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

Feedstock, potential, supply and logistic

Work package:	WP1
Deliverable Nº:	D1.3
Due date of deliverable:	30/12/2014
Actual date of delivery:	13/04/2015
Version:	1.0
Responsible:	IUNG[1], SYNCOM[2], FHOO[3],
Authors:	Rafal Pudelko[1], Magdalena Borzecka-Walker[1], Simon Kühner[2], Eric Pitzer[3]
Contact:	rpudelko@iung.pulawy.pl, mwalker@iung.pulawy.pl S.Kuehner@syn-com.com, erik.pitzer@fh-hagenberg.at
Dissemination level:	Public

Publishable Summary

This report presents summary of the results obtained during 36 months of realizing WP1 of BioBoost project. The main outcomes are:

1. feedstock potentials of biodegradable residues and organic wastes in EU-27 and Switzerland on the level of NUTS-3 (full description in the Deliverable 1.2)
2. costs of feedstocks at field site (full description in the Deliverable 1.1)
3. transport and logistic concept for year round feedstock supply to conversion sites (full description in the Deliverable 1.4)
4. Geoportal to demonstrate GIS results

The deliverables can be found at: http://bioboost.eu/results.php

Feedstock potentials. Estimates were made for spatial unit's NUTS-3, due to the approximate representation of the basic economic potentials, are fairly typical units for the development of distributed energy scenarios. The main assumption for the potential modelling of these regions was to use only waste and residues biomass, thus not competing with food production and to respect the principles of sustainable production and environmental protection. This approach is in the line with current trends in the use of biomass, such as the implementation of second-generation fuels and the development of methods to optimise the bioenergy production. The modelled results of the biomass potential, derived from waste and residues, are illustrated by maps of theoretical and technical potentials in NUTS-3 (full description: Deliverable 1.2). The largest potential in the biomass provision based on residues and waste is straw, because of its share related to mass (37%), as well as to energy content (48%). The second largest potential could be generated from residues from forestry (29%, both in terms of biomass weight and energy). The third place is taken by biodegradable municipal waste (17% of the biomass, and 12% of the energy). Other types of biomass (natural conservation matter, roadside vegetation, selected waste from the food and wood industry) do not have much significance in the European energy sector. In certain areas, individual types of biomass may play a regional role.

Costs of feedstocks. The conversion technologies Fast Pyrolysis, Catalytic Pyrolysis and Hydrothermal Carbonisation studied in the BioBoost project apply a broad feedstock spectrum of lignocellulosic fuels from dry to wet. Suitable biomasses occur in various waste and residue streams from agriculture (straw, surplus manure), forestry, land management, food processing and settlement (waste wood, organic municipal waste). In order to cover the whole value chain the biomass cost determination was included. However as the primary focus of the project is on the conversion technologies and the overall concept of remote bioenergy intermediates for final energy commodity production in central facilities, the costs have been determined based on published information. In the assessment chain, the biomass cost report receives information on available amounts as input from the biomass potential

assessment (WP1.1) and contributes to the logistic- (WP4) and the overall techno-economic assessment (WP5). In general, results are that:

- Wastes are more economic than residues and may generate an income for the conversion process,
- Dry feedstock wet is more expansive than wet,
- Ash-rich is more economic than low-ash biomass

Transport and logistic concept. The BioBoost supply chain considers core logistics processes in transport, storage and handling. First, assets used within logistics processes are specified for each reference feedstock. Second, cost calculations were made by means of specified assets in order to determine target metrics, i.e. EUR/t/km and EUR/t. Third, additional analyses related to biomass logistics are conducted.

Implementing an intermediate depot between feedstock sources and a decentral conversion plant implies additional storage and handling costs. A case study shows that these extra storage fixed costs will only pay off at a certain transport distance. In such a 4-echelon supply chain setting, cost advantages of trucks can be exploited for transports between the intermediate depot and the conversion plant to a greater extent.

These findings represent essential input data for the holistic logistics model as well as for the sustainability report defined in WP6.

Geoportal. The Geoportal presents the analysis of the biomass potential in the EU-27 with their possible use for energy purposes. Estimates were made for spatial unit's NUTS-3, which are small regions with geocode standard for referencing the subdivisions of countries for statistical purposes. The web application allows interactive browsing the spatial data presenting density and technical potential of:

- agricultural (straw, orchard's pruning, hay) and animal residues (manure surplus),
- forestry residues,
- natural conservation matter (urban maintenance of green areas, hay and shrubs),
- roadside vegetation,
- urban and industrial waste (biodegradable municipal waste, selected waste from the food and wood industry).

Table of content

List of figures

List of tables

TASK 1.1. FEEDSTOCK POTENTIALS OF BIODEGRADABLE RESIDUES AND ORGANIC WASTES IN EU-27 AND SWITZERLAND ON THE LEVEL OF NUTS-3

Estimates for biomass potential were made for the following types of biomass:

- agricultural residues (straw surplus, orchard's pruning, hay and manure surplus),
- forestry residues,
- natural conservation matter (management of urban green areas, hay and shrubs),
- roadside vegetation,
- urban and industrial waste (biodegradable municipal waste, selected waste from the food, and wood industry).

The estimates were carried out for the third level of territorial units (NUTS-3 Nomenclature of Territorial Units for Statistics), distinguished for statistical purposes by the European Statistical Office (Eurostat) - NUTS, 2003, 2011. The analysis of the biomass potential were calculated for the EU-27 and Switzerland to maintain consistency of geographical study.

The potential of biomass has been analysed by many authors. The technical potential vary considerably between studies, as a result of a number of different factors taken into account in the analysis. The differences are due to the definitions of agricultural residues, different time, availability of data, various restrictions included in the models, etc. The main assumption for the potential modelling of these regions was to use only waste and residues biomass, thus not competing with food production and to respect the principles of sustainable production and environmental protection. This approach is in the line with current trends in the use of biomass, such as the implementation of second-generation fuels and the development of methods to optimise the bioenergy production.

There is high significance in the regional studies that allow verifying and updating the pan-European models is taken into consideration. Estimates into the technical potential, allow an approximate evaluation of global and regional sourcing possibilities of biomass for energy. However, there are other limitations in the acquisition and use of these resources. This applies mainly to the straw, which is one of the most promising resources. In some regions, problems in the immediate acquisition can be found. For example, the Lublin region that is rich in straw (eastern Poland) has highly fragmented farms. The farms may often have no more than 1 ha, which definitely makes it difficult to prepare straw for transportation (baling) in addition to its subsequent logistics. As a contrast to straw, the best situation in collecting biomass can be identified for biodegradable municipal waste. EU policy places great emphasis on sustainable waste management, which enforces segregation and proper disposal. In addition, metropolitan areas and cities are a natural focus of these resources, and greatly allow the facilitation of logistics for transport, storage and utilisation for energy purposes. The energy use of biodegradable municipal waste does not compete with its other use, so the theoretical potential of this type of biomass is close to its technical potential. This cannot be said about by-products from agriculture and forestry, which have a number of alternative uses. Animal residues are a very valuable fertiliser, which should find their primary use in soil conservation. Part of manure can be used for energy production, where the residues are generated by large farms as a surplus. However, this can only be conducted by first considering where due to environmental considerations it would be an arduousness task to collect.

The maps below show the total biomass resources and their mass (Figure 1) and energy (Figure 2) in the NUTS-3. The list of the potential can be a valuable indication to support the development of local decision-makers. These maps, due to differences in the surface NUTS-3 do not reflect the actual spatial distribution of biomass resources. These relationships were visualised on maps showing the 'density' of resources (Figure 4Figure 3, Figure 4), which was presented as values normalised by the surface potential of the region. In this way, these maps allow the regionalisation of the biomass potential.

The most prosperous biomass regions include:

- In France: Pays de la Loire, central region Ile-de-France, Picardy, Champagne,
- In Germany: Nordrhein-Westfalen, Niedersachsen, Sachsen-Anhalt,
- In Great Britain: East Midlands, East Anglia, South East
- Hungary and W-Slovakia
- In Italy: Lombardy and Veneto (in the valley of the river Po),
- In addition all surrounding of larger agglomerations.

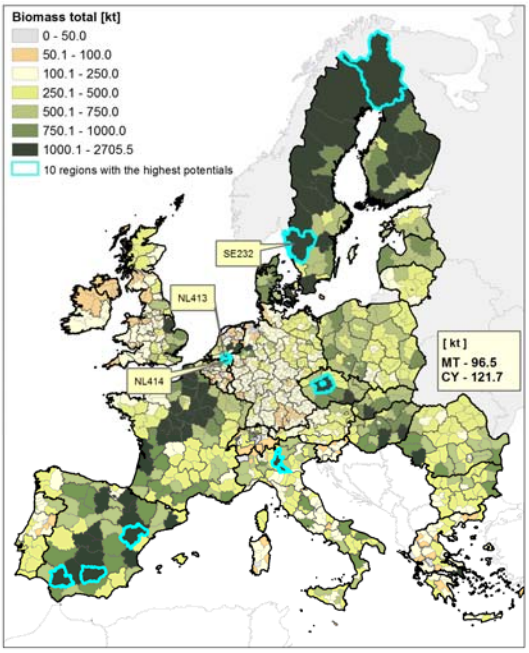

Figure 1. Summarised biomass potentials in NUTS-3

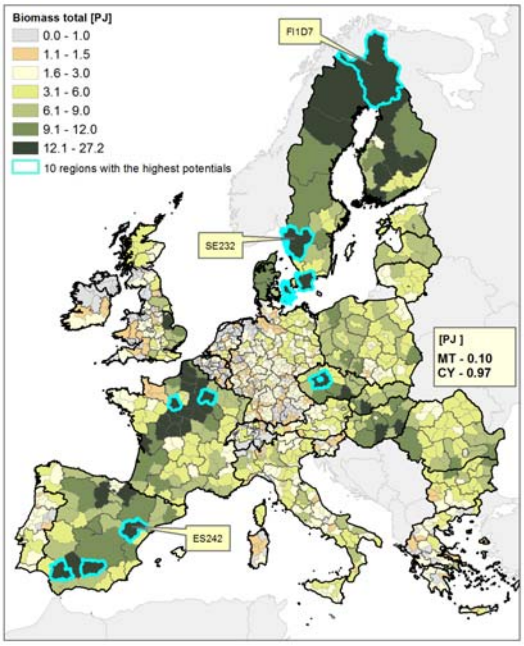

Figure 2. Summarised energy potentials in NUTS-3

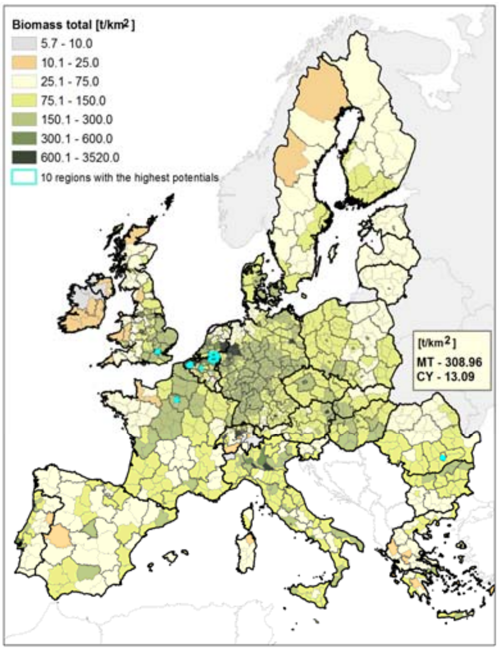

Figure 3. Summarised biomass potentials (density) in NUTS-3

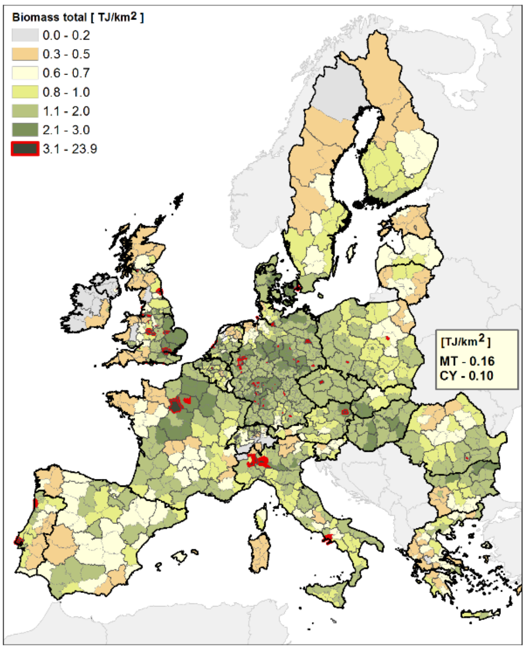

Figure 4. Summarised energy potentials (density) in NUTS-3

A comparison of the assessed energy potential for Europe (Figure 5, Figure 6) shows a dominance of three types of biomass. The most notable is straw. This represents 36.5 percent of the total mass. This percentage increases when comparing the results converted into energy. This is due to the high-energy content of straw and relatively low humidity at the time of acquisition (ca. 15%). The second most important potential is forestry biomass residue (29 % of the total mass and energy). The third assortments is biodegradable municipal waste (17,4% of the total mass and 12 % of energy). All other biomass resources (excluding straw, forestry and biodegradable municipal waste) are estimated at a 17.4 % share in the mass structure and in the energy structure of 11.9%. Therefore, the individual ranges cannot be regarded as a strategic resource in the pan-European energy policy. They may however, as it was shown in a study be an important source of the biomass in some regions.

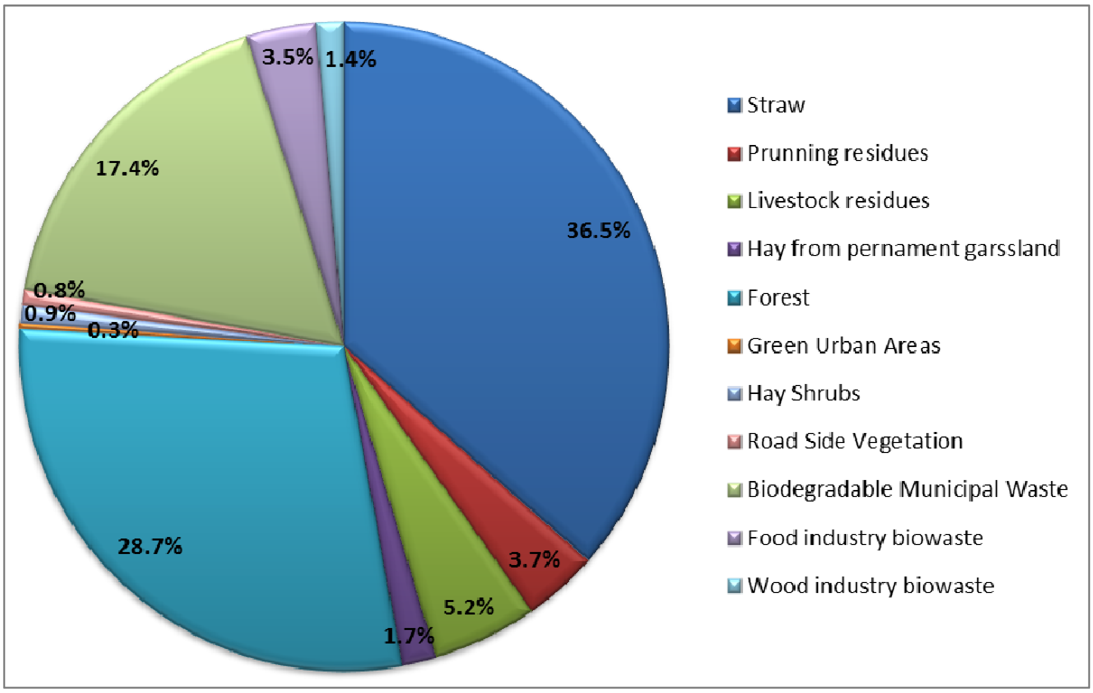

Figure 5. Partition of biomass resources in kt bioenergy production

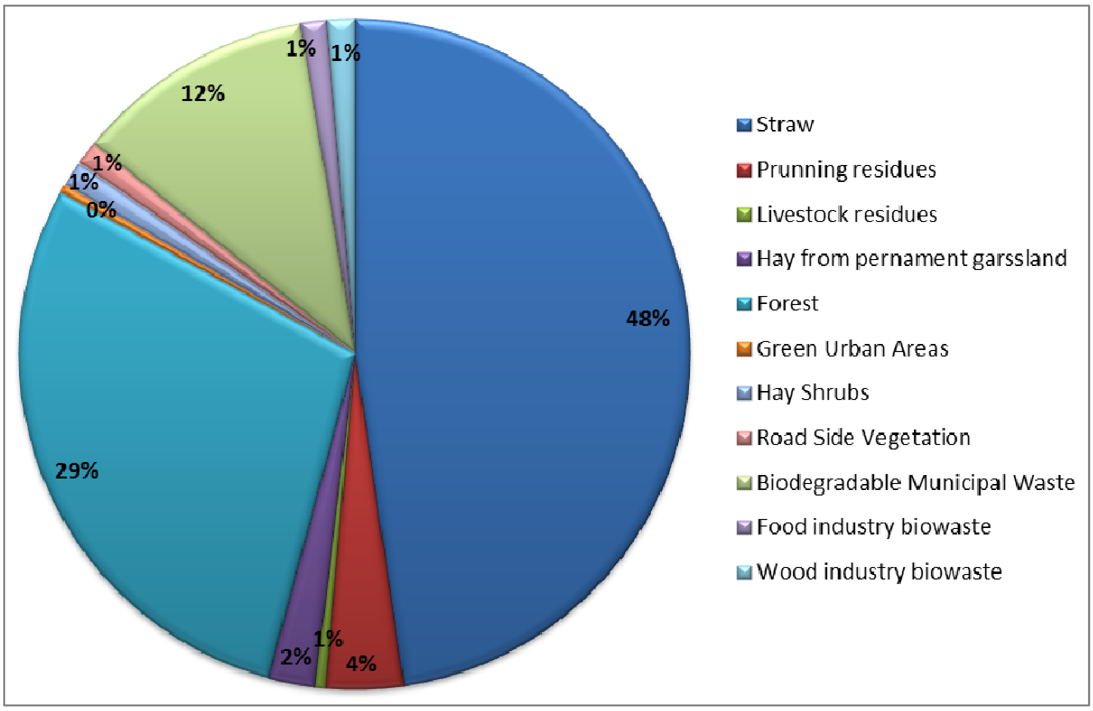

Figure 6. Partition of biomass resources in PJ bioenergy production

AGRICULTURAL RESIDUES

The agricultural residues available for energy production are straw, orchard's pruning, animal residues (manure surplus) and hay from permanent grassland.

Straw is the most available source of biomass from agricultural production, which can be used for energy purposes. The straw theoretical potential was assessed by using ratio grain to straw for each evaluated crop. The technical straw potential was assessed by subtraction of the amount of straw necessary for animal bedding and feeding in addition to the part of straw that is needed for incorporation into the soil. In calculating the modelling technical potential this does not include the straw used in horticulture, food processing, construction, etc. The alternative use of straw is dependent on economic conditions. Therefore, the competitiveness of the straw for energy uses with others uses outside agriculture should be estimated with calculations of the economic potential. Taking into account the re-use of straw resources in agriculture, the surplus can be treated as by-yield or residue and used for the 'green' energy production (Edwards et al., 2005). The total assessed feedstock potential of straw residues amounts at: 149.7 Mt (1960 PJ).

Residuals of pruning were calculated from pruning of permanent plantations: olive trees, vineyards, fruit trees, were assessed. Residuals of pruning – the main residuals: cut branches and the other biomass, which can be treated as a year's net primary productivity (grass, shrubs). The total assessed feedstock potential of permanent crops pruning amounts at: 15.4 Mt (152 PJ).

Livestock Residues are defined as livestock excreta, and associated losses, bedding, wash waters, sprinkling waters from livestock cooling, precipitation polluted by falling on or flowing onto an animal feeding operation, and other materials polluted by livestock. The assessment into the amount and availability of residues from livestock production in Europe is difficult because of the differences in animal rearing and the use of natural fertilisers in crop production of individual European countries. These differences result from dissimilar climatic and geographical as well as economic and agricultural conditions. The livestock residues are used as natural fertilisers as a source of organic matter and rich and beneficial bacterial flora. The use of organic fertilisers is in line with the principles of Good Agricultural Practice, may reduce the dose of mineral fertilisers, in addition, such fertiliser is cheaper. Big problem also appears in case of specialisation of holdings leading to animal production regions and crop regions. The total theoretical potential of residues from livestock production in Europe is huge (about 1.23 Gt). However, despite the high potential of the theoretical assumption of the primacy for the use of manure production, there were virtually no more possibilities of obtaining this type of biomass for energy purposes. Only in the three regions there is a surplus of manure, excess in terms of nitrogen, the possibility of total consumption in agriculture. These are areas in the region Noord-Brabant (Netherlands), where per hectare of arable land account up to 254 kg N (NL414 and 413), NW Belgium (> 223 kg N/ha) and Portugal (Pinhal Litoral region, 180 kg N/ha).

Hay derived from permanent grassland, due to the large acreage, can be found as a theoretically significant potential of biomass. Regions with a high proportion of pastures and meadows are used for intensive livestock, mainly cattle. In these regions, pastures are used for grazing animals, and for feeding in fresh form or as hay, and silage). It was assumed that the excess hay is estimated as the difference between the potential productivity of biomass under permanent pasture and hay demand associated with the farming of ruminants. Hay besides crops grown on arable land and forest, is the largest resource of biomass. However, similar to the case of straw and manure, prime hay use is determined by its need in agriculture. Total theoretical potential of hay is estimated at 116.2 Mt.). A surplus of hay, like manure surpluses, are in a small clusters, which generally show an inability to use hay in Europe as a significant and accessible resource base. The total potential of surplus hay, which can be used for energy purposes, is only 6.9 Mt (92.6 PJ).

FORESTRY RESIDUES

Forestry residuals were assessed based on the BEE definition and methodology (BEE (ed. Vis M.W. and van den Berg D.) 2010). The forest residues were defined as:

- Stemwood: biomass from pre-commercial and commercial thinning and final fellings, available for energy production, including whole trees and delimbed stemwood from pre-commercial thinning's.
- Primary forestry residues: logging residues, stumps.
- Secondary forestry residues: wood processing industry by-products and residues – sawdust and cutter chips, bark, slabs, lump wood residues and black liquor.
- Woody biomass from short rotation plantations on forestlands.
- Trees outside of forests such as trees of settlement areas, along roads and on other infrastructural areas.

Yield was estimated for forest areas determined based on CLC map (Bossard M., et al. 2000). From this map, deciduous, coniferous and mixed classes were extracted. For each NUTS-3 region, the average NPP for value were found based on the WDC-RSAT data (Tum M. and Gunther K.P 2011). The relative differences of net primary productivity have been used (as weighting factors) to redistribute the theoretical and technical values of potentials from countries level to the raster map. The total assessed theoretical potential of forestry residues amounts at: 321 Mt (3230 PJ). The total assessed technical potential of forestry residues amounts at: 117,9 Mt (1186 PJ).

NATURAL CONSERVATION MATTER

Green urban areas are composed of biomass from leaves, shrubs and grass, can be obtained as residues from the conservation of green urban areas, port and leisure facilities. The total assessed feedstock potential of green urban areas amounts at: 1.18 Mt (17 PJ).

Hay and shrubs are composed of biomass potentials from shrubs and grass that can be removed from pastures located on NATURE 2000 areas (SPA). Methodology was developed base on the framework of Polish agro-environment scheme, where 9 agro-environmental packages are implemented, of which the two following are strictly oriented on protection of biodiversity. According to the package's rules grass should be moved after maturity, so this biomass is available for energy purposes. As a result, a raster map of biomass potential from pastures protected by NATURE 2000 (SPA) was assessed. Values determined as a grid 100x100m were tabulated for 1313 BioBoost NUTS-3 regions. The total assessed feedstock potential of hay and shrubs amounts at: 3.68 Mt (49 PJ).

ROADSIDE VEGETATION

The roadside biomass, due to the road network density and the limited use of roadside areas, creates a huge theoretical biomass potential. This vegetation can be treated as new kind of biomass residues, which can be possibly used for energy purposes. The main problems in obtaining this type of biomass are the lack of technology for synchronous harvesting and loading and its local use. Due to the large demand of biomass for energy purposes and its high theoretical potential, an attempt to estimate the possible resources was undertaken as well as including a study on the impact of roadside biomass as local biomass fuels. For the analysis, the main classes (motor ways, primary ways and trunk ways) of roads were extracted. This subset of roadside vegetation potential was assessed at 3.17 Mt (47 PJ).

URBAN AND INDUSTRIAL WASTE

The urban and industrial waste was composed of biodegradable municipal waste, bio-waste of food industry and forest industry waste potentials.

Biodegradable municipal waste consists to a larger extent of waste generated by households, but may also include similar wastes generated by small businesses and public institutions and collected by the municipality; this part of municipal waste may vary from municipality to municipality and from country to country, depending on the local waste management system. For areas not covered by a municipal waste collection scheme, the amount of waste generated is estimated. The waste paper and the cardboard (and textile) were excluded from the municipal biodegradable waste. The total assessed theoretical potential of biodegradable municipal waste amounts at: 90,0 Mt (605 PJ). To calculate technical biodegradable municipal waste potential a geostatistical and geoprocessing analyses were applied for finding the most customised barrier separating urban areas from scattered settlements. In the result the minimal area, where technical potential was taken into account, was defined as a cluster of min. 3 km^2 with potential greater than 30 t for each one.

Additionally all spots of 1 km^2 with potential greater than 120 t were assumed. The total assessed theoretical potential of biodegradable municipal waste amounts at 71,2 Mt (477 PJ).

Bio-waste of food industry which include other kinds as beet pulp, molasses, waste malt, meal, whey, waste from fruit and vegetables, are difficult to quantify due to the lack of regional data and their distribution. Further difficulties were found due to some use of those products as animal feed (no statistics) and in recent years, due to changes of the production structure, which were the result of the Common Agricultural Policy. This applies especially to the production of sugar and milk (Eurostat). Due to the limited data and the ability to conduct at regional NUTS-3, two types of waste were identified that were generated in the production of olive oil and grape processing (mainly in the production of wine). Spatial modelling of the technical potential of these types of biomass was possible due to detailed information about the location of the cultivation of grapes and olives, given on the land use map (CLC). In addition, according to a review of the literature (Blasi et al., 1997; Mahro and Timm, 2007) the processing of the raw material is done mostly locally. The technical potential of residuals and waste from the olive and grape processing industry, which can be used for energy purposes, was 14.3 Mt (51 PJ).

Bio-waste of wood industry by-products. The data about wood industry waste was obtained from the Renew project. The potential of biomass from wood industry is grouped in four fractions: by-products from sawmills, by-products from pulp and paper industry, by-products from board industry, by-products from other wood processing industries. The method of theoretical potential assessment was based on specific factors, which allowed conversion of input data from the international database into amounts available for BtL uses. The estimation was based on the areas covered by forest available for wood supply, net annual increment and felling rates specific for each European country (TB FRA, 2000; TB FRA, 2005). The values of regional specific factors, which were not possible to derive from the database, were taken from literature or relevant experts. If it was not possible to define the factors on a national level, the average value for Europe was used. In order to assess the technical potential available for BtL the theoretical potential was reduced. Ecological restrictions are necessary for proper and sustainable functioning of forest ecosystem. Various difficulties make it technically or economically impossible to harvest and supply the residues (small, scattered felling areas, slopes, etc.). Finally, part of the harvestable residues is utilised by wood industry, like the fibreboard industry, and must be excluded from the total available potential for BtL if the rule that food and fibre production cannot be affected is applied. Due to the fact that fibre production cannot be affected for each scenario wood demand for wood industry is taken into consideration. The total assessed feedstock potential of Wood industry amounts at: 5.59 Mt (56 PJ).

MODELLING AND VALIDATION

Estimates of the technical biomass potential published as Deliverable 1.2 of BioBoost were modelled based on scenarios concentrated on available statistical and spatial data. In the case of disaggregation of statistical data (which are already loaded are some errors) in using spatial data (for the generalisation corresponding scale map) the overall calculation error can propagated. In addition, models and algorithms were created according to their universal application across Europe. For this reason, in certain regions, the technical potential estimates may not correspond to the actual real situation. In addition, the authors are aware of regional and / or national specific conditions, which affect the possibility of obtaining biomass. These are mainly: the structure of agricultural production, centralisation or decentralisation of agrifood industry and wood processing and microclimate.

The appendix 1 to report Deliverable 1.2 shows some of the methods that can be used to validate the models. In selected areas, the test also shows the specificity of regions characteristic, which may affect the obtained results. The first section of the appendix the risk, uncertainty and location analysis presents an assessment of the entire model for all NUTS-3 regions. In the next chapter, the occurrence of hypothetical regions with self-sufficient energy. In chapter 3 is indicated by regions in which it can be assumed that the current resource base is the most optimal for the processing in one of the three preferred project BioBoost methods (FP, CP, HTC). Then a comparison of the BioBoost model with the biomass potential assessed and based on high resolution satellite images (in two regions of Europe) was done. The final two chapters present the validation of the types of waste biomass, which can be made only on the basis of statistical data. This applies to biomass from industrial and biomass alternative.

Uncertainty analysis and biomass density map were used for the optimisation of the results obtained so far, in terms of location capabilities of biomass pre-treatment plants or bioenergy facilities. This analysis assumes the designation of such an NUTS-3 regions in which one can obtain sufficient, for technological reasons, amounts of biomass in the most favourable locations, in terms of logistical reasons - distance. Classes of technical potential were adopted on the basis of assumptions from the BioBoost project whose main goal is to develop practical technology to convert waste and excess biomass into intermediates of energy carriers. Based on these assumptions, specified interval demand for biomass (10, 60, 120 and 200 kt) were defined. In the optimisation of raw material bases, a very important issue is the area from which biomass is harvested. This is because of the fact that the carriage at a distance of 80-100 km energy consumption for transport equals energy value of transported biomass (Sokhansanj and Fenton 2006, Castillo et al. 2010, Strašil et al. 2010, Kowalczyk-Jusko 2012). However, the most rational radius transport of biomass should not exceed 20 km (Börjesson 1996). For these reasons, it was assumed that the NUTS-3 will be divided into four classes, where the created biomass demand ranges are possible to achieve within a radius of 20 km. The potential availability of biomass in the regions was calculated as the average of the total technical potential of biomass resources in a circle with a radius of 20 km, taking into account any amendments to the uncertainty. The calculation uses the biomass density map and a cluster map. The result of the analysis is the map of the optimal location of biomass-based power plants (Figure 7). Given the scale of the work, the basic unit on the map is NUTS-3, and the situation shows the average values that result from the use of biomass potential density maps. Therefore, the actual locations are based on studies for a local variation of biomass resources per unit that will lead to even better choice of locating power plants, i.e. those that are in close proximity to biomass sources selected for conversion. Based on the map, you can say that in Europe there are two regions particularly suitable for the production of bio-energy. Those are contiguous clusters of NUTS-3 in the Netherlands, Belgium, Germany and northern Italy. It should be noted however, that these regions are also at high risk of overestimation of the technical potential biomass availability. The European regions with the least favourable locations include Scandinavia, Baltic States and north-eastern Poland.

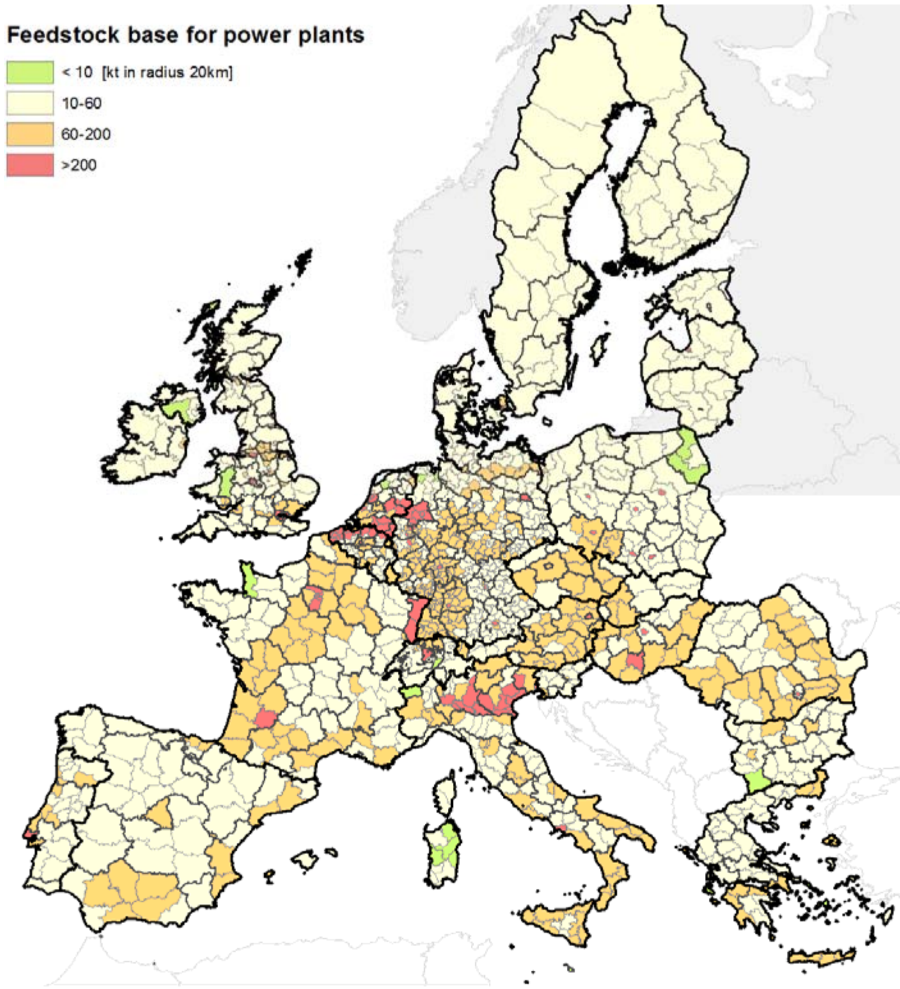

Figure 7. Optimal location for biomass-based power plants

For each of three production technology, different types of biomass have been chosen as feedstock for energy carrier production by fast pyrolysis (FP), catalytic pyrolysis (CP) and hydrothermal carbonisation (HTC). The detailed description of these types of biomass can be found in Deliverable 2.1 Feedstock selection, Characterisation and Preparation.

These are the biomasses according to technologies:

FP (fast pyrolysis):

- Middle fraction (residues from flour production)
- Miscanthus
- Scrap wood (industrial residue wood)
- Wheat straw

CP (catalytic pyrolysis):

- Beechwood (commercial wood biomass under the brand name Lignocel)
- Miscanthus
- Wheat straw

HTC (hydrothermal carbonisation):

- Organic municipal waste
- Spent grains from breweries
- Wheat straw

In the following analysis, each of the NUTS 3 regions was assessed in terms of biomass types that are adequate as substrates for three processing technologies: fast pyrolysis (FP), catalytic pyrolysis (CP) and hydrothermal carbonisation (HTC). The analysis resulted in the attribution of a preferred processing technology for each NUTS 3 region. The idea of the preference assignment was based on comparing processing requirements for substrates with a combination of biomass potentials in regions (Deliverable 1.2). A rough description of the algorithm is as follows: for a region under consideration, one takes such a processing type, for which the substrates are in abundance in the region. The algorithm also takes into account (to some extent) levels of preference for substrates by the biomass processing types. In the below section a precise and formal description of an algorithm that was used is presented.

Straw, which is an important type of biomass in each of types of processing under consideration, is omitted because it occupies the same place in the preference list of these processes. So a distinction between the two types of pyrolysis and hydrothermal carbonisation is made by the use of the technical potential value of Miscanthus, biodegradable municipal waste and the sum of forest residues as well as wood Industry residues.

The map shows that fast and catalytic pyrolysis are most likely for application. Processing HC can be used effectively only in a few regions in Europe, mainly in Great Britain, Belgium. Netherlands and Switzerland.

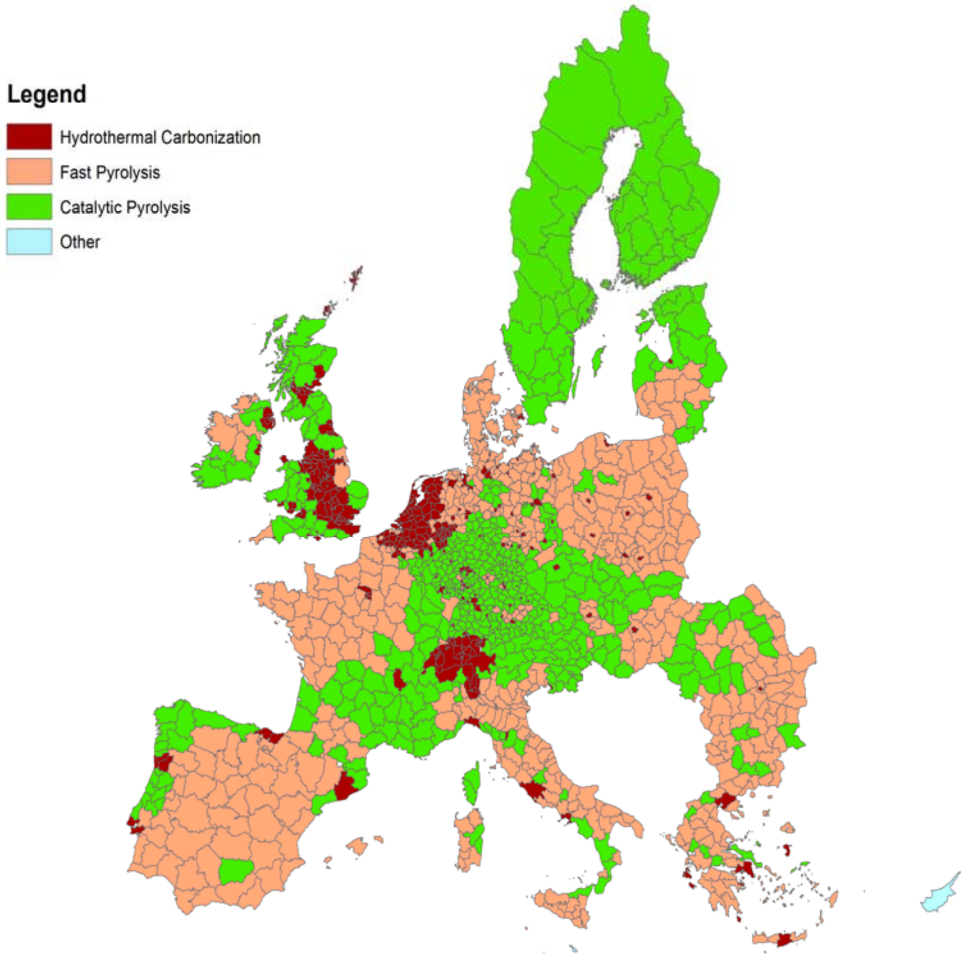

Figure 8. Preferred process type for NUTS 3 regions.

TASK 1.2 FEEDSTOCK COSTS

The conversion technologies Fast Pyrolysis, Catalytic Pyrolysis and Hydrothermal Carbonisation studied in the BioBoost project apply a broad feedstock spectrum of lignocellulosic fuels from dry to wet. Suitable biomasses occur in various waste and residue streams from agriculture (straw, surplus manure), forestry, land management, food processing and settlement (waste wood, organic municipal waste). The value chain starts at the biomass, which is covered in 3 topics and respective tasks:

- The sustainable and available biomass potential, determined in task 1.1; and disseminated in task 1.4
- Biomass costs/prices in task 1.2;
- Feedstock logistics in task 1.3;

The objective of task 1.2 was to determine the price of the biomass feedstock, which is needed to assess the economic performance of the energy carrier pathways. The focus of the feedstock cost assessment was on the 3 reference biomasses, straw for fast pyrolysis, forest residues for catalytic pyrolysis and organic waste for hydrothermal carbonisation. Further to these fuels, prices for alternative feedstocks as landscape management material, energy crops, demolition wood and food processing residues were assessed. Costs and prices were determined for bale stacks free field side, wood chips free forest road, and pre-treated organic waste free yard. The subsequent logistic costs (storage, handling and transport) are treated in task 1.3.

The approach was to focus the data gathering on the most advanced member states, analyse the production process and its cost items, collect information on other member states and develop a transfer approach in order to get comparable results. This is in line with the assumption that most efficient, state-of-the-art equipment is operated by dedicated contractors to supply the large biomass amounts required to fuel the BioBoost conversion technologies. The results were then matched with published prices. In a subsequent step this methodology was extended on the effect of supply and demand on the biomass price of the reference feedstocks. The advantage of this approach is the high degree of comparability of the regions within the BioBoost model although it may not includes all constraints in the respective areas. However, as the results are based on a sort of 'best practice', the comparability to actual prices is limited as the operated technology and its associated costs are different in most areas.

In general (and as expected), results on biomass provision costs are that

- Wastes are more economic than residues and may generate an income for the conversion process;
- Dry feedstock is more expensive than wet;
- Ash-rich feedstock is more economic than low-ash biomass

The results were reported in Del 1.1 of the BioBoost project.

Straw

The straw costs free field side stack were determined as difference to the alternative use of leaving it on the field. The straw cost assessment focuses on wheat straw due to its abundance and low competition from alternative applications. Cost items are fertilizer replacement, baling and bale chasing. The latter two depend on equipment and operation efficiency which is influenced by field size, straw amount and labour costs. Applying the most efficient technology as condition for the supply of several ten- to hundred-thousand tonnes to decentral conversion plants leads to straw **costs** free field side stack between € 31 and € 39 per tonne. This is in contrast to average **prices** (costs plus profit) between €20 and €180 per tonne recorded in 2011.

Fertilizer cost

The first cost item –need for fertilizer replacement- is determined by the amount of fertilizer in the straw, the availability of its constituents for the following crop (fertilizer efficiency) and the price. The fertilizer content in the straw depends on many influences and is very variable even within a field. The figure below gives an overview on the content and the values used for this assessment.

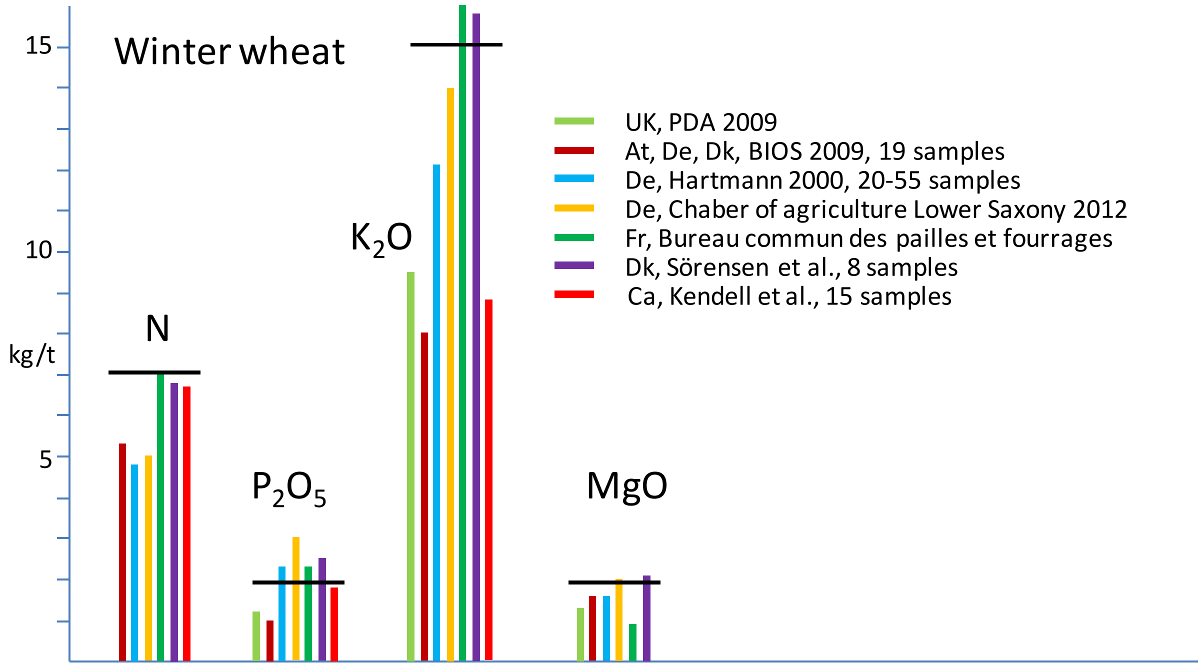

Figure 9 Average content of fertilizers in wheat samples of different origin. The black bars show the values used for this cost assessment.

The fertilizer elements withdrawn by removing the straw from the field are very different in their accountability as input for the next crop. The phospate (P_2O_5, 2kg/t) and magnesium (MgO, 2 kg/t) from the straw are plant available and typically bound to the soil particles making it 100% accountable for the next crop. The potassium salts (K_2O, 15kg/t) have a high solubility and are easily washed out of the straw. The developing plants of the following crop are typically not able to prevent leaching of all of the potassium, leading to an efficiency of 50%. The nitrogen (N, 7kg/t) content of the straw is bound to the lignocellulosic matrix and leads to humic substances, which are not plant available (0% efficiency). However, the humic substances (Corg) feed soil dwelling organisms and are very important for the soil fertility, which is why the N-value is accounted to 75 % in this assessment. For comparison the JEC-well to tank (wtt) assessment[1] uses 0.13 g P_2O_5 and 0.71 g K_2O per MJ straw which is equivalent to 2.21 and 17.1 kg per tonne dry matter, respectively. The purchase price for fertilizers is also highly variable, depending e.g. on type, amount, time of order and distance to producer/harbour. Assuming a balance in the EU-common market allows to use single prices, which were averaged to € 0.95 for N, € 1 for P_2O_5, € 0.75 for K_2O and € 0.87 for MgO per kg nutrient giving a total fertilizer value of € 14.05.

Baling and chasing cost

The most efficient baling equipment are high density, large square balers making bales of e.g. 1.2 m width, 0.9 m height and typically 2.4 m length with a weight of 500 to 550 kg. These bales allow use of the full payload of ~27 tonnes of platform trucks. Storage is also more efficient as the volume is ¾ of the conventional, 1.3 m high Hesston bales of the same weight. This compensates the higher purchase price and increased fuel consumption of the 200 to 220 kW tractor. With 50 bales per hour the full costs were calculated to be € 14.52 per tonne of straw. The most efficient way to clear the field is a tractor-pulled bale chaser, which is operated by a single person, typically takes up to 16 bales and stacks them 7.5 m high. At 80 bales per hour the bale collection costs € 3.29 per tonne free field side stack.

[1] JEC wtt appendix 4 version April 2014, http://iet.jrc.ec.europa.eu/about-jec/sites/iet.jrc.ec.europa.eu.about-jec/files/documents/report_2014/wtt_appendix_4_v4a.pdf

Figure 10: Straw cost assessment is based on most efficient equipment, which are high density, large square balers and bale chasers for clearing and field side stacking. Copyright: Krone, Big Bale Transtacker

However, these values depend on the time to reach the field, field size, straw amount per hectare, loan and fuel costs. A calculation tool (KTBL) which is based on practical data was used to assess the effects of field size and straw density. According to it, the cost difference between a field of 1 ha and 20 ha is 27 % and between 2.75 t/ha and 6 t/ha is 15%. Both relations are power functions, which was used to fit the regional data. Comparable data on cereal field size are not public available for the EU, reported values range from 0.29 to 70 ha per field. Values from some member states were used to fit the only common source available EU-wide on area, the utilized agricultural area of cereal farms. The approximated field size ranges from 0.3 ha to 36 ha. The amount of straw per field area was calculated from information of the feedstock potential assessment (task 1.1). It ranges between 0.67 t/ha to 5.52 t/ha. The entry loan for a worker in agriculture spreads between € 0.93 and € 15.3 per hour. However, the high value of the equipment and the required training ask for a certain category of personnel, which was assumed to cost € 15 to € 25 per hour, giving a loan of € 0.93 to € 1.55 per tonne straw. Altogether, this leads to average prices between € 31 and € 39 per tonne of straw in most of the European NUTS 2 regions.

From cost to price

However, the price the customer has to pay is composed of the costs and a margin, leading to prices between € 20 and € 180 per tonne as observed in 2011. So in a second step straw prices were modeled on base of findings from a farmer survey published by Cochin of INRA

Economie Rurale in 1977. For one additional ‘fertilizer value’ as profit up to 50 % of the farmers would offer their straw for baling. For higher sourcing ratios the offered profit would gradually have to rise up to the 5-fold fertilizer value. With the current data of the BioBoost cost assessment this leads to an average straw price of € 47.5 for sourcing between 0 and 50 %. For higher sourcing ratios the price increases to € 103 per tonne at 100 %.

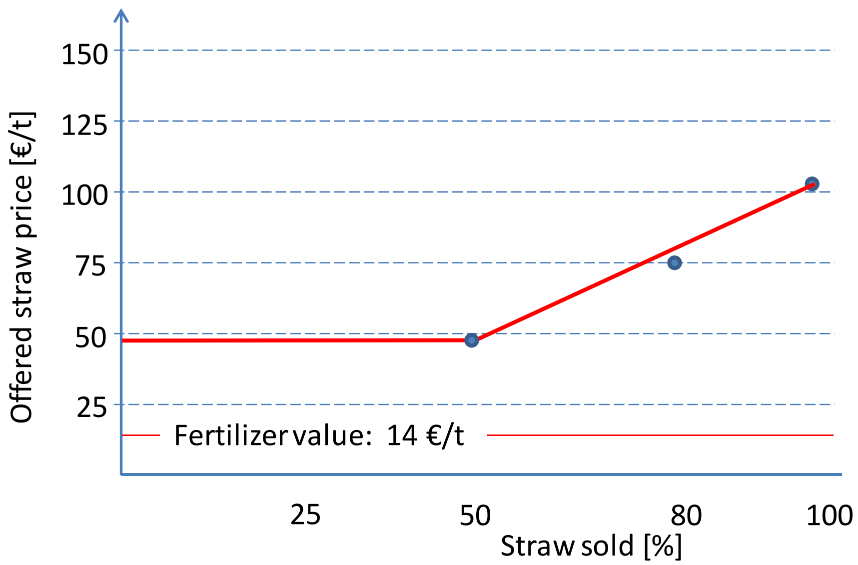

Figure 11: Model relation of feedstock price [€/t] and degree of sourcing [%] of wheat straw in large square bales on base of costs for fertilizer replacement, baling and chasing (€ 33.5 per tonne in average). 0 to 50 % - € 47.5/t (includes a single fertilizer value or € 14/t as profit); 50 to 100 % - linear increase to € 103/t, includes the 5-fold fertilizer value or € 70/t as profit.

Table 1: National straw potential and averaged prices. A single straw price (shown in € per tonne and € per GJ) applies for sourcing ratios between 0 % and 50 %; At higher sourcing ratios it increases to the 100% value

Country	Technical Potential	BioBoost price			
		0-50% sourcing		at 100% sourcing	
	wheat straw kt	€/t	€/GJ	€/t	€/GJ
Austria	1000.48	47.11	3.37	103.11	7.37
Belgium	282.32	47.37	3.38	103.37	7.38
Bulgaria	3235.64	46.84	3.35	102.84	7.35
Cyprus	9.18	51.09	3.65	107.09	7.65
Czech Republic	3580.99	45.39	3.24	101.39	7.24
Denmark	3769.73	46.09	3.29	102.09	7.29
Estonia	206.78	46.93	3.35	102.93	7.35
Finland	699.75	47.71	3.41	103.71	7.41
France	18624.82	45.58	3.26	101.58	7.26
Germany	14842.66	45.95	3.28	101.95	7.28
Greece	1489.41	51.28	3.66	107.28	7.66
Hungary	4082.73	47.40	3.39	103.40	7.39
Ireland	0.00	46.08	3.29	102.08	7.29
Italy	4056.83	49.84	3.56	105.84	7.56
Latvia	406.94	46.87	3.35	102.87	7.35
Lithuania	1210.46	47.09	3.36	103.09	7.36
Luxembourg*	1.14	47.23	3.37	103.23	7.37
Malta	0.00	62.21	4.44	118.21	8.44
Netherlands	275.63	47.52	3.39	103.52	7.39
Poland	7776.43	49.06	3.50	105.06	7.50
Portugal*	504.97	48.61	3.47	104.61	7.47
Romania	2981.07	50.08	3.58	106.08	7.58
Slovakia	1271.34	46.19	3.30	102.19	7.30
Slovenia*	151.43	50.21	3.59	106.21	7.59
Spain	4626.04	47.85	3.42	103.85	7.42
Sweden	1720.25	45.70	3.26	101.70	7.26
United Kingdom	7472.14	45.28	3.23	101.28	7.23

* no technical straw potential of w heat, data for 'other cereals'

Forest residues

The price of forest fuel chips free forest road from residues like slash, thinning wood and stumps was determined on base of actual quotes. However, the quality (water content, ash content, chip size), condition (free forest/supplier/customer) and reference (MWh, tonne, m^3) make the quotes difficult to compare. Also it was not possible to get information from all of the 27 member states and some actually do not make wood chips at all. Prices rise from € 25 per tonne dry matter for low quality residues to € 80 to € 100 for high quality wood chips.

Concerning the effect of supply and demand on the price some regions in the most advanced forest fuel countries Sweden and Finland already face a short supply in forest fuels. In these regions the demand for forest fuel is covered either by long distance transport or by chipping of pulp wood or industry wood as most economic timber segment.

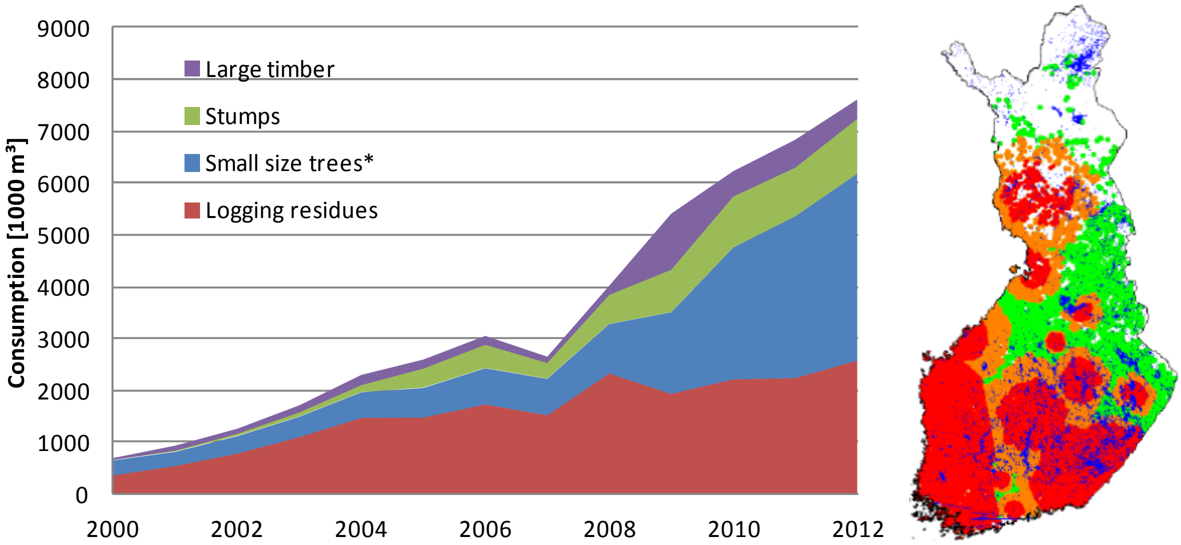

Figure 12: Composition of wood fuel of heat and power plants in Finland (left). The category ‘small size trees’ includes delimbed- and whole tree- thinning wood as well as pulp wood. Regions of high competition for wood fuel in some regions of Finland (right) are shown in red while others still have more forestry residues available (green). Source: Metla, Metsätilastollinen vuosikirja 2013, Ranta et al. 2012

The outlook study of the European Forest sector was used as source for harmonised values as it is based on a very deep investigation of stand conditions, ownership, management and harvesting practise as well as demand for wood products. So the price/supply model uses the € 40 to € 55 per tonne dry matter of chipped forest residue for sourcing ratios between 0 and 50 %, which increases to the price of chipped pulpwood of € 91 to € 151 per tonne dry matter on base of the EFSOS2 forecast of pulp wood prices in 2020.

Table 2: Modeled (white) and recorded (orange) industry wood or wood chip prices and derived price/supply points for the modeling in BioBoost (green). Actual wood chip prices are typically free plant, all other are free forest road. The EFSOS pulpwood chip prices were calculated using an exchange rate of 1.3 $/€, € 5 per m³ for chipping and 2.2 m³ per tonne dry mass. A single chip price applies for sourcing ratios between 0% and 50%; At higher sourcing ratios it increases to the 100% value. Conversion factor: 19 GJ per tonne dry matter. Source: EFI, various

Country	EFSOS2 model pulpwood price 2010 $/m³	Actual industry wood prices 2012 €/m³	EFSOS2 model pulpwood price 2020 $/m³	Calculated EFSOS2 p'wood chip price 2020 $€/t_{dm}$	Calculated actual wood chip price 2012 $€/t_{dm}$	BioBoost forest residue chip price 0-50% $€/t_{dm}$	BioBoost pulpwood chip price @ 100% $€/t_{dm}$
Sweden	51*	32	57*	105	81	50	105
Finland	52*	30	56*	103	77	45	103
Estonia	32*	27	49*	91	70	40	91
Latvia	26	33	49	91	84	40	91
Lithuania	32	23	52	96	62	40	96
Denmark	49		64	117		50	117
Germany	55	50	64	117	121	50	117
Netherlands	67		77	139		50	139
Belgium	64		74	134		50	134
Luxemburg	67		84	151		50	151
France	44		64	117		50	117
Austria	54	36	62	113	90	50	113
United Kingdo	67		74	134		50	134
Ireland	58		66*	120		50	120
Poland	38	37	64	117	92	45	117
Czech Repub	33	34	52	96	86	45	96
Slovakia	43		78	140		45	140
Romania	33		53	98		50	98
Slovenia	46		54	100		50	100
Croatia	55*		55*	102		50	102
Hungary	34		75	135		45	135
Bulgaria	34		73	132		45	132
Greece	65		73	132		50	132
Cyprus	67		84	151		50	151
Italy	67		79	142		55	142
Spain	58		64*	117		50	117
Portugal	57		77	139		50	139

*: lower of two pulp wood prices of the wood energy scenario selected

Organic waste

Organic wastes from municipalities or food processing is a very diverse feedstock: Biowaste from kitchen/food production has typically a water content of 50 to 75 % and 20 to 60 % ash which results in a lower heating value of 0 to 7 GJ per tonne as received. Waste from gardening and maintenance of communal greens is characterised by a water content of 30 to 55 %, 15 to 40 % ash and a heating value between 4 and 11 GJ/t. It has a waste yard gate fee of € 60 to € 20 per tonne (€ 180/odt at 67 % moisture). Beside the treatment, this includes costs for reception, handling, pre-treatment and sorting, which excludes the use of the gate fee as input for the economic assessment. Various treatment processes are applied on organic waste as e.g. incineration, anaerobic digestion, in-vessel composting or windrow composting. For the BioBoost cost assessment in-vessel composting was selected as reference There the biowaste is intensively rotten under controlled conditions applying filtration of the off-gases. The result is a compost of relatively high quality. It has the second lowest full costs after windrow composting, which is at 50% of in-vessel full costs but is considered more suitable for garden waste due to emissions and hygienisation. The price for organic waste in BioBoost is based on an in-depth analysis of the sector prepared by ARCADIS for the European Commission. The cost level for the first 50 % of the available biowaste is set to the full costs for in-vessel composting, which are between € 30 and € 41 per tonne. This is equivalent to € 90 to € 123 per tonne ash-free dry matter or € 4.8 to € 6.5 per GJ. Assuming the broad implementation of an efficient biowaste treatment process for energy generation, a scenario of high competition is expected as observed after the liberalisation of the German waste sector. The treatment costs are expected to drop to the in-vessel composting OPEX-costs at 100 % sourcing, ranging between € 10.7 to € 13.1 per tonne.

Table 3:Organic municipal waste treatment costs are given in [€/t]. For the BioBoost assessment a single organic municipal waste price (green shading, in €/GJ) applies for sourcing ratios between 0% and 50%; At higher sourcing ratios it increases to the 100% value. A negative price means, that an income is generated by the uptake of the biowaste. The conversion factor is 6.3 GJ per tonne of organic municipal waste. Source: ARCADIS[2]

	In-vessel-composting		BioBoost Org. mun. waste price	
	full costs (0-50%) [€/t]	OPEX (@100%) [€/t]	(0-50%) [€/GJ]	(@100%) [€/GJ]
Austria	38.3	12.5	-6.1	-2.0
Belgium	40.6	13.0	-6.4	-2.1
Bulgaria	30.0	10.7	-4.8	-1.7
Cyprus	32.4	11.3	-5.1	-1.8
Czech Republic	31.8	11.1	-5.0	-1.8
Denmark	41.0	13.1	-6.5	-2.1
Estonia	31.1	11.0	-4.9	-1.7
Finland	39.0	12.6	-6.2	-2.0
France	40.0	12.9	-6.3	-2.0
Germany	39.0	12.7	-6.2	-2.0
Greece	32.4	11.3	-5.1	-1.8
Hungary	31.6	11.1	-5.0	-1.8
Ireland	38.3	12.5	-6.1	-2.0
Italy	38.3	12.5	-6.1	-2.0
Latvia	30.4	10.8	-4.8	-1.7
Lithuania	30.7	10.9	-4.9	-1.7
Luxembourg	40.7	13.0	-6.5	-2.1
Malta	32.4	11.3	-5.1	-1.8
The Netherlands	39.3	12.7	-6.2	-2.0
Poland	31.4	11.1	-5.0	-1.8
Portugal	33.3	11.4	-5.3	-1.8
Romania	30.3	10.8	-4.8	-1.7
Slovakia	31.2	11.0	-5.0	-1.7
Slovenia	33.3	11.4	-5.3	-1.8
Spain	34.9	11.8	-5.5	-1.9
Sweden	39.0	12.6	-6.2	-2.0
United Kingdom	38.3	12.5	-6.1	-2.0

[2] ARCADIS (2010) Assessment of the option to improve the management of biowaste in the European Union.

As consequence of the liberalisation of the German waste market, new build composting capacity was nearly exclusively windrow composting, in most cases not even roofed. The costs of windrow composting are half of those for in-vessel composting. Although in-vessel composting has a far better environmental performance, the price competitiveness seems to be the ruling factor under the actual German conditions. On the other side, a separate treatment of organic waste and other waste types is not evenly developed in the EC-member states.

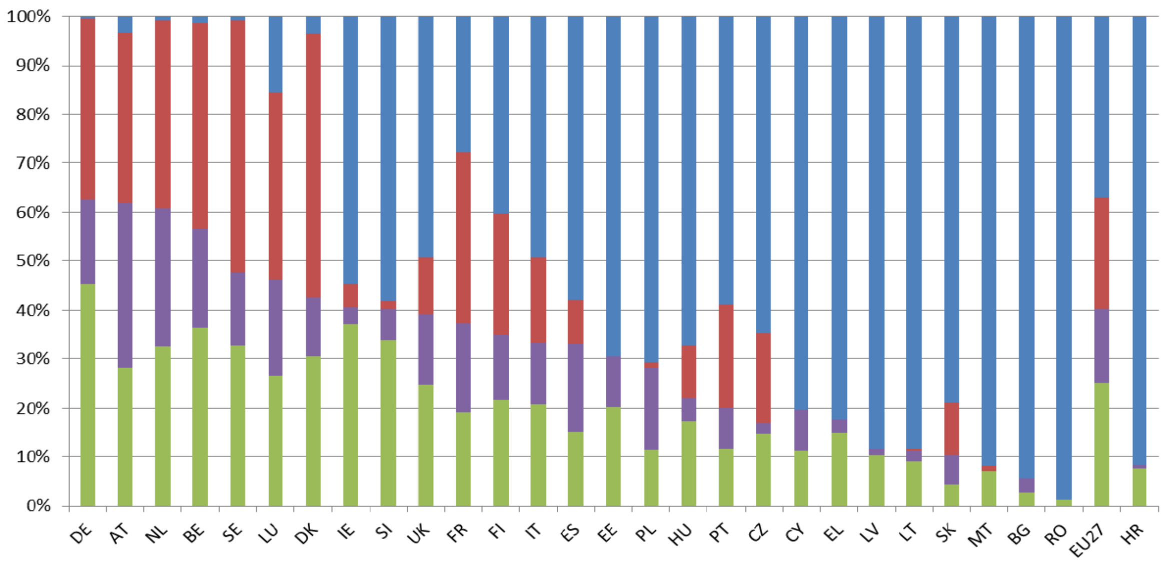

Figure 13: Municipal waste treatment in 2011 in Europe. Green-recycling; violet-composting; red-incineration; blue-landfill. Source: Eurostat

Waste wood

Waste wood has gate fees typically between € 60 per tonne of contaminated or treated wood up to a receipt of € 15 per tonne of untreated wood, this depends on the region and the season. However, the gate fee includes further costs for quality control/sorting, chopping and screening.

Land management material

Land management materials occur in various clearing and maintenance operations, as e.g. on road sides, hedge cutting, invasive species removal or environmental protection. The biomass density is often low, the occurrence irregular, the composition diverse and often moist and ash rich. An economic option to tap the potential of biomass from various landscape management operations seems to be the BioBaler. This versatile system of a forestry mulcher coupled to a round baler is suggested for clearing of e.g. invasive species from protected areas, road side green or power line tracks, and collection of pruning residues. The rough cut, round-baled biomass air-dries in road side stacks. After chopping biomass cost between € 66 and € 81 per tonne dry matter, depending on terrain, biomass density and forwarding distance.

Figure 14: The BioBaler around the clock in invasive species removing, baling of fruit tree prunings, landscape protection and removal of understory vegetation. Copyright: Anderson Group co.

Energy crops

Lignocellulosic energy crops as e.g. willow or poplar SRC, Miscanthus or cardoon are typically priced in the upper end of the comparable commodities *wood chips* and *straw* according to their combustion properties. The harvest of Miscanthus and switchgrass in late winter / early spring is 7 month after the cereal straw harvest which would save storage costs of about € 10/t. So energy crops with a € 10/t premium on top of the straw price would be competitive. This might make the production of energy crops profitable in regions of high straw demand.

TASK 1.3 LOGISTIC SIMULATION MODEL FOR BIOMASS SUPPLY TO PLANTS

In Task 1.3 a transport logistic simulation model was created that integrates different biomass types, potentials and costs free field/yard with respective handling and transport from the field to the gate of the de-central conversion plants. Transport costs were assessed for preselected vehicle-trailer combinations and for each reference feedstock type, whereas handling costs were evaluated for each feedstock type considering both handling and corresponding vehicle-trailer combinations. A case study was conducted to demonstrate when an intermediate depot between feedstock sources and conversion plants should be introduced. Facing individual infrastructure, capacities, storage periods and dry matter losses, different unit storage costs were calculated. Furthermore, data on the impact of carbon dioxide through applying these logistics processes are given.

For the determination of transport costs, the distances between feedstock source, e.g. field or collection site, and de-central conversion plant have been pre-estimated using average route lengths. Another important issue was to consider market saturation, as feedstock prices rise with increasing demand. The simulation model was adapted to allow for rising feedstock prices, once a certain rate of the available feedstock in a region is bought.

The simulation and optimization software developed in WP4 was used to perform a first optimization experiment of the transport logistics for a restricted area (France, Luxembourg, Belgium and the Netherlands). Therefore, conversion costs, as well as costs/prices for products of conversion processes where also incorporated into the simulation model. Eventually, the model is used to calculate total costs for resulting scenarios, which are described by locations and capacities of de-central conversion plants, as well as the amounts of acquired feedstock in each region and transportation targets.

The conducted scenario analysis for the first echelon demonstrated that the margin between feedstock costs and prices of intermediate products has to be high enough, otherwise the optimization algorithm down-regulates the feedstock purchases to zero, which means no feedstock is bought and neither plant costs nor transportation costs arise. In Figure 1, a solution example is shown. Based on actual logistic cost rates, a straw price of 60 €/t and a Biosyncrude value of 250 €/t, the shown scenario results in a profit of 160 M€.

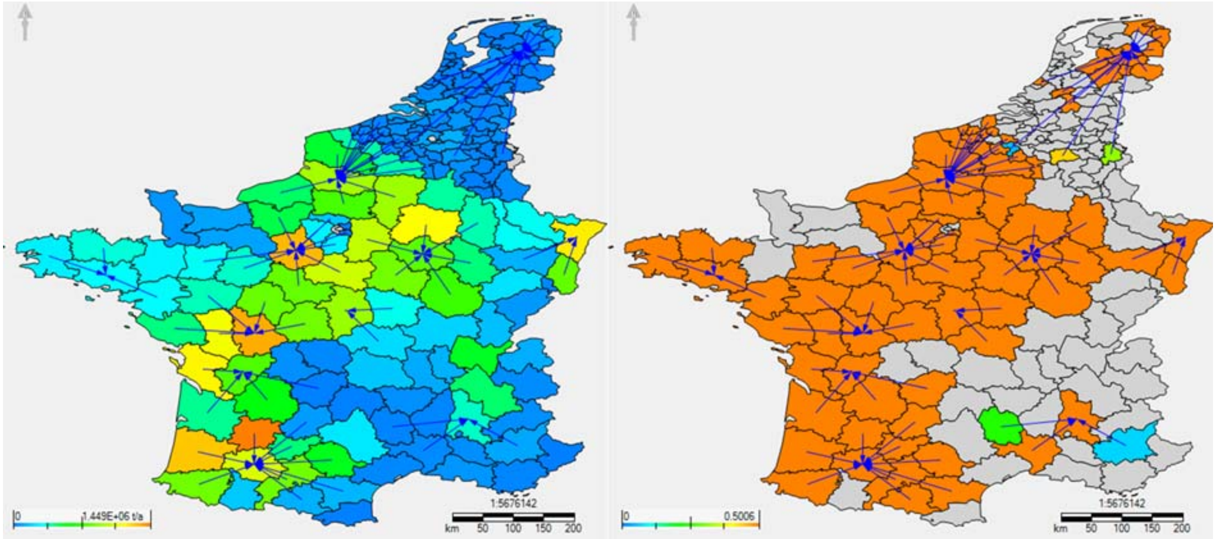

Figure 15 Solution example with feedstock potentials (left) and utilizations (right). Arrows indicate straw transports.

More details about the scenario analysis for the intermediate market and essential data collected as input for the holistic logistics model are documented in D1.5.

TASK 1.4 GEOPORTAL

The main purpose of the Geoportal is dissemination of WP1 results as digital maps in GIS formats. The Geoportal presents the analysis of the biomass potential in the EU-27 with their possible use for energy purposes. Estimates were made for spatial unit's NUTS-3.

The web application allows interactive browsing the spatial data presenting density and technical potential of the all kinds modelled biomass types.

An interactive map is based on the Web browser on the visitor side (client side), when releasing data (i.e., the server side [server-side]). Service does not require special action, any special infrastructure, databases, applications, and any plugins (Fla sh, Java), or preinstalled GIS software. The geoportal is located on IUNG servers (ServerName bioboost.iung.pl, ServerAlias www.bioboost.iung.pl bioboost.iung.pulawy.pl www.bioboost.iung.pulawy.pl.

To create the page the following formats, standards and libraries were used:

- HTML 5 - language to create the structure and content of web pages,
- CSS 3 and CSS 2.1 - specification to create the appearance of web pages,
- JavaScript - programming language,
- Leaflet.js library (open source; language library responsible for displaying the map on the website):
- Google Maps provider plugin by Pavel Shramov
- source data: NUTS-3, units with attributes (name, value identifiers) together with the geometry,
- source data in a GeoJSON format,
- develop a shortcut: Geographic JavaScript Object Notation
- result of the conversion of ESRI Shapefile format and optimize the application Mapshaper,
- with Google Maps JavaScript API ver. 3 (application programming interface)
- OpenStreetMaps Tiles API

Interactive maps are based on a web browser and are supporting operations like:

- panning and zooming
- display of selected object attributes
- change of a base layer between OpenStreetMap and Google Maps
- change the contents of overlay layer

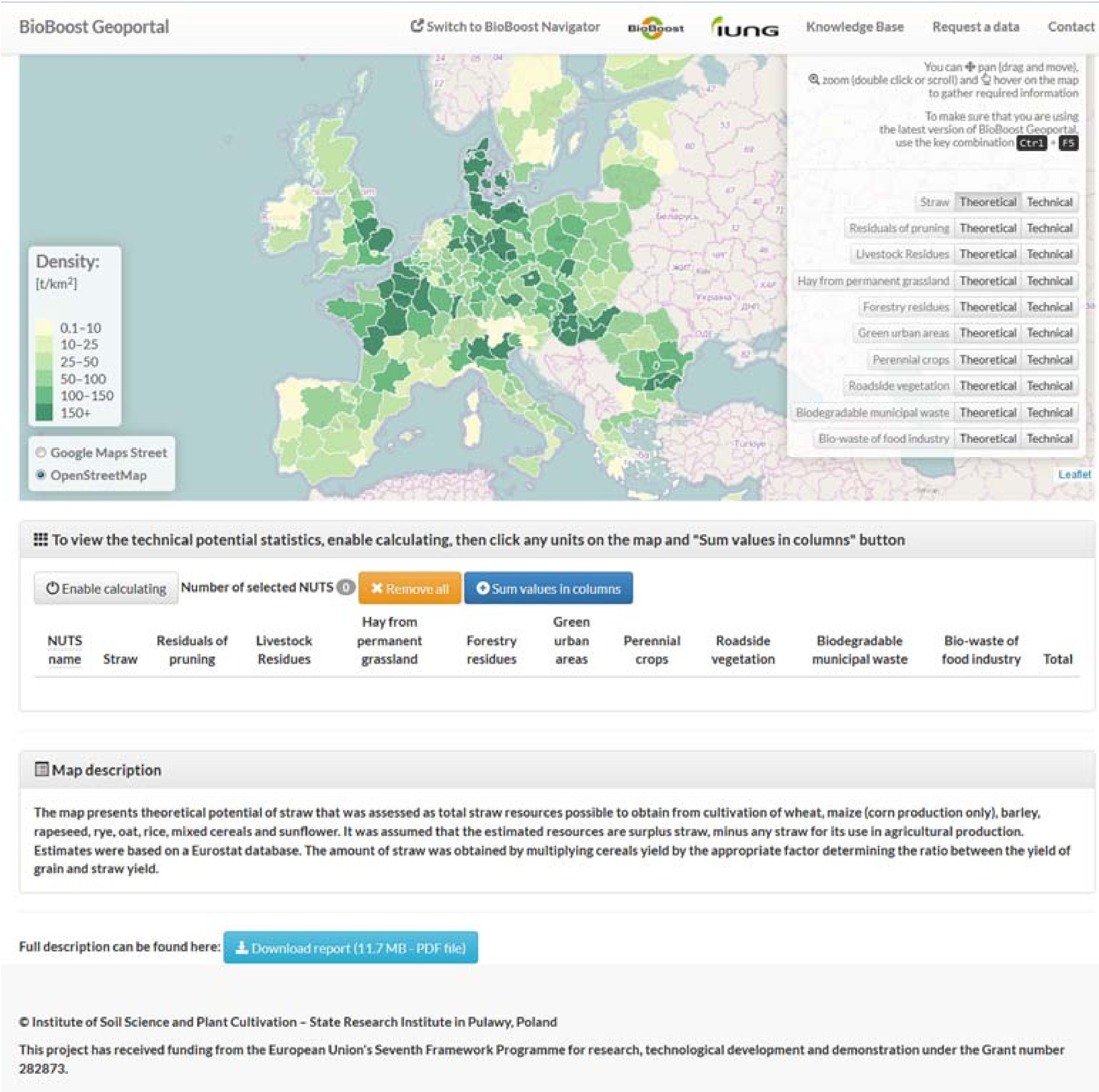

Figure 16. Geoportal interface.

The full description of geoportal can be found in the deliverable 1.6.

REFERENCES

Blasi C.Di., Tanzi V., Lanzetta M.: A study on the production of agricultural residues in Italy. Biomass and Bioenergy, 1997, 12(5): 321-331(11).

Börjesson P., Gustavsson L.: Regional production and utilization of biomass in Sweden. Energy, 1996, 21: 747-764.

Bossard M., Ferenec J., Otahel J.: CORINE land cover technical guide – Addendum 2000. EEA, Technical report No 40, Copenhagen, 2000.

Castillo A., Panoutsou C., Bauen A.: Report on biomass market segments within the transport, heat and electricity – CHP sectors for EU-27 and Member States. 2010. http://www.biomassfutures.eu/work_packages/WP2 [08.01.2013]

Edwards R.A.H., Šúri M., Huld M.A., Dallemand J.F.: GIS-based assessment of cereal straw energy resource in the European Union. Proceedings of the 14th European Biomass Conference & Exhibition, Biomass for Energy, Industry and Climate Protection, 17-21 October 2005, Paris.

Kowalczyk-Juśko A.: Zasady sporządzania bilansu odnawialnych źródeł energii i oceny zasobów biomasy. Nawozy naturalne. W: Odnawialne źródła energii. Rolnicze surowce energetyczne, B. Kołodziej i M. Matyka (red.). PWRiL Warszawa, 2012, s. 436-456.

Mahro B., Timm M.: Potential of biowaste from the food industry as a biomass resource. Eng. Life Sci., 2007, 7(5): 457–468.

Sokhansanj S., Fenton J.: Cost benefit of biomass supply and pre-processing. Research Integration Program – BIOCAP Synthesis Paper, 2006, pp. 32.

Strasil Z., Kara J.: Study of knotweed (Reynoutria) as possible phytomass resource for energy and industrial utilization. Res. Agr. Eng., 2010, 56: 85-91.

Tum M., Gunther K.P.: Validating modelled NPP using statistical yield data. Biomass and Bioenergy, 2011, 35: 4665-4674.

A. List of abbreviations

BEE – Biomass Energy Europe

CLC –Corine Land Cover

ESRI – Environmental Systems Research Institute, Inc., in Redlands, California

EUROSTAT – Statistical Office of the European Communities,

GIS – Geographical Information System

NPP - Net Primary Productivity

NUTS- Nomenclature of territorial units for statistics,

RENEW- Renewable fuels for advanced powertrains

TBFR- Temperate and Boreal Forest Resource Assessment