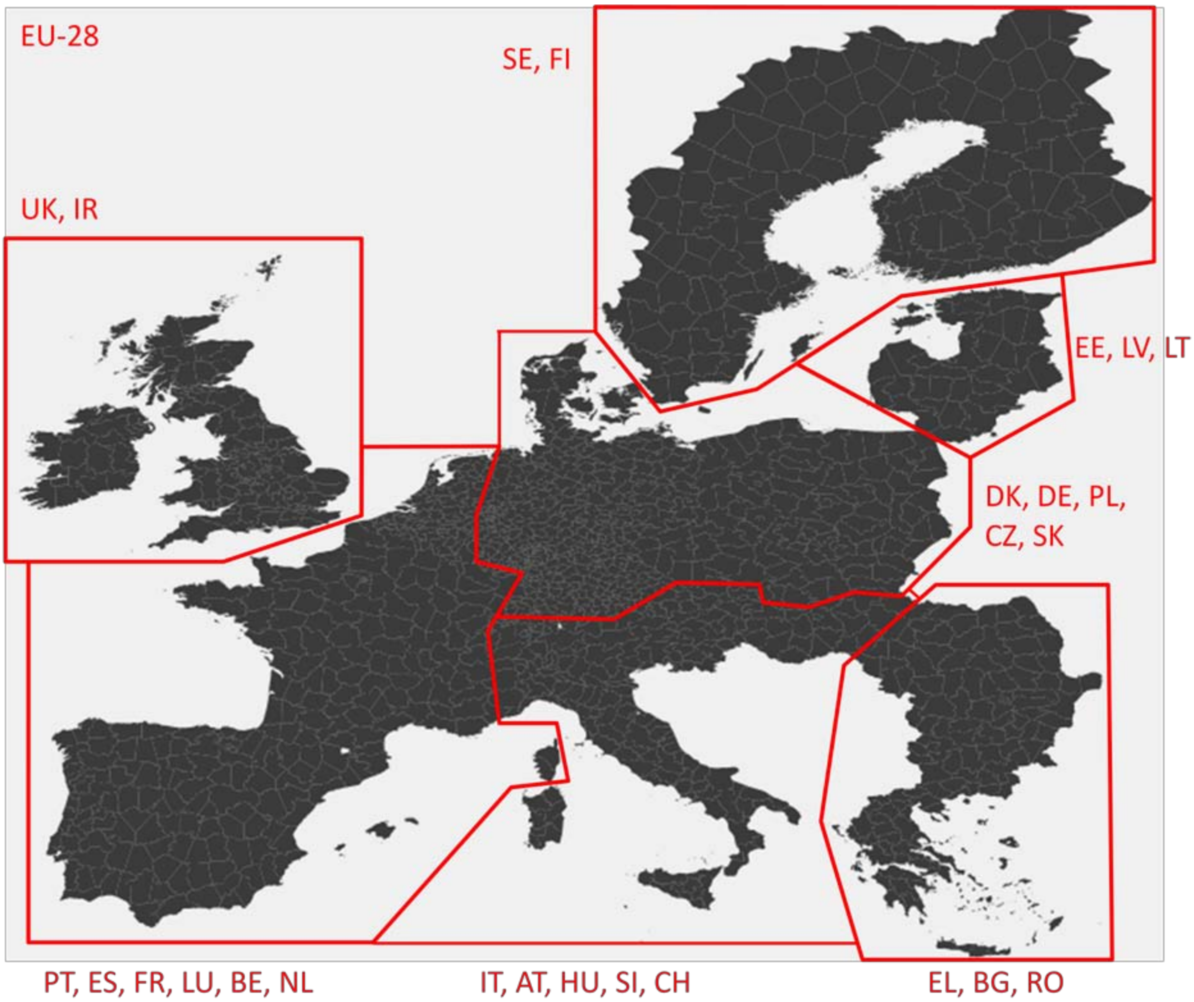

Figure 3: Selectable geographic areas.

4. Biomass feedstock price

Three different price levels can be selected by the online user. Compared to the default values (middle) these are 25 % lower or 50 % higher. The optimisation model operates with feedstock prices, which depend on the degree of utilization (sourcing ratio) as the price of a commodity depends on offer and demand in a free market. Facilities with a feedstock demand in the range of tens to hundreds of thousand tonnes biomass are expected to change established offer/demand ratios (and thus the price) considerably. For feedstock sourcing between 0 and 50 % (x-axis) a single price (y-axis) is assumed, which increases with higher utilization rates as shown in the figure below for the European average.

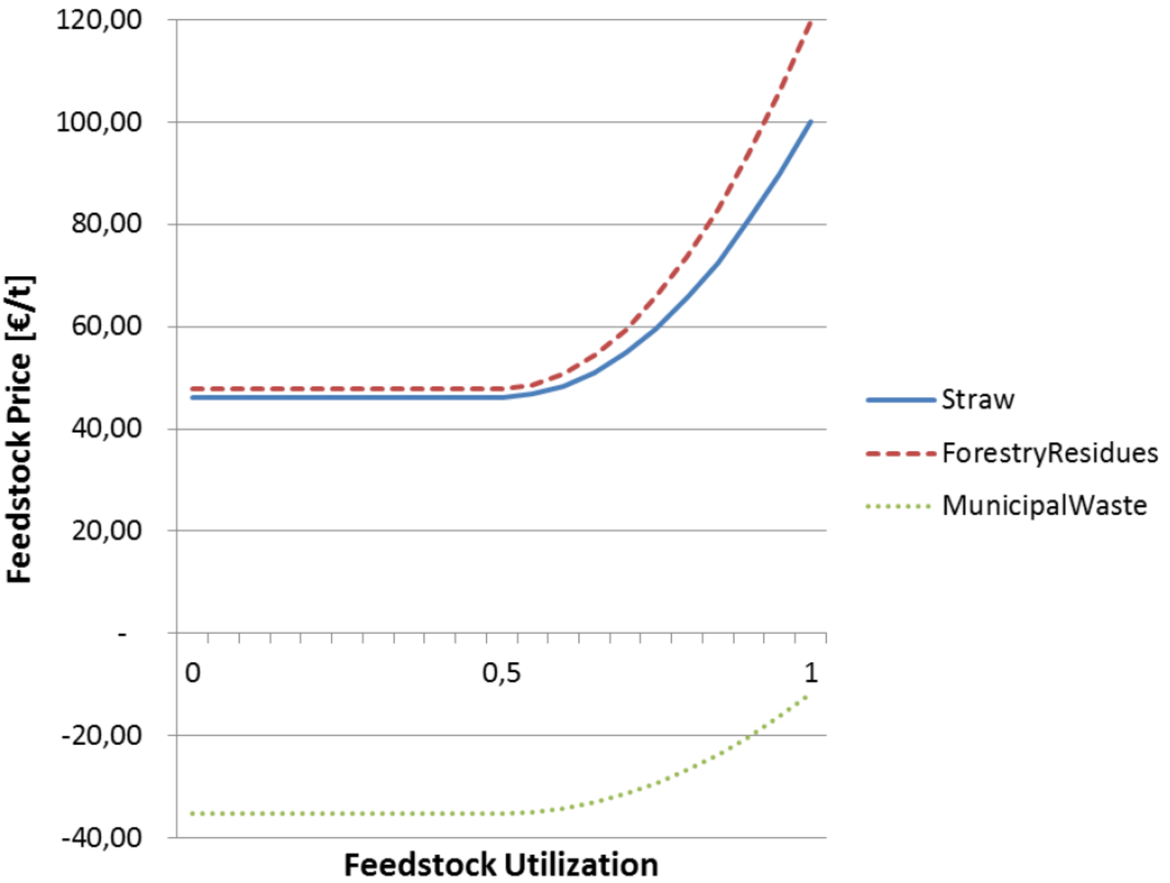

Figure 4: The feedstock prices (y-axis) depend on degree of utilization (x-axis). Increasing prices were assumed, if more than 50% of the available residue and waste feedstock is marketed.

5. Implementation phase

Three different implementation phases can be selected:

- First plants: Every commercial implementation starts with the first plants located at the best sites. The produced amount of biofuel is low but the specific production costs are favorable.
- Medium implementation: With progressing implementation, all good sites are occupied and the competition for biomass feedstock increases. The biofuel production capacity increases significantly. Efficiency gains due to learning curve effects are not reflected here for sake of transparency.
- Broad implementation: In this final stage a high share of the biomass feedstock available for bioenergy generation is used also in less competitive areas. This significantly increases the production costs, but relatively large amounts are produced.

6. Explanation on layers at the example of the CP-pathway

Forestry residue potential: (Csv-name: ForestryResiduesPotentials) Amount of forestry residues like tree-tops, branches and thinning wood, which is technically available e.g. for bioenergy applications. Given in tonnes per area.

Forestry residue price: (Csv-name: ForestryResidues total costs at source (relative)). Average price of forestry residues as feedstock for energy carrier production in this optimisation. The price reflects the degree of utilization in this optimisation run acknowledging the influence of feedstock competition. Given in EUR per tonne forestry residues normed to a water content of 8 %.

Forestry residue utilisation rate (csv-name: ForestryResidues utilizations (effective)): Share of technically available forestry residues purchased as feedstock in this optimisation run. Given in % of the forestry residue potential.

CP-plant capacity (Csv-name: ForestryResidues converter capacities) Feedstock conversion capacity of the Catalytic Pyrolysis plant. Given in tonnes forestry residues per year (normed to 8 % water content)

Biooil upgrading capacity (csv: Biooil converter capacities) Capacity for the upgrading of the energy carrier biooil in the refinery. Given in tonnes biooil per year.

Feedstock purchase costs (csv TransportFuel feedstock costs (relative)): Costs for the purchase of forestry residues. Given in EUR per 5.6 tonnes forestry residues (normed to 8 % water content), which is the amount required for the production of 1 tonne transportation fuel.

Forestry residue logistic costs (TransportFuel logistic costs (decentral aggregated, relative)): Costs for transport, handling and storage of forestry residues to the catalytic pyrolysis plant. Given in EUR per 5.6 tonnes forestry residues (normed to 8 % water content), which is the amount required for the production of 1 tonne transportation fuel.

Catalytic pyrolysis costs (Csv: TransportFuel conversion costs (decentral aggregated, relative)) Costs for the conversion of forestry residues to the energy carrier biooil in the catalytic pyrolysis plant, feedstock provision costs excluded. The costs are given in EUR per 1.45 tonnes biooil, which is the amount required for the production of 1 tonne transportation fuel.

Energy carrier logistic costs (csv: TransportFuel logistic costs (central aggregated, relative)): Costs for transport and handling of the biooil from the decentralised Catalytic Pyrolysis plant to the refinery. Given in EUR per 1.45 tonnes energy carrier, which is the amount required for the production of 1 tonne transportation fuel.

Refinery upgrading costs (csv: TransportFuel conversion costs (central aggregated, relative)): Costs for the upgrading of the energy carrier biooil to transportation fuel in the refinery, feedstock provision costs excluded. The costs are given in EUR per tonne transportation fuel.

Transport fuel production costs (csv: TransportFuel total costs at source (relative)): Total production costs of transportation fuel from forestry residue purchase to refinery upgrading. Given in EUR per tonne transportation fuel

Transport fuel amount (csv: TransportFuel amounts at source): Total produced amount of transportation fuel in the refinery. Given in tonnes transportation fuel per year

Local added value (csv: local added value): Distribution of added value generated due to the implementation of the Catalytic Pyrolysis pathway to transportation fuel

7. Quick guide to the BioBoost Navigator

Aim:
The aim of the BioBoost Navigator is to inform about modeled costs, sites and sizes of three pathways for the conversion of residue biomass to usable bioenergy products in the European Union. The modeling was made with the Heuristic Lab software of the University of Applied Science Upper Austria http://dev.heuristiclab.com. Results are not absolute but approximations, which may differ from model run to run.

Broken conversion pathways:
The pathways are characterised by biomass conversion to a long-distance transportable energy carrier in smaller plants and upgrading to the final product in large, central plants, as shown in the figure below.

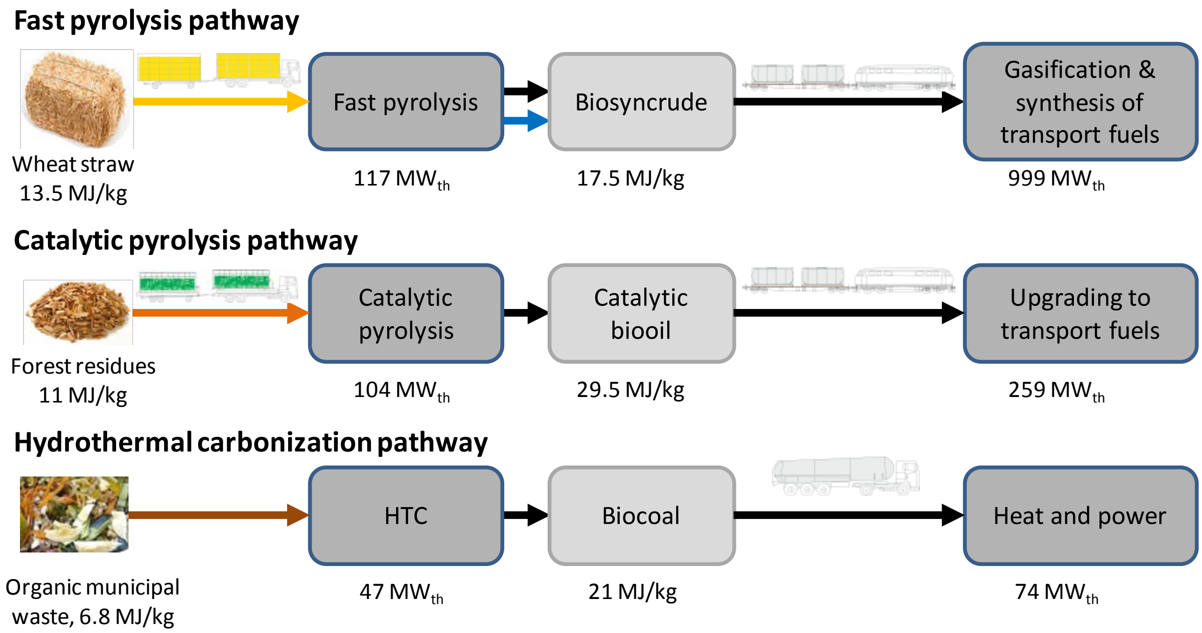

Figure 5: Feedstock, process steps and products for the three reference pathways along with the LHV of fuels (moisture, ash as received) and design (input) capacities of conversion plants.

Scenario selection:
Select…

- one of the 3 biomass conversion technologies (see above)
- the geographical area (EU or part of it)
- the biomass feedstock price (low, -25% / normal / high, +50%)
- the implementation phase (first plants at best locations / medium / broad implementation with high degree of biomass use)

Click on the GENERATE MAP-button to display the scenario.

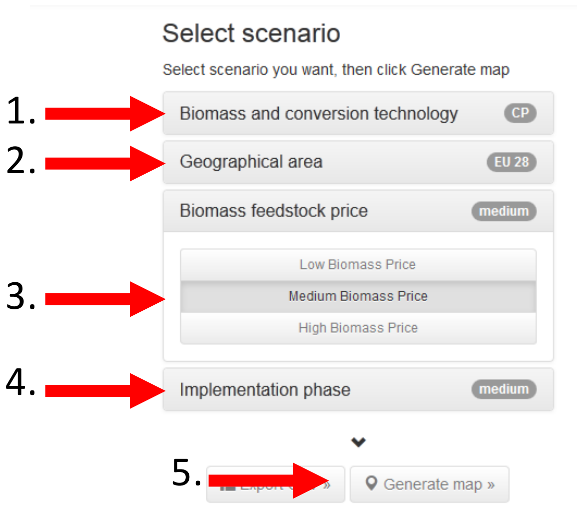

Figure 6: How to select a scenario

<u>Display of modeling results:</u>
Heuristic optimisation of the pathways leads to 117 values for each of the 1486 NUTS[1] 3 units of the EC. The whole dataset can be downloaded as csv (see data export). The 13 most interesting layers can be displayed online in the Navigator. Categories in the left column show absolute values (e.g. price per tonne biomass), those in the right column are related to the end product (e.g. price of the biomass needed to produce 1 tonne of biofuel).

Table 1: Explanation on displayed layers

Left column (absolute values):	
Biomass potential	Technically available potential. Given in metric tonnes per year [t/a] in this region.
Biomass price	Average price of residues as feedstock for energy carrier production. The price reflects the degree of utilization in this optimisation run acknowledging the influence of feedstock competition. Given in EUR per metric tonne biomass [EUR/t].
Biomass utilisation rate	Share of technically available residues purchased as feedstock in this optimisation run. Given in % of the biomass potential.
Decentral plant capacity	Biomass conversion capacity of the energy carrier plant. Given in metric tonnes biomass feedstock per year [t/a]
Energy carrier upgrading capacity	Capacity for the upgrading of the energy carrier to the marketable bioenergy product. Given in metric tonnes energy carrier per year [t/a].
Local added value	Distribution of added value generated due to the implementation of the bioenergy pathway. Given in EUR per year [EUR/a]
Right column (relative values):	
Biomass costs	Biomass costs that occurred in the production of 1 tonne end product. Given in EUR per metric tonne end product [EUR/t]
Biomass logistic costs	Biomass logistic costs that occurred in the production of 1 tonne end product. Given in EUR per metric tonne end product [EUR/t]
Energy carrier production costs	Costs for the conversion of biomass to energy carrier that occurred in the production of 1 tonne end product. Given in EUR

[1] Nomenclature of Territorial Units for Statistics. For technical reasons, some large NUTS were split in the Navigator

	per metric tonne end product [EUR/t]
Energy carrier logistic costs	Energy carrier logistic costs that occurred in the production of 1 tonne end product. Given in EUR per metric tonne end product [EUR/t]
Upgrading costs	Costs for the upgrading of energy carrier to 1 tonne end product. Given in EUR per metric tonne end product [EUR/t]
Total production costs	Total costs for the production of 1 tonne end product. Given in EUR per metric tonne end product [EUR/t]
Total production amount	Amount of end product. Given in metric tonnes end product per year [t/a]

<u>Map features:</u>
The map can be zoomed and the displayed section can be moved by mouse drag. The NUTS name and the value are displayed on mouse click.

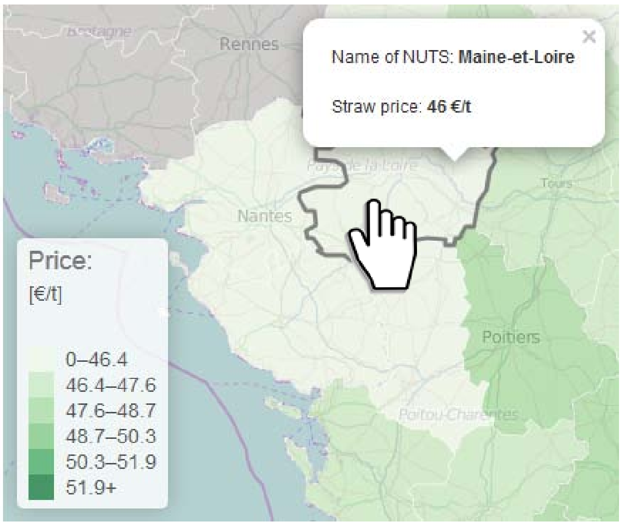

Figure 7: Map features

<u>Comparison of production costs components:</u>
Plants can be compared by the composition of the production costs and the amounts in a chart. The comparison is restricted to the end product.

1. Select a layer from the right column (showing results for the final product)
2. Click on ENABLE CHART COMPARE
3. Select plants for comparison by click on the respective NUTS.

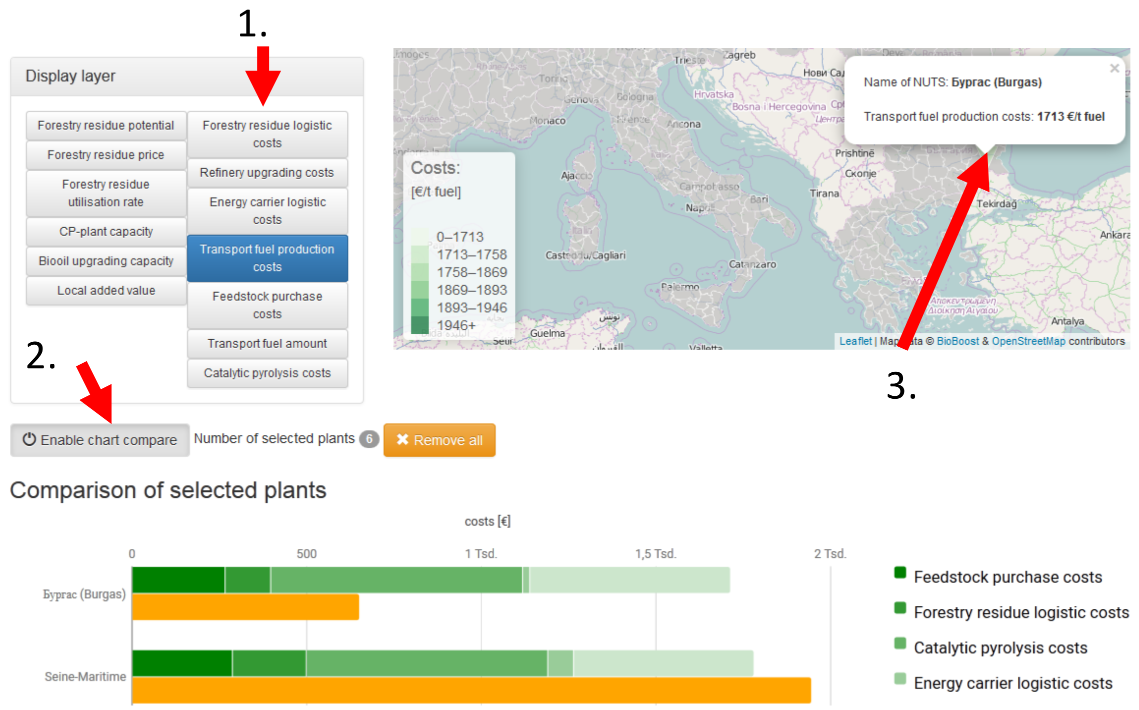

Figure 8: How to compare production costs

<u>Data export:</u>
The complete dataset (117 parameters) of the selected scenario can be downloaded as csv by click on the EXPORT CSV-button.

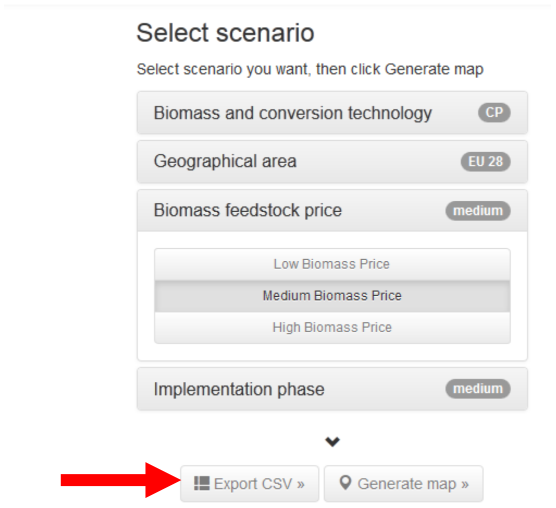

Figure 9: How to export all background data

<u>Support and advise/consultation</u>
If you …

- are interested in visualized results of layers not displayed in the Navigator,
- search for the optimal site for your bioenergy project
- have a pathway with different input parameters
- ???

…do not hesitate to contact the

➢ SYNCOM R&D consulting, e-mail link mailto:office@syn-com.com .

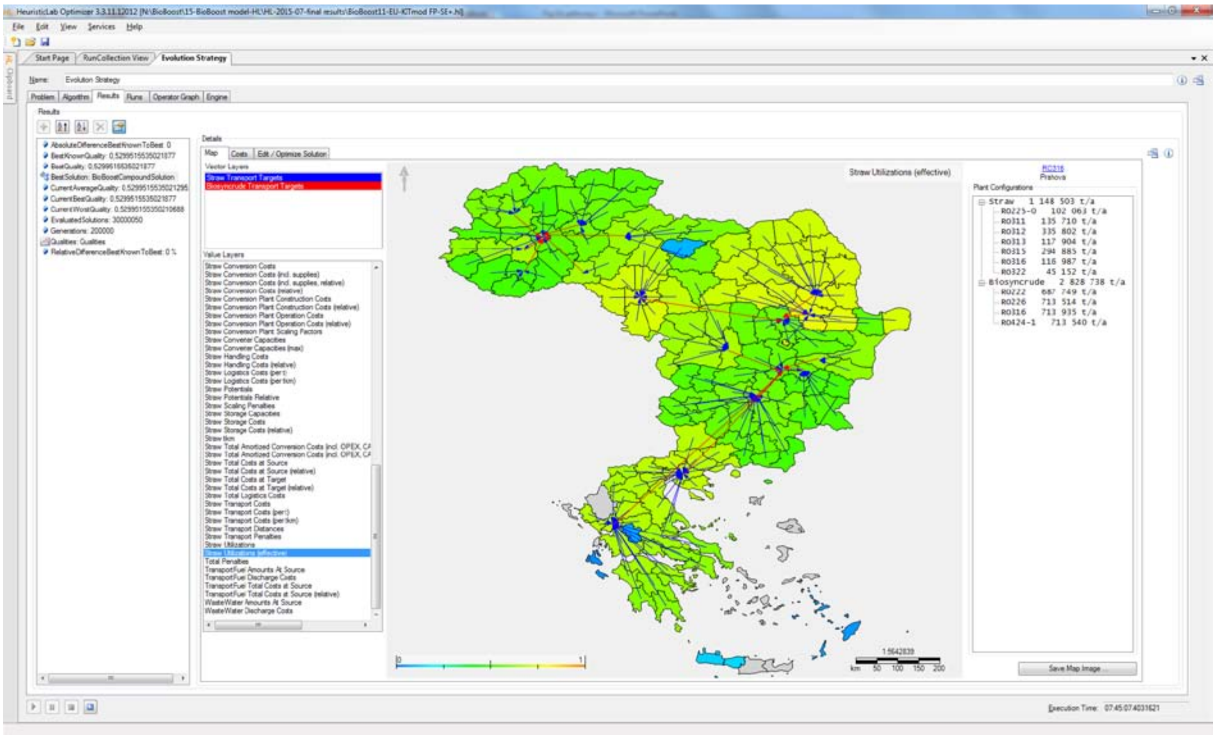
Figure 10: Screen print of an optimisation result from the Heuristic Lab-tool

8. Outlook

SYNCOM intends to use the tool in other projects and to extend its functionalities and database according to customer demands. For the fourth quarter 2015 it is planned to visualise the transport routes of biomass and energy carriers along the pathway to the central plant as final customer.