CONVERGE

CarbON Valorisation in Energy-efficient Green fuels

A H2020 Research and Innovation Action project, Grant Agreement number 818135

D6.1: Methodology for country specific biomass supply chains

This Deliverable 6.1 report is part of a project that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 818135

WP 6: Business Case and Supply Chain

Task 6.1: Methodology for country/region specific supply chain

Lead beneficiary	CA.RE. FOR. Engineering
Authors	Marco Ugolini, Lucia Recchia and Pietro Fino
Contributing beneficiaries	Polimi, Biorecro, ENVIRAL, Campa Iberia, ECN-TNO
Contributors	Giampaolo Manzolini, Julien Meyer, Nicole Michaelis, Petra Ondrejickova, Elena Querol

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Executive Summary

CONVERGE project involves multi-step processes in which the first one is the biomass selection as feedstock. The process scheme is very flexible and not feedstock-specific, allowing a wide range of different kinds of biomass.

This Deliverable aims to define the criteria that will be applied in the task 6.2 and follows, to set up case scenarios of low-carbon, resource-efficient and sustainable secondary biomass supply chains suitable for the commercial application of CONVERGE technology.

Though almost all parts of the biomass supply chain are interrelated, this document explains the process of developing the chain by breaking it down into several distinct areas and consider a broad framework to develop the methodology with references to non-technical barriers, availability assessment, logistic complexity for country specific supply chains.

In chapter 3 the methodology is described by a synthetic approach and by a process scheme.

The document follows with defining the framework related to this methodology.

In particular the concept of residual biomass (chapter 4) and the description of the biomass in scope for the production of the advanced biofuel (chapter 5) in respect of Directive (EU) 2018/2001 are illustrated. Here the single types of residual biomasses grouped in the main categories, Agricultural residues, Forestry residues and Agro-Forestry industrial residues and wastes are described.

In the present Deliverable (chapter 6), supply side barriers are considered with peculiar focus on biomass for feedstock supply and particular evidence has been given to the increased feedstock competition that may limit the biomass availability and increase feedstock price.

Chapter 7 deals with the assessment of the availability of the biomass to use as feedstock for the CONVERGE process to analyse at European region level. The methodology is explained and tailored to each of the residual biomass groups.

Together with the actual biomass availability it is necessary to take into account some aspects related to the supply chain such as the collection from the origin places, the transformation in the products useful for the energetic valorisation and the transfer to the place of final use. These aspects are illustrated in chapter 8. Here the importance of the spazialization of the data is also underlined and a Geographic Information Systems (GIS) approach appears to represent an appropriate tool for attaining this goal.

Moreover, the existence of bioeconomy clusters, together with their thematic focus and level of maturity, will represent key factors for the localization at area NUTS2 level of the suitable sites of implementation of the CONVERGE technology on a commercial scale.

Finally, the biomass requirements are depicted in chapter 9 which consider physical and chemical characteristics demanded by the gasification process and the specific involved reactor, traceability and sustainability in compliance with the criteria and GHG saving thresholds of the Directive (EU) 2018/2001.

As consequence of the framework described above, the strong competition assumed from today to 2030, the industrial plant will be focused to small and medium scale and not-feedstock specific; this means with short supply chains as an option for profitable and sustainable models and capable of using the greatest number of different types of biomass.

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1-Introduction

CONVERGE project involves innovative multi-step processes configuration in which the first one is the biomass selection as feedstock. The process scheme is very flexible and not feedstock-specific, allowing a wide range of biomass to be assessed.

Though almost all parts of the biomass supply chain are interrelated, this document explains the process of developing the chain by breaking it down into several distinct areas.

Due to the bulky, distributed nature of biomass and the high volumes of the relatively low energy density materials that have to be moved to the conversion equipment, the setting up of a biomass supply chain is complicated and tailored-made solutions need to be developed (Tallaksen, 2009).

There is a high potential for biomass value chains across Europe and its use as renewable raw materials for industrial applications (EIP-AGRI, 2015).

The sustainable exploitation of this potential is depending on type of biomass, biomass availability, conversion technologies and markets.

Due to a significant number of competing production plants which are anticipated to come online within 2020, it is anticipated that feedstock access will become increasingly challenging (E4tech, 2017).

So, while there should be sufficient feedstock available for early deployment of advanced biofuel plants, the potential is expected to become a relevant constraint by 2030.

For these reasons it is very important to build up biomass supply chains on the basis of sustainability criteria, partner cooperation, bioeconomy cluster approach, etc. and forecast their change in availability from now to 2030.

However, long-term deployment would need to rely more on not feedstock-specific production plants, on feedstock imports, or switching feedstock use from power to biofuel applications.

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2-Objective and scope

This Deliverable aims to define the criteria that will be applied in the task 6.2 and follows, to set up case scenarios of low-carbon, resource-efficient and sustainable secondary biomass supply chains suitable for the commercial application of CONVERGE technology.

The feedstocks in scope for the CONVERGE project are the agricultural residues, the forest and forestry product residues, the agro-forestry industrial residues and wastes. Imported feedstocks meeting the same scope are also considered.

Setting up a dependable supply chain is important because it will keep a more constant and reliable feedstock for the energy conversion process and thus limit risks to capital.
Therefore, the present document considers a broad framework to develop the methodology with references to non-technical barriers, availability assessment, logistic complexity for country specific supply chains.
Environmental sustainability is also an important concern for a biomass supply chain. Poor environmental planning can harm the environment and limit available resources. For these reasons and others, it is important that comprehensive planning for the supply chain begins before or simultaneously as the energy conversion technology is being discussed.

The large number of conversion technologies, energy uses, and different types of biomass make almost every biomass conversion project somewhat unique. In addition, the parties involved will often bring a unique set of skills to a biomass supply chain. Therefore, the objective of the document is to generalize and standardize the process. Standardization is in fact a key to lowering production costs (Tallaksen, 2009).

Objectives of the present document are:

1) To shape a methodology to identify biomass supply chains for the CONVERGE technology and processes in four distinct geographical regions: Scandinavian, North Sea, Central European and Mediterranean;
2) To identify challenges and potential barriers that might occur from now to 2030 scenario
3) To highlight the biomass requirements in terms of physical-chemical characteristics, traceability, sustainability and GHG saving
4) To shape the criteria to determine the potentially suitable locations for the thermochemical biomass conversion plant

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3- The Methodology for country specific biomass supply chain: schematic guidelines

As it will be illustrated in the further chapters of the present document, the biomass suitable for CONVERGE technology must be residual, abundant and included in an already developed and tested supply chain. Therefore, the biomass supply chains must be logistically structured in a complete and organized succession of the different production phases: extraction of residual biomass, collection, pre-treatment, storage and delivery.
For this purpose, the biomass value chain should preferably belong to an existing bioeconomy cluster or be suitable for its integration into one of them and as consequence linked to a mature, structured, innovative and dynamic ecosystem.
Finally, the compliance with the Directive EU 2018/2001 have to be guaranteed in term of environmental sustainability, traceability and GHG saving.

Other principles that could be taken into consideration for a country specific biomass supply chain with an objective advantage for the project are (Froese H.J., EIP-AGRI Workshop, 2015):

- Preference for paths of use with higher value creation
- Support for key technologies
- Compliance with social, environmental, nature and animal protection standards
- Implementation of voluntary certification standards
- Involvement well-trained and well-informed specialists
- Creation of added value in the rural area
- Improvement of efficiency (e.g. biomass flow, bioenergy production/use)
- Knowledge transfer to other regions (twin regions)
- Extension of existing value chains

The methodology of the study to select adequate, fairy and suitable biomass supply chains for CONVERGE technology is summarize in the following figure (Fig.1).

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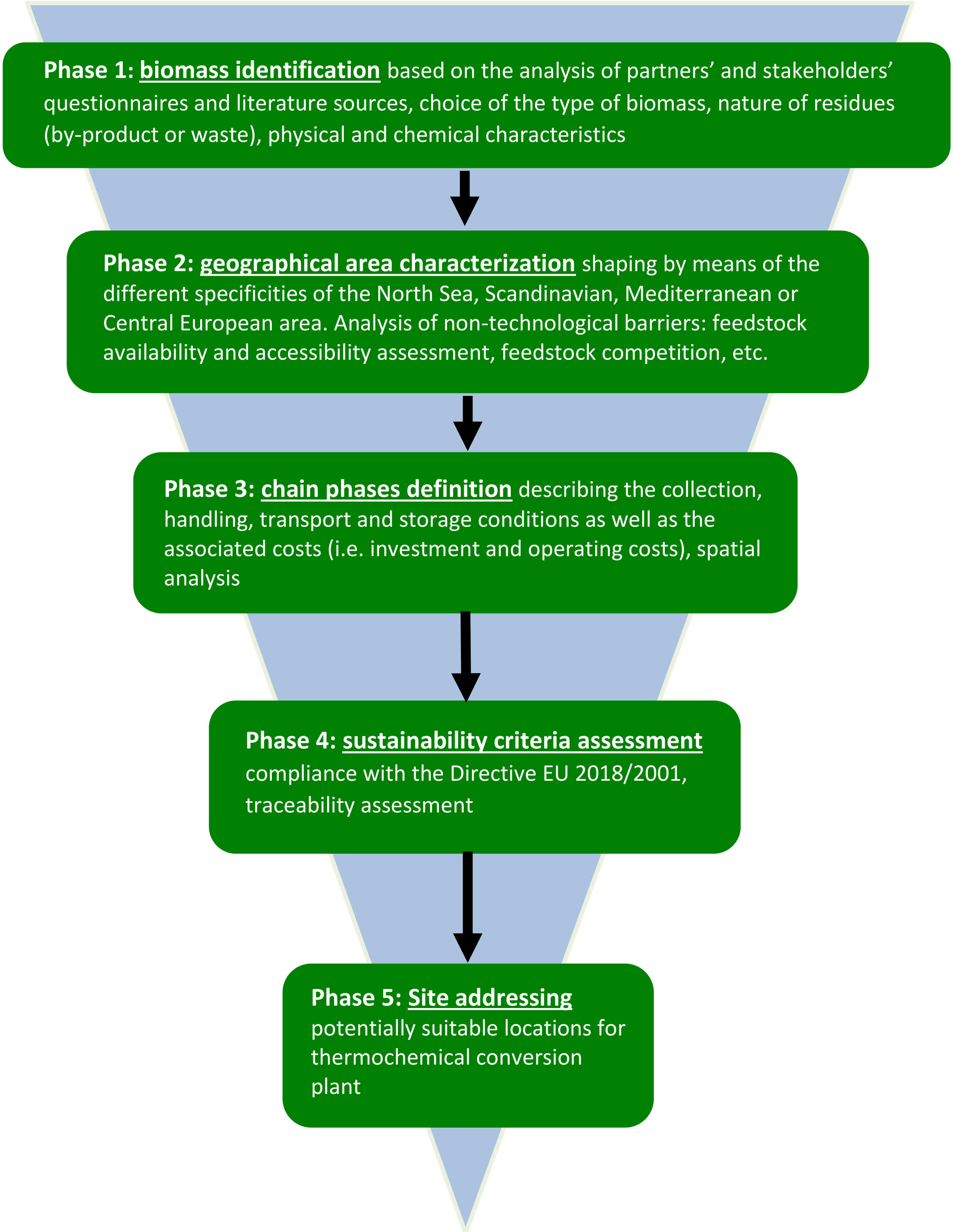

Figure 1 – Schematization of the methodology for country specific supply chain

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4-The concept of residual biomasses

The residual biomasses consist of a whole series of mechanically treated plant materials that originate from normal agricultural or forestry production. In fact, residual biomasses for energy production can derive from forestry and logging, agricultural cultivation and, indirectly, from subsequent handling activities, marketing and industrial processing.

4.1 Definition of residual biomasses from RED II

The RED II Directive 2018/2001 of 11 December 2018 will be operative starting from 1st July 2021 for the biofuels, bioliquid and biomass fuels (i.e. gaseous and solid fuels produced from biomass).
In this directive, the definitions of residues and waste can be found at the art.2:

- *waste* which means waste as defined in point (1) of Article 3 of Directive 2008/98/EC, excluding substances that have been intentionally modified or contaminated in order to meet this definition;
- *residue* which means a substance that is not the end product that a production process directly seeks to produce, not being a primary aim of the production process that has not been deliberately modified to produce it;
- *agricultural, aquaculture, fisheries and forestry residues* which means residues that are directly generated by agriculture, aquaculture, fisheries and forestry and that do not include residues from related industries or processing.

4.2 Residual biomasses classification as waste or by-product

In order to quantify the CO_2eq emissions associated with the particular biofuel/bioliquid, as we will describe later, it is necessary to check in advance if the biomass is classifiable as waste/residue or by-product.
Several aspects contribute to defining whether the residual biomasses are to be considered as waste or by-product, as listed in the following:

1. the European laws and Directives about wastes;
2. the market value of the biomasses;
3. the eventual treatment operations for the use of the biomasses in other production processes.

Waste Framework Directive, or Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 provides for a general framework of waste management requirements and sets the basic waste management definitions for the EU.
Moreover, Decision 2000/532/EC establishes a list of wastes and the classification system for wastes, including a distinction between hazardous and non-hazardous wastes.
The main useful definitions are:

- *waste*: any substance or object which the holder discards or intends or is required to discard;
- *waste producer*: anyone whose activities produce waste (original waste producer) or anyone who carries out pre-processing, mixing or other operations resulting in a change in the nature or composition of this waste;
- *waste holder*: the waste producer or the natural or legal person who is in possession of the waste;
- *product*: all material that is deliberately created in a production process;

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- *production residue*: a material that is not deliberately produced in a production process but may or may not be a waste;
- *by-product*: a substance or object, resulting from a production process, the primary aim of which is not the production of that item, may be regarded as not being waste.

In particular, the physical-chemical characteristics of a by-product are well determined, while the composition of the waste can be quite uncertain. A material must always be classified as a by-product if it is shown that the manufacturer deliberately chose to produce it, although they had the possibility of producing the main product without producing this material. Alternatively, another proof of the fact that the material may be the result of a technical choice is given by the modification of the production process, to give this material specific technical characteristics.

For a correct classification of the residual biomasses the scheme proposed in the COM(2007) 59 and reported in Fig. 2 can be used.

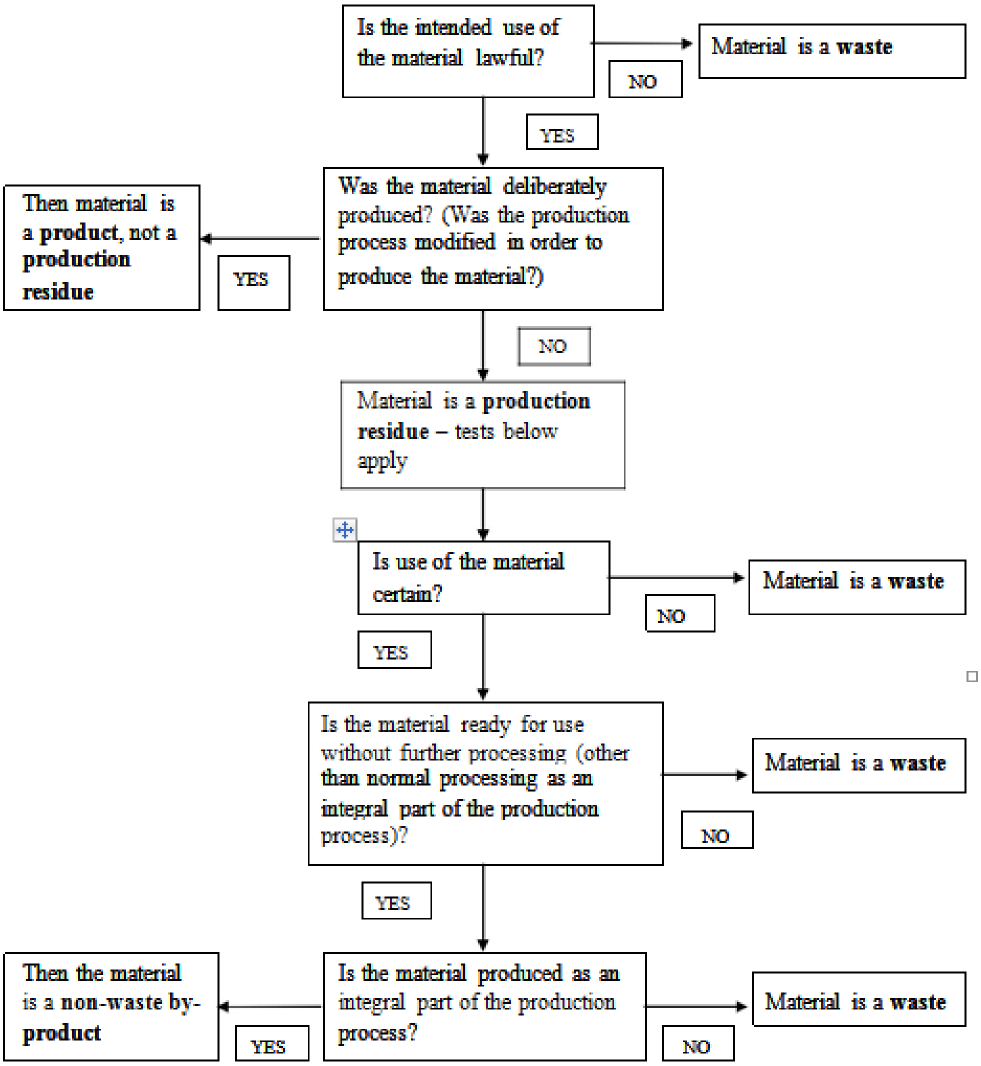

Figure 2 – The decision tree for waste versus by-product decision. Annex II of the COM (2007) 59.

5-The biomass feedstocks in scope

The biomass feedstocks in scope for CONVERGE project are wastes and residues, primarily agricultural and forestry residues, followed by agro-forestry industrial waste and residues and finally the organic fraction of municipal solid waste. Imported feedstocks meeting the same scope are also considered.
Feedstocks which are not likely to be part of the present project (such as food crops, non- food energy crops, used cooking oil and animal fats), as well as others with very limited availability in the EU are not included in this deliverable.

The RED II Directive (EU) 2018/2001 at the art.2, gives the following definition of advanced biofuel: *biofuels that are produced from the feedstock listed in Part A of Annex IX (Table 1).*
According to the Article 25 in order to mainstream the use of renewable energy in the transport sector, each Member State shall set an obligation on fuel suppliers to ensure that the share of renewable energy within the final consumption of energy in the transport sector is at least 14 % by 2030 (minimum share). Within the minimum share, the contribution of advanced biofuels and biogas produced from the feedstock listed in Part A of Annex IX as a share of final consumption of energy in the transport sector shall be at least 0,2 % in 2022, at least 1 % in 2025 and at least 3,5 % in 2030.
Moreover, according to the Article 27 "**Calculation rules with regard to the minimum shares of renewable energy in the transport sector**" for the purposes of demonstrating compliance with the minimum shares referred to in Article 25, the share of biofuels and biogas for transport produced from the feedstock listed in Annex IX may be considered to be twice its energy content.

Table 1 – List of feedstocks able to double the GHG savings for biofuels and biogas for transports.

Feedstock for biogas for transport and advanced biofuels (Annex IX - Part A)	*Feedstock for biofuels and biogas for transport (Annex IX - Part B)*
(a) Algae if cultivated on land in ponds or photobioreactors; (b) **Biomass fraction of mixed municipal waste**, but not separated household waste subject to recycling targets under point (a) of Article 11(2) of Directive 2008/98/EC; (c) **Biowaste** as defined in point (4) of Article 3 of Directive 2008/98/EC from private households subject to separate collection as defined in point (11) of Article 3 of that Directive; (d) **Biomass fraction of industrial waste not fit for use in the food or feed chain**, including material from retail and wholesale and the agro-food and fish and aquaculture industry, and excluding feedstocks listed in part B of this Annex; (e) **Straw**; (f) Animal manure and sewage sludge; (g) Palm oil mill effluent and empty palm fruit bunches; (h) Tall oil pitch; (i) Crude glycerine; (j) Bagasse; (k) **Grape marcs and wine lees**; (l) **Nut shells**; (m) **Husks**; (n) **Cobs cleaned of kernels of corn**; (o) **Biomass fraction of wastes and residues from forestry and forest-based industries**, namely, bark, branches, pre-commercial thinnings, leaves, needles, tree tops, saw dust,	(a) Used cooking oil; (b) Animal fats classified as categories 1 and 2 in accordance with Regulation (EC) No 1069/2009.

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cutter shavings, black liquor, brown liquor, fibre sludge, lignin and tall oil; (p) **Other non-food cellulosic material**; (q) **Other ligno-cellulosic material** except saw logs and veneer logs.	

Among the feedstocks listed in Annex IX Part A, the following list is considered interesting to be investigated as feedstock for the CONVERGE technology:

1. Straw
2. Grape marcs and wine lees
3. Nut shells
4. Husks
5. Cobs cleaned of kernels of corn
6. Biomass fraction of wastes and residues from forestry
7. Biomass fraction of wastes and residues from forest-based industries
8. Other non-food cellulosic material
9. Other ligno-cellulosic material
10. MSW (Biomass fraction of mixed or separate municipal waste)
11. Biomass fraction of industrial waste

Some waste biomass feedstocks such as tallow and used cooking oil (RED Annex IX Part B feedstocks) are outside of the scope of this report as production of biodiesel from these feedstocks is already well established, and they are unlikely to be eligible as a feedstock for development fuels[1].
Perennial energy crops, such as Miscanthus and short rotation forestry, are also excluded from the project scope. They are not anticipated to be a significant resource by 2030[2] (Matthew A. and McDermott F., 2012), though could complement other feedstocks to feed a plant.

The single types of residual biomasses can be grouped in three main categories, as summarized in the table 2:

- ☐ Agricultural residues
- ☐ Forestry residues
- ☐ Agro-Forestry industrial residues and wastes

[1] A 'development fuel' is a fuel made from a sustainable waste or residue (subject to waste hierarchy test and excluding UCO and tallow) or a non-biological renewable fuel. This is subject to an upcoming consultation of changes to the Renewable Energy Directive (RED). Hood, J. (2016).

[2] Uptake of perennial non-food energy crops has been limited due to lack of specialist planting and harvesting equipment, previously poor establishment and management practices, limited local supply infrastructure, high upfront establishment costs and low economic viability for farmers.

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Table 2 - Types of residual biomasses by Dir. (EU) 2018/2001 for advanced biofuel

Category of residual biomasses	Definitions by Dir. (EU) 2018/2001	Types of residual biomasses by Dir. (EU) 2018/2001 for advanced biofuel
Agricultural residues	Agricultural biomass: biomass produced from agriculture as indicated in Article 2, point 25	Straw Grape marcs and wine lees Nut shells Husks Cobs cleaned of kernels of corn Other non-food cellulosic material Other ligno-cellulosic material
Forestry residues	Forest biomass: biomass produced from forestry as indicated in Article 2, point 26	Biomass fraction of wastes and residues from forestry
Biomass from agro-forestry industrial residues and wastes	Waste, bio-waste and residues (as indicated in Article 2, point 23, 29 and 43 respectively) originated b agro-forestry industrial process	Biomass fraction of wastes and residues from forest-based industries MSW (Biomass fraction of mixed or separate municipal waste) Biomass fraction of industrial waste

5.1 Some specifications for agricultural residues

Residues from agricultural biomass originate from the operations carried out at the end of the crop cycle for the annual crops (cutting, harvesting, etc.) or from the operations carried out with varied periodicity on the multi-year crops (pruning and explanting).
Residual biomasses from herbaceous crops are mainly cereal straws such as wheats, oats, barley, rye, rice, as well as maize stalks and corncobs and sunflower stalks.
The main tree crops taken into consideration are: olive, vine, apple, pear, peach, nectarine, plum, apricot, citrus, hazel, almond and actinidia.
The parts that can be used for energy transformation can be collected directly in the field such as the grain stalks (wheat, corn, rice, etc.), corn cobs and industrial crops (sunflower, tobacco), from the processing of the product (the stalks of the grapes, bracts, rice husks, glumes and glumettes) or from branches and trunks derived from pruning and explants at the end of the crop cycle of fruit plants. Residues that cannot be recovered for technical reasons (roots, fine materials, leaves), for economic or chemical-physical reasons (not suitable for energy transformation processes) are not considered useful for energy transformation.
For all these crops the residue can undergo more or less important quantitative variations in the time from year to year.
The estimated residues of these category will not include the shells of dried fruits in fruit pits destined for the canning sector which will be discussed in the chapter on agro-industry residues.

The crop residues have intrinsic characteristics that make them different both from the main products from which they derive and from any co-products. The main differences concern:
- composition of the dry substance;
- water content at the time of collection;
- apparent volume mass;
- lower calorific value (LHV);
- content of ash and other minerals.

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A generic biomass supply chain to be analysed for agricultural residues is reported in Fig. 3, indicating the phases of collection, handling, transport and storage.

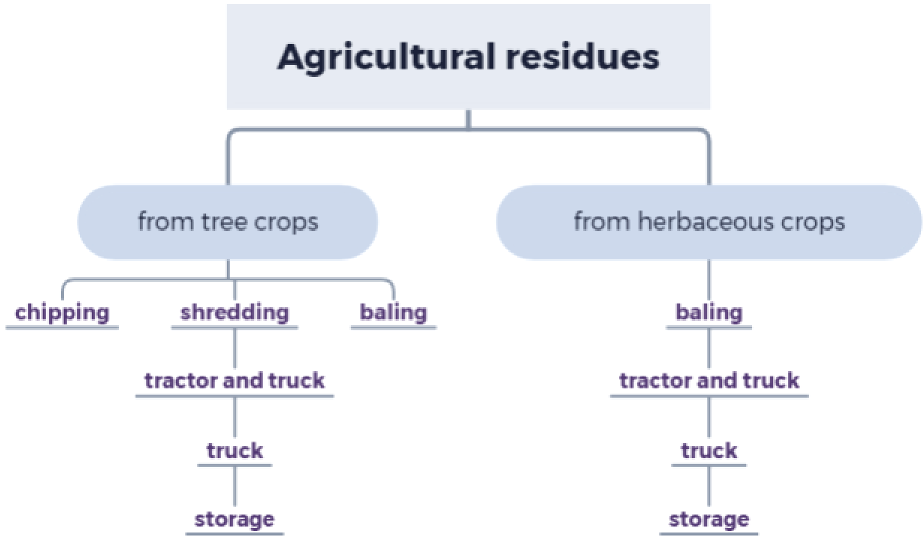

Figure 3 – Generic supply chain for different typologies of agricultural residues.

According to Ricardo (2017) the amount of feedstock that is not currently used, taking into account any additional sustainability or logistical constraints on feedstock access, is considered to be the amount available for biofuel production.

However, currently, it is necessary to keep in mind that the convenience to the energetic valorisation of many agricultural, forestry and residues of agro-industrial operations must be compared also with the impoverishment of organic substance that the soils can suffer for the excessive removals operated.

This aspect has its greatest value for herbaceous crop residues where often the landfill constitutes a source of chemical, physical and biological fertility for agricultural land.

5.2 Some specifications for forestry residues

The by-products of the forest consist of all those residues that result from forestry and logging (cutting, preparation, limbing, debarking, de-rigging, etc.), like branches, slush, bark, leaves and roots.

One of the main principles of sustainable forest management is to maintain the stability of the ecosystem services they provide. Along with this principle, in order to sustain the productivity and sustainable supply of products, the rate of wood harvesting should not be higher than its production rate over time (FAO, 2017).

As indicated in Directive (EU) 2018/2001, art. 29 point 6, the production of forest biomass shall meet criteria to minimize the risk of using biomass derived from unsustainable production and respect the legality of harvesting operations.

To shape more precisely the residual forest biomass it is convenient to refer to the definition of the Ministère des Forêts, de la Faune et des Parcs du Québec in *Developing the Value of Forest Biomass: An Action Plan* (2009) where forest biomass is referred to “trees or portions of trees included in the allowable cut that are not subject to allocation or reservation [e.g. supply guarantee], in addition to the trees, low woody plants, crowns, branches, and leaves that are not part of the allowable cut.”

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This definition helps us to distinguish (legally specifies in Quebec) what is convenient to use as raw material for manufacturing wood residues or other bio-products and what should be excluded.
Five potential forest biomass sources are consistent with the previous definition:

- harvest residues (branches and tops left in cutting areas);
- certain types of hardwood trees of low quality (i.e. birch and poplar), unsuitable for traditional forest products such as lumber or some paper grades;
- small diameter/natural defect stem wood unsuitable for lumber or paper production;
- deadwood (dry but undamaged wood);
- severely defoliated trees or dead trees from pathogens and diseases.

The whole plant harvesting is usually applicable for medium-sized plants (coppices or thinning); it provides for the removal of the whole plant from the wood and the subsequent operations are carried out at the warehouse, where the resulting material (branches and tree top) become usable.
A generic biomass supply chain to be analysed for forestry and forest product residues is reported in Fig.4.

Figure 4 – Typologies of forest and forestry product residues.

5.3 Some specifications for agro-forestry industrial residues and wastes

Potentially, the sectors of origin and the types of residues and by-products for the CONVERGE project are various.
It should be noted that choice of feedstock may depend on or influence the conversion technology to be deployed. In general, thermochemical processes are less sensitive to variable feedstock composition,

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compared to biochemical conversion[3], and more able to treat contaminated or heterogeneous waste (such as MSW), but often with equipment maintenance and product clean-up issues (E4tech, 2017).

This category includes the food processing industries that produce waste in quantities and qualities suitable for a possible energy use. The feedstock to be considered is related to the processing of products typical of certain geographic areas such as wine and alcoholic beverages, oil, rice, and, to a lesser extent, of the meat processing industry, the dairy industry and the canning industry (ENAMA, 2010).
In this sector the most significant types of residual biomass, compared to their potential for recovery as a possible energy source, can be classified as follows:

- ☐ Residues of the oil industry: virgin and exhausted pomace
- ☐ Residues of the alcoholic beverage industry: grape marc, fresh and exhausted pomace, lees
- ☐ Residues from the rice industry: chaff, husk, etc.
- ☐ Residues of the canning industry: fresh fruit pits, dried fruit shells, seeds and tomato and potato peels

These vegetable scraps can be used for energy recovery with different methods depending on their chemical characteristics; waste of the same type, but obtained from different production processes can have profoundly different characteristics. The most important parameters to determine suitability for different energy uses are humidity, PCI and the C / N ratio. A possible classification is shown in the following table (Tab. 3):

Table 3 - Functional parameters for energy conversion for some agro-industrial residue or waste

Process	C/N Ratio	Moisture (%)	Residues
Biochemical conversion (biogas production)	≤ 30	≥ 50	Distillation boards; vegetation water, fruit and vegetable waste, slaughter waste, whey
Thermochemical conversion (combustion or gasification)	> 30	< 50	Shells, hazels, exhausted pomace, grape seeds

Moreover, as illustrated in Fig.4, the supply chains should indicate if and how the biomass residues will be treated from a chemical and/or physical point of view, highlighting the needed equipments/machines and the associated costs.

Forestry industrial residues and wastes can be addressed to primary and secondary wood processing. Primary processing includes the production of roundwood, lumber, and composite panel products. Consequently, residues from primary processing include bark[4], sawmill slabs and edging, sawdust[5], and peeler log cores.

These residues are ready for utilization because generally they are clean, uniform and low in moisture content.

[3] due to the specialised nature of the microorganisms involved
[4] Bark is the outermost part of woody stems and branches and makes up about 9 to 15 percent of a log's volume.
[5] Sawdust is the wood residue created when a log is cut by saw to make lumber.

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Secondary processing utilizes primary forest products and further manufactures them into other products. Residues from secondary processing include sawdust, shavings, wood chips, sander dust, and solid wood residues.
Manufacture of wood and wood products mainly refers to parquet, carpentry, furniture, panels and veneers industries.

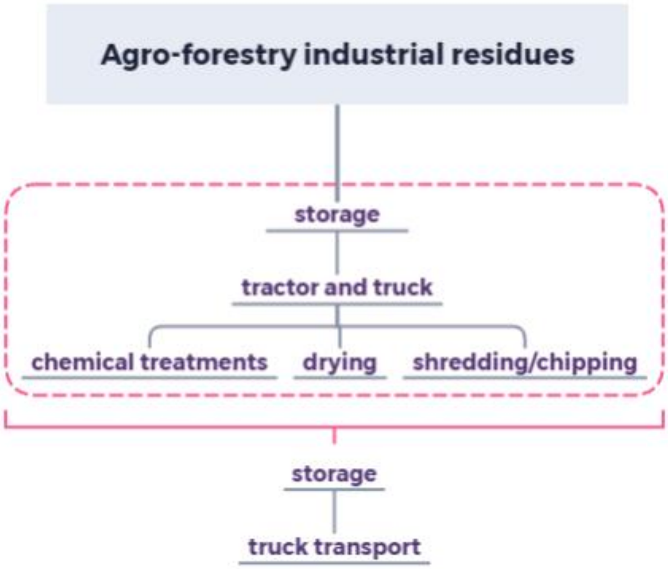

Figure 5 – Typologies of agro-industrial residues and wastes.

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6-Building up biomass supply chains: main non tech-barriers

6.1 Methodology for defining the biomass supply chains

As reported in Fig. 6, the biomass supply chains will be defined developing the following steps:

1. the biomass identification, based on the analysis of partners' and stakeholders' questionnaires and literature sources;
2. the geographical area characterization, shaping in order the different specificities of the North Sea, Scandinavian, Mediterranean or Central European area. Moreover.
3. the chain phases definition, describing the collection, handling, transport and storage conditions as well as the associated costs (i.e. investment and operating costs). Particularly, the usual agricultural machines and transport means will be assumed, indicating also their operating capacity, annual operation time, power, fuel consumptions.

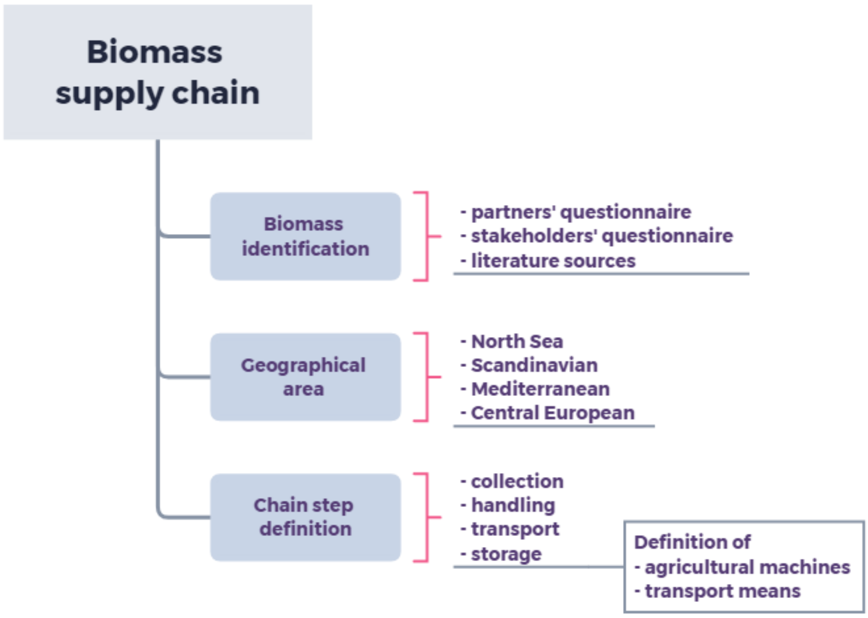

Figure 6 – Definition of the biomass supply chains.

6.2 Main Barriers

The thermochemical conversion of biomass to liquid biofuel proposed by CONVERGE concept has to face a number of significant technical barriers and development to progress the technologies towards commercial scale.

Besides this, a number of non-technical barriers to commercial development and deployment has to be faced.

The non-technical barriers can be associated to supply side and demand side barriers, and include a number of sub-categories (E4tech, 2017):

- Supply side: project finance, feedstock, infrastructure, environmental and social aspects (D6.1 and 6.2)
- Demand side: market, policy and regulation (D6.3 and 6.4)

In the present Deliverable (D6.1), the supply side barriers are considered with peculiar focus on biomass for feedstock supply, infrastructure, environmental and social aspects, as shown in Table 4.
Secondly to project finance (to be analyzed in D6.3) feedstock supply barriers play an important part in the overall project success and the performance and profitability of a plant over time.
Given that a technology is usually designed specifically for a certain feedstock, addressing and mitigating feedstock barriers is critical.

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Table 4 - Barriers related to agriculture and forestry residues and processing co-product

Barrier Type	Barrier	Significance	Impact	Sector/routes most affected
Biomass Feedstock	Variable feedstock quality (lack of specifications/standards)	May impact plant performance and guarantees. Reduces amount of feedstock available and increases price.	High – particularly for MSW	-
	Feedstock availability	Availability relates to the abundance of feedstock relative to project needs, and variation in production over time. These factors can increase project risk, and impact production security.	Medium – highly site & feedstock specific	-
	Feedstock accessibility	The logistics and quality of feedstocks dictates Infrastructure investment requirements.	Medium – highly site & feedstock specific	-
	Feedstock competition	Increased feedstock competition may limit availability and increase feedstock price. Severely limited access (e.g. supplies locked into 25 years waste contracts) could deter investment.	Medium – but increasing (especially where long-term waste contracts are in place)	MSW routes
	Cost variability	Feedstock cost forms a major part of production costs, and impacts price of end product. Uncertain prices heavily impact profitability.	Low – unless outside of a supply contract	-
Infrastructure	Immature supply chain for feedstocks	Increases project risk as well as costs, potentially creating unfeasible project economics. Impacts ability to procure sufficient feedstock volumes. Supply logistics will become more important as development accelerates & feedstock competition increases.	Medium	Straw, manure, forest residues more affected than MSW (given established waste management chains)
	Immature supply chain for technology components	Increases project risk if large items of equipment are not available in time, need to be imported from abroad, or end up costing significantly more than first budgeted.	Medium	-
	Batch supply of intermediates from multiple locations could be problematic for refiners	Processing multiple batches together (to form a homogenous fuel product) requires additional time/cost for individual batch testing.	Low	Those relying on upgrading, e.g. pyrolysis and HTL oils
Environmental and social	Unclear sustainability characteristics of feedstock (e.g. soil quality, water, forestry carbon debt, biodiversity)	Some advanced biofuel feedstocks may not be sustainable in the long-term in certain regions. Policy makers may change categorisation/ accounting rules in future.	Medium – depending on feedstock	-
	Lack of factual knowledge about advanced biofuels (public awareness & perception)	Public opinion may change, or not realise the benefits compared to 1G biofuels. Policy may change categorisation/ accounting rules in future.	Medium	-
	Environmental sustainability policy implementation	Compliance with standards admin may increase operating costs; may be a barrier to entry to smaller players. Inconsistent approaches globally may lead to inconsistent results & market fragmentation.	Low	-
	Site planning permission and building permits	Results in delays in project development.	Low	-

(Source: E4tech, 2017)

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A short description of the main barriers for agriculture and forestry residues follows below.

Considering the agricultural residues and processing co-products the main barriers are economic challenges due to price fluctuations and competition from other uses of the residues.
A second point to address is cultural issues, for example due to the lack of communication between industries and the primary sector and the skepticism of farming communities about collecting residues.
Other aspects to consider as barriers for Agricultural residues and processing co-products:

- biomass use for producing biofuels and biochemicals is a relatively new business and it faces resistance from farmers;
- lack of technical and non-technical know-how, concern about soil depletion due to residues collection;
- the different steps in the biomass supply chain are complex, and logistics, organisation and management are recognised as main challenges;
- the lack of information regarding successful business cases.

Referring to the residues and processing co-products from forestry, the top barriers are economic:
1 woody biomass and forestry residues tend to be expensive in Europe and the competition from imported biomass is high.
2 the structure of forest ownership, public or private, (i.e. parcelling out), is seen as a structural barrier.
Less concern has to be given to technical challenges, even if a long list of technical barriers could be listed including the productivity of crops yield and the necessary know-how to develop innovative value chains. Instead in the forestry sector, technologies and knowhow are largely available, demonstrating that it has reached a certain level of maturity in Europe (EIP-AGRI, 2015).
Other aspects to be considered as barriers for Forestry residues and processing co-products are:

- forestry resources are distributed unevenly in Europe;
- production is poorly organized in some countries;
- the structure of the ownership of forests can be an issue (e.g. parcelling out, small size of exploitations);
- technological barriers (Mediterranean countries) limit the use of forestry biomass (e.g. lack of harvesting techniques), of side-products and of co-products;
- woody biomass for the bio-based economy suffers for competition with cheaper, non-renewable alternatives and with cheaper imported woody biomass; so that in some cases in Europe, forestry residues are not even collected.

6.3 Market overview and understanding

Concerning **agricultural residues**, the greatest potential in Europe are cereal straws. The current EU market for residues is of medium size and has a potential of more than 100 million tons; the average price of residues seems in line with industry needs (50-100 €/ton).
Forestry residues are largely available in Europe. The main subcategories are slashes, un-merchantable wood and processing co-products with a potential of more than 100 million tons. The average price of forestry residues (< 50 €/ton) make them very appealing for bio-based products (EIP-AGRI, 2015).

Investigations conducted at European level have revealed that stakeholders of the supply chains show a high level of knowledge regarding indirect land use change (ILUC) and sustainability issues. Moreover, they have a good understanding of the bioenergy sector (i.e. biofuels, heat & power and biogas), while

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for biofuels, they did not consider that second generation products should have a higher market price compared to first generation products.

More details are listed in the following table (Tab. 5).

Table 5 – Experience and market understanding: biomass production and availability in Europe
(Source: EIP-AGRI, 2015)

	Feedstock type	EU Market size	Average price (€)	Profitability	Availability	Potential	Sustainability certification
Agricultural residues	Wheat straw, other straws, stover, cobs, co-products	Medium	50-100	Medium	> 100 million tons	High	Good knowledge of ILUC discussion; Medium experience with sustainability certification schemes; High sustainability for agricultural residues.
Forestry residues	Slash and small trees from thinning and clearings, slash from final fellings, un-merchantable wood and processing coproducts	High	< 50	Medium	> 100 million tons	Medium-High	Medium knowledge of ILUC discussion; Medium/high experience with sustainability certification schemes; High sustainability for forestry residues.

6.4 Competition for Biomasses

The assessment of waste and residue feedstock potential for locally available supplies, in general, indicates that currently the greatest opportunities are the biogenic fraction of household, commercial and industrial wastes; straw from cereal cropping; and the co-products and residues of the timber value chain. As previously indicated due to a significant number of competing plants which are anticipated to come online between now and 2020, it is anticipated that feedstock access will become increasingly challenging (E4tech, 2017).
So, while there should be sufficient feedstock available for early deployment of advanced biofuel plants, the potential is expected to become significantly more constrained in the period up to 2030.

Based on the assessment of all the technologies currently under development, given their current TRLs, it is likely that only a small number will be available for production in the near-term and many routes will not commission their first commercial plant until after 2022 and reach full operation until about 2025 (Table 6).
Moreover, the construction and operation facilities will also depend on factors beyond just the technology status such as feedstock availability, financing, long-term policy support etc.

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Table 6: Current conversion biomass projects in Europe (Source: E4tech, 2017)

Company & plant location	Feedstock	Product(s)	Scale	Status (Start date)	Production capacity (ML/yr)	Technology
Kaidi (Finland)	Forest residues	FT diesel, jet	First commercial	Planned (2020)	256	Gasification with Fischer-Tropsch synthesis (5)
TÜBİTAK MRC - ENERGY INSTITUTE - TURKEY	Hazelnut shell, olive cake, wood chip & lignite	FT liquids	Pilot	Operational (2013)	0.32	
BioTfuel - Uhde (France)	Torrefied wood	FT diesel, jet	Demo	Under construction (2017)	0.08 (slipstream)	
BIOENERGY 2020+ (Austria)	Syngas slipstream Frontline Bioenergy (USA) from wood gasification	FT liquids	Pilot	Planned (~2018)	0.05	
Velocys (Austria)	Syngas slipstream from wood gasification	FT diesel	Pilot	Finished (2011)	0.03	
BTG (Netherlands)	Wood biomass and/or residues	Pyrolysis oil	First commercial	Operational (2015)	15.1	Fast pyrolysis and upgrading (5)
SynSel / CRI (Norway)	Forest residues	Gasoline, jet, diesel	Demo	Planned	2.1	
Bioliq / Karlsruhe Institute of Technology (Germany)	Wood, waste wood, straws, hay	Pyrolysis oil	Pilot	Operational (2007)	1.8	
Next BTL / Future Blends (UK)	Lignocellulosics	Upgraded pyrolysis oil	Pilot	Operational (?)	0.03	
LignoCat / VTT Fortum / UPM / Valmet (Finland)	Pyrolysis oil	Upgraded pyrolysis oil	Pilot	Planned (likely at Joensuu plant within 5 years)	Not yet public	
Altaca / SCF Technologies (Turkey)	Sewage sludge, food waste	Bio-crude	Demonstration	In commissioning	9.1	Hydrothermal liquefaction and upgrading (6)
Biochemtex / ETH / KLM / RECORD (Italy)	Lignin	Jet	Demonstration	Planned (2018)	2.5	
Next Fuels (Netherlands/SE Asia)	Palm waste	Bio-crude	Pilot	Planned	0.42	
Shell HTU (Netherlands)	Wastes, wood, residues	Bio-crude	Pilot	Finished (1999)	0.05	
Steeper Energy/Aalborg Uni (Denmark)	DDGS, peat, wood, tall oil	Bio-crude	Pilot	Operational (2013)	0.02	
Chalmers University (Sweden)	Lignin	Bio-crude	Pilot	Operational	0.00	
Swedish Biofuels (Europe)	Ethanol (from wood, wastes)	Jet fuel	Demo	Planned (2018)	6.2	Catalytic conversion of 2G alcohols to hydrocarbons

The following figure (Fig. 7) provides the projected global capacity increase within 2030 in a 'realisable maximum' scenario. This is useful to understand how the competition for biomass will affect the availability of biomass in the future (E4tech, 2017).
As expected, those technologies that achieve the greatest capacity globally are those with the highest TRL (gasification + FT, pyrolysis + upgrading), or those able to be scaled up the fastest (catalytic conversion of 2G alcohols).

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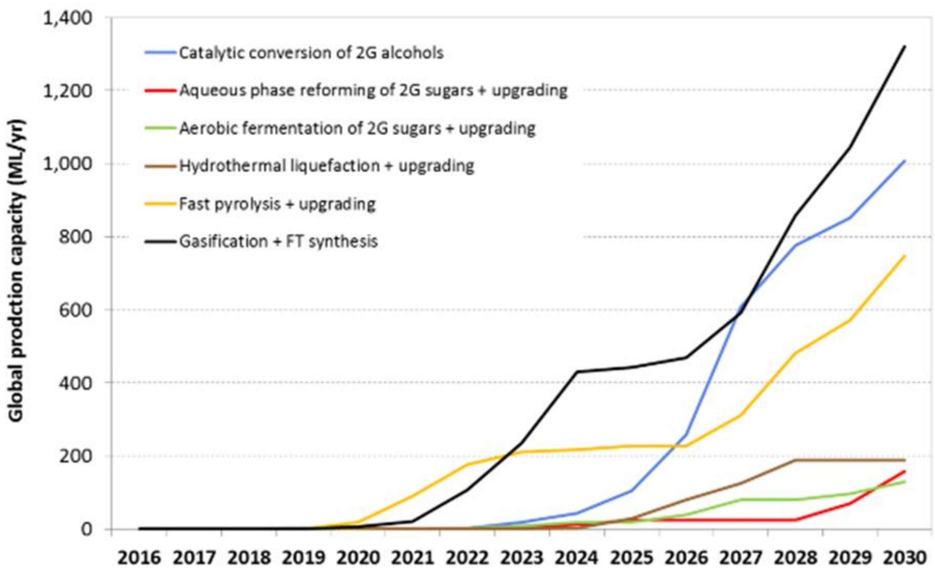

Figure 7 - Projected global capacity ramp-up to 2030 in a 'realisable maximum' scenario (Source: E4tech, 2017)

According to the above mentioned considerations, an investigation will be carried out about the current and future (to 2030) reuse chains.

The reuse chains investigated will be:

1) sectors of traditional use of residues;
2) the current and future bio-energy sector;
3) the green chemistry and bio-materials sector.

The data collection will be based on:

- ☐ Agricultural statistical databases AGRISTAT National, Chambers of Commerce, FAOSTAT Eurostat review articles;
- ☐ European sector publications, projections on the construction of the plants currently under construction and implementation on a commercial scale
- ☐ Contacts (questionnaires and interview) with national stakeholders, referring to the bio-economy clusters on thematic focus as Biomass supply residues and wastes, Biomass processing and conversion, Biobased products, etc.

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7-Feedstock availability assessment

One of the critical issues in shaping a supply chain is the availability assessment of the biomass. It will consist on the research, collection, analysis, comparison and in the organization of the available data, both through a compilation work and through the direct contribution of the main stakeholders, in order to provide a single, standardized and adequate level of knowledge useful for a critical and constructive assessment of the potential and effective availability in biomass of the European territory useful for the implementation of the CONVERGE technology on a commercial scale.

7.1 Methodology for feedstock availability assessment

The quantities of crop residues annually recoverable depend on numerous factors including: cultivated areas, crop productivity, harvesting methods and operating conditions, biomass mobilization and legislation. In addition, the seasonality of the collection and the possibility of storage of the by-product also affect availability.

The assessment of the available biomass to use as feedstock for the CONVERGE process is a very important issue to analyse, at European region level. In fact, the overall potential feedstock availability and regional variations are necessary to establish potential suitable locations for production plants, and whether feedstock availability or access will be a constraint to advanced fuel production.
A regional breakdown of the current feedstock availability assesses whether the volumes in a given area might be able to supply a commercial-scale conversion plant (E4tech, 2017).
Therefore, for each feedstock the current EU production shall be analysed, in task 6.2 and presented in D6.2, along with details of how this feedstock is used in the EU.

Data on feedstock availabilities will be taken exclusively from publicly available literature, for current production and, if possible, for the projections up to 2030.
For the present task, we consider that a first commercial-scale advanced drop-in biofuel plant is likely to need at least 200 –500 ktpa of feedstock (to produce about 35 – 130 million litres of fuel, depending on the technology, E4tech 2017), but the CONVERGE technologies could potentially operate commercially at smaller scales.

The methodology adopted and the information sources that will be consulted for the quantification of the availability of residual (agricultural) biomasses will be conducted on an extensive bibliographic research carried out on the basis of the competences of the members of the CFE working group and of the partners of Task 6.1 and 6.2, as well as following consultations with operators and experts in the sector.
It will be illustrated how the different amounts of residues occur for a given biomass along its specific value chain (Ćosić B. et al., 2016).
In order to have homogeneous and standardized information throughout the EU countries, the basic data (cultivation surfaces, primary productions and related residues productions) will be taken both from EUROSTAT sources and from estimates and evaluations of the main trade associations of producers at national level.
For all the types of biomass the calculations will be completed for every EU28 country, using data that is collected from EUROSTAT at regional level (NUTS2 Area). Import and export data will be collected from FAOSTAT
The survey will cover a period of at least four years, from 2015 to 2018, so that an estimated average value will be minimally affected by the annual fluctuations of the surfaces invested and the productions attributable mainly to climate factors and market conditions ENAMA 2010.

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The bibliographic analysis will allow us to analyze the most relevant studies on the subject, carried out in recent years by qualified organizations and research centers (e.g. in Italy ENEA, CRPA, RENAGRI, CNR, University, etc.) in order to be able to have an exhaustive picture of data, indexes, methodologies adopted in similar studies.

7.1.1 Availability of residues from agricultural biomass

From the application of the above described criteria the potential availability of agricultural residues produced annually will be calculated. These potential availabilities will then be followed by reductive corrections to define the quantities, which, in relation to a series of evaluations carried out, could actually be collected and used.

These values take into account logistic and economic factors such as the splitting up of agricultural companies, their concentration in specific areas, the current use of by-products, which together reduce the potential availability of conveniently available waste.

For example, on the basis of analyses conducted in Italy it is reasonable to consider that the effective availability of wheat straw, which can be used for energy use, is 40%, while for fruit tree prunings this varies between 45% and 50%.

The quantities of crop residues annually recoverable depend on numerous factors including: cultivated areas, crop productivity, harvesting methods and operating conditions. In addition, the seasonality of the collection and the possibility of storage of the by-product also affect availability.

The analysis of the economic potential of using the residues cannot overlook the mechanization factor of the operations of collection, loading, transport, unloading and storage, which vary depending on the type of material, size of the company and destination of the raw material.

However, today, if there are simple adaptations of the machines operating in the agricultural sector for certain types of agricultural residues, in other cases the recovery of the same is more difficult and requires innovative solutions.

It must also be considered that although suitable mechanical solutions exist, not all surfaces lend themselves to recovery operations due to anomalous structural conditions (excessive ground pulverization and fragmentation of agricultural holdings), due to high distances between the plots and the centres of use or due to the significant slope of the land.

7.1.2 Availability of residues from forest biomass

One of the main problems related to the use of renewable energies, with specific reference to secondary biomass of forest origin, is the use of suitable models for estimating the resources available due to the high number of variables, from the technical obstacles to the management of forests.

The net availability of wood biomass can be significantly reduced compared to the sustainable potential productivity, in relation to the spatial distribution of forest stands (altitude and slope steepness), soil fertility and the different physiognomic composition in tree species of forest.

The methodology for the assessment of the effective availability of biomass from forest residues taken from forest stands by the forestry activities is based on the knowledge of the estimated annual potential productivity (t_{dm}/y) with respect to the sustainable forest management criteria, as before said at the paragraph 4.2. A reductive correction factor has to be applied to this value in order to determine the actual availability of woody biomass that can be used for energy purposes[6].

[6] average productivity/year/hectare of forest residues

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In fact not all the annual potential sustainable productivity is currently available for the conversion of biomass into energy. Beyond respect for the principles of environmental sustainability, even in the most favorable local conditions for the mechanization, the limitations connected to the accessibility of forest stands can deeply influence the economic advantage of the forest exploitation.
Especially in Mediterranean contexts where there is a lack of forest roads, steep terrain, remote location of forest stands, these factors could make the forest management unproductive.

Therefore, it will be necessary to refer to in-depth studies to determine the resources actually available in a given area in relation to ecological criteria (intrinsic characteristics of natural formations / ecosystems present in different contexts) and economic ones (the so-called LOCALIZED biomass production) [Fagarazzi and Tirinnanzi, 2015].
For this purpose, we will consider, when available, econometric models on GIS platform as for example the *Green Energy Model* (GEM): *a GIS oriented model for the farm and the territory energy planning* able to evaluate the availability of the resources both from an ecological and economic point of view.
It is important in fact to estimate both biomass (wood chips) derived from the residues of silvicultural activities and traditional assortments having their own settled market and guaranteeing a good profitability.
The GEM estimates the availability of biomass guaranteeing an annual collection of natural resources compatible with the growth capacities of forest stands, and an economic sustainability of the silvicultural interventions necessary for the recovery of these resources.
An application of this methodology was made by CREAR (Research Center on Alternative and Renewable Energies) [Bernetti, Fagarazzi, Sacchelli, Ciampi, 2009] which considers the growth models of forest formations, cross-cutting, locally practiced prices for different product assortments and other variables from the 1998 Forestry Inventory of the Tuscany Region (e.g. the output assortments: the different types of wood products that can be made downstream of the forest production process, such as poles, beams, sawn timber, firewood, etc.)
In this work different production scenarios have been defined according to the different types of forest yard organization and their possibility of development in terms of logistics optimization and degree of mechanization. The supply curves of wood assortments currently used for energy purposes have been estimated: firewood and wood chips.

7.1.3 Availability of residues from agro-industrial processes

The analysis criteria used to estimate the current availability of residues from agro-industrial processes on the member state territory, as well as the possible current and future uses, will be based on the interpretation of the few data available at EUROSTAT and especially at the main Associations, Consortia and Entities of producers (e.g. in Italy ASSITOL, Ente Nazionale Risi, UNAPROA, in Spain Almazaras De La Subbetica, in Sweden Lantmännen, etc.).

The result of these consultations could lead to a picture of the situation where estimates often differ greatly from one another. Assessments should be then carried out supported by the comparison of other studies recently conducted and by the opinions of experts in the sector including the most relevant stakeholders. The variability of the values detected by official sources may occur due to:

- the absence of defined and uniform categories;
- the change in the time reference of the analyses performed;

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- strong market fluctuations;
- the different purposes of the studies carried out.

For these reasons it should be necessary to identify different and specific research methods to be applied to each of the investigated sectors (ENAMA, 2010).

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8-Analysis of the logistic complexity and size of the biomass supply chain

Together with the actual biomass availability it is necessary to take into account some aspects related to the supply chain such as the collection from the origin places, the transformation in the products useful for the energetic valorisation and the transfer to the place of final use.
However, the dispersed nature of biomass resource involves complex transportation problems within the supply chain (Williams and Larson, 1993; Zhang et al., 2011) [Bernetti et al., 2013].
It is widely assessed that if each step of the whole bioenergy chain is not optimised, the final cost of the produced biofuel may result not competitive in comparison with the fuel from traditional fossil source (Biosit, 2003). The costs of the fuel from residual biomass are mainly: biomass collection, treatment, storage, transport and conversion costs. One of the most important problems in using biomass as a fuel in fact is the spreading out of supplies together with the low territorial density, in comparison with the traditional fossil fuels. Moreover, the biomass supply is also in most of the cases seasonal, namely variable in time, thus creating the need of a temporarily stockpiling before and after the delivery to the processing plant.

8.1 Particular features of the biomass supply chain

By its nature, biomass is a distributed resource on the territory; part of this resource, already "available", as constituted from residues of various types of primary and secondary activity. For most of the residual biomasses, problems concerning the optimization of the production cycle, logistics in situ costs (extraction and preparation) and to localization costs (collection and transport to the material sales centers, in the first analysis identified in the centroids of the municipality) and advanced energy conversion processes, must be carefully evaluated (ENAMA, 2010).
Furthermore, it must be considered that for a correct calculation of the biomass production costs, a geographical analysis could be necessary in order to assess the morphological, logistic, ownership characteristics of the land where the biomass is originated: for instance, not all surfaces allow the recovery operations due to anomalous structural conditions, i.e. relevant slope of land, high distances between the plots and the centres of use, farms fragmentation.
These considerations lead to argue that the analysis of the economic potential of using the residues cannot overlook the mechanization factor of the operations of collection, loading, transport, unloading and storage, which vary depending on the type of material, size of the company and destination of the raw material. Moreover, mechanization influences the production costs and its incidence can further weigh when the machines are not used in a rational way. The optimization of mechanisation and the consequent logistics of the movement of the biomass, arise as basic prerequisites for the choice of each step of the supply chain.
For instance, in both Mediterranean and temperate climates, as for example in South Tuscany (GR) Mediterranean Forest or Catalogna the traditional source of wood from small forest and woodland is now uneconomic. In these cases, it is necessary to spread the use of small-scale extraction technology (harvesting and forwarding machinery, and woodland management training).
To reduce the logistics costs, participants at the EIP-AGRI Workshop of the May 2015 (EIP-AGRI 2015) suggested that small/medium scale bio-refineries with short supply chains may be an option for profitable

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and sustainable models. Large-scale plants can also coexist with the small-scale ones using biomass with high density and energy content.

8.2 Analysis of the logistic complexity and dimension of the biomass supply chain

According to the aims of the present Deliverable, the task 6.2 for each case scenario should depict environmentally and logistically efficient supply basins (SB), taking into consideration the geo-morphological characteristics of the territory and the **regional energy supply network** (RESN) optimisation that is able to satisfy the District Bio-Energy Plant (DEP) demand, based on technical-logistic and environmental parameters (Bernetti et al., 2013).

The design of an efficient RESN is a difficult task, as it must jointly consider logistic, economic, social and environmental aspects.
For the CONVERGE project, the organisation of RESN and its compliance with a scalar system that comprises the demand point (district energy plants – DEPs) and bio-energy sources (supply basins – SBs) will be investigated.
In addition, if necessary, a methodology able to aggregate SBs to define **regional energy clusters** (RECs) suitable for the implementation of biomass terminals (BTs) will be adopted.
In fact, a literature analysis highlights that to meet the increasing bio-energy demand and to ensure its continuous supply, it is necessary to optimise the wood-energy chain, and more generally the biomass energy chain, by including (BT) biomass terminals (Kanzian et al., 2009) [Figure 8].
The main aims of BTs are the storage and the processing of biomass for energy purposes (De Mol et al., 1997). In particular, in the case of woody biomass, in mountainous areas and in central and northern European countries, BTs serve as stock reserves of biomass during winter and spring seasons (Gronalt and Rauch, 2007).

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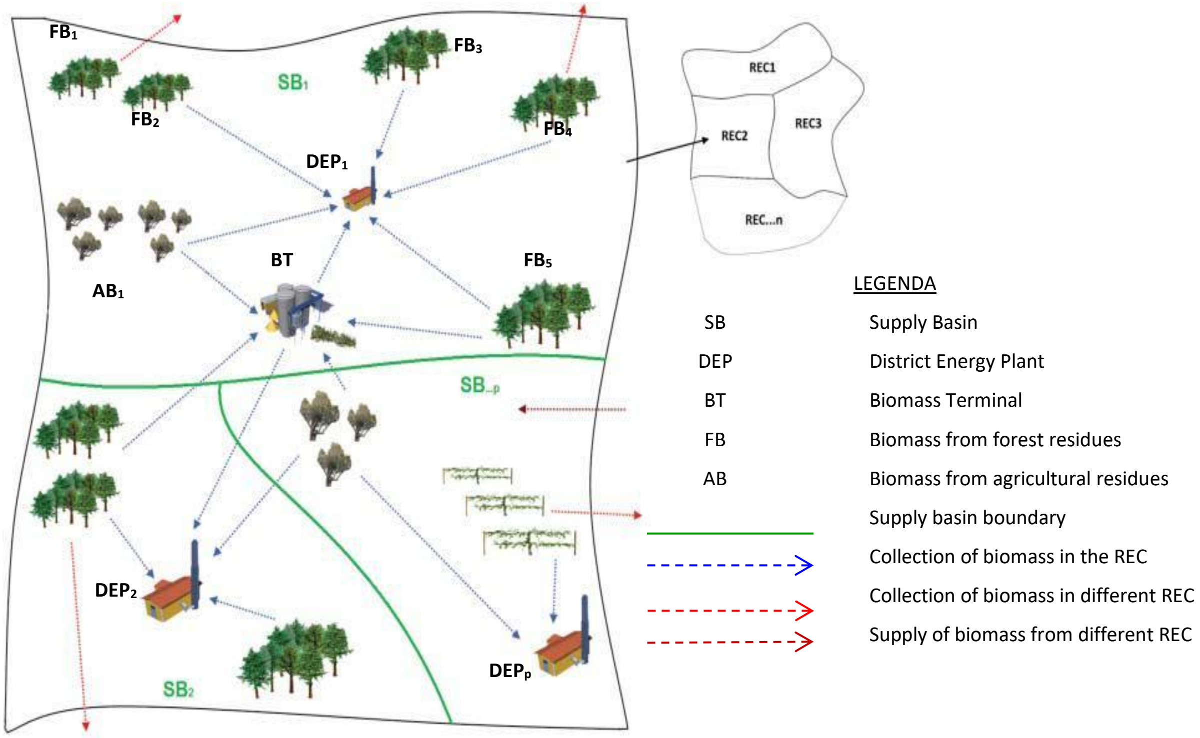

Figure 8 – Logistics of a regional energy supply network (RESN) [Source: Bernetti et al., 2013]

However, several scientific contributions show a series of analyses based on the geographic information system (GIS) and related to the optimal allocation of biomass.

According to Bernetti et al. (2013) regarding the optimal allocation of bio-energy resources, the examined literature shows that these issues are still unsolved.
First, with respect to the energetic-environmental perspective, an efficient methodology is not provided for the definition of SBs regions which are designed in an anisotropic geographical space that does not consider the critical geo-morphological characteristics for minimising the costs of both the collection and the carbon emissions related to the transport of biomass.
In addition, multiple objectives models (considering jointly logistic, socio-economic and environmental aspects) for the optimisation of the biomass energy chain in a spatially explicit area have not yet been used because the presence of multiple objectives and spatialised variables implies highly non-linear models whose solutions are difficult to ascertain from a computational perspective.

Moller and Nielsen (2007) consider the optimal allocation of wood chips in relation to the minimisation of the transportation costs of the wood fuel from the forest areas to the end users (district heating systems or individual households for the production of thermal energy or cogeneration). Panichelli and Gnansounou (2008) developed the BIOAL analysis algorithm to simulate the allocation of forest biomass into two roasting plants. In the paper, the algorithm allowed for the definition of a logistics of the chain that was able to minimise the transportation costs through the detection of the optimal demand localisation up to its saturation.
Sultana and Kumar (2012) use the GIS to determine optimal locations, sizes and number of bio-energy facilities (pellet plants) in Alberta (Canada) while optimising the transportation cost.

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8.2.1 - Geographic information system for biomass availability

Each link of the biomass supply chain - biomass supply, intermediate and final storage, biomass delivery to the conversion plant - is directly dependent upon the geographical location and contributes to different costs and potentials of these sources thus affecting the choice of biomass supply.
Therefor the foreseen cost of biofuel cannot be computed independently from the biomass supply costs. It is then evident that in order to reach a competitive feasibility of the use of biomass for energy production a detailed biomass supply analysis is strictly necessary.
A Geographic Information Systems (GIS) approach appears to represent an appropriate tool for attaining this goal. Several studies have analysed GIS and spatial analysis instruments as tools for biomass chain evaluation at the European, national and local levels (Sacchelli et al., 2013).
The use of the GIS tool may result in the identification of the best geographic position of each link of the biomass to biofuel chain, supporting also the choice of biomass resource, being able to evaluate and possibly minimise the effect of every factor on biofuel production.

Therefore, it is important to implement a database as Geographic Information System for the territorial analysis, on the basis of the following thematic vectorial database publicly available:

- ☐ Corine Land Cover (last release 2018)[7]
- ☐ Forest Inventory at region level (NUTS2 area) or national level (NUTS0 area)
- ☐ Digital Terrain Model (DTM)

These data are useful for defining areas with a specific level of availability of biomass and a suitability for implementing a biomass supply chain.
This information toll permits to evaluate the following aspects:

- potential availability of residual biomass,
- actual availability of residual biomass,
- localisation of bioeconomy clusters,
- evaluation of transport facilities/infrastructures,
- additional economic and environmental evaluations.
- Location potentially suitable for plant.

Once the agricultural and forestry surface will be calculated, taking into account the residues density (i.e. mass per hectare), the average amount of the potential available biomass could be calculated (Recchia, 2010). In addition, other information could be considered as the coverage percentage, the eventual temporal absence of vegetation, the current abandonment of the agricultural land (Recchia, 2006) and the vulnerability profiles of forest vegetation (Ugolini and Barbati, 2001).

Based on the potential availability, the actual availability will be estimated considering

- the technical possibility of collecting the biomass, i.e. the accessibility of the land (e.g. land slope, roads, etc.);
- the possible alternative uses of the considered residues (Fig. 9).

[7] According to CLC seamless data coverage (19/12/2018) each country interested at the Converge project has the Corine Land Cover up to date at last release 2018.

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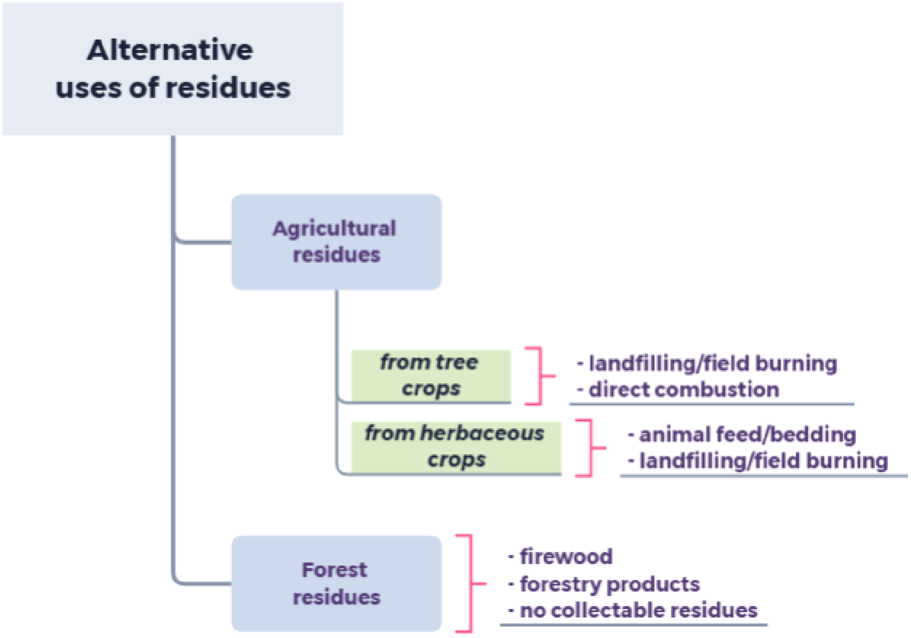

Fig.9 - Possible alternative uses of the residues.

8.3-Bio-economy cluster in the EU regions

8.3.1- The concept of bioeconomy cluster

For the purposes of the CONVERGE project, the biomass selection criteria must be well defined from the beginning. The biomass must be residual, abundant and included in an already developed and tested supply chain as well mature and reliable.

This is easy to understand if we consider that the production cost of an advanced biofuel could be affected for around 50% and above by the supply of feedstock.

With respect to these general criteria it is helpful to relate the supply of the biomass to the concept of bioeconomic clusters, where biomass production is generally linked to a mature, structured, innovative and dynamic framework.

Clusters are an important tool to investigate the territorial pattern of bioeconomy and to gather stakeholders around specific bioeconomy sectors/products, especially in strongly industrialised regions, but also increasingly in rural regions.

In comparison to traditional industrial clusters, bioeconomy related clusters often need to integrate also producers of biological resources, i.e. farmers and fishermen, as well as their associations, e.g. cooperatives (Spatial Foresight et al. 2017). Examples of these are: Lantmännen (Sweden), Almazaras De La Subbetica (Spain).

Since 2011 **bio-cluster** are defined as "*heterogeneous entities, varying widely in structure, evolution and goals that represent a local complex system where different types of organisations interact for research, innovation and economic growth*".

Existing literature suggests that the clusters offer key competitive advantages with respect to three key variables: employment, innovation, and productivity (PwC, 2011)

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According to the BERST project among the key elements identified at regional bio-cluster level (BERST 2015) is cited a continuous supply of biomass resources of constant quality as critical factor for the development of bioeconomy products.
Therefore, the approach to the selection of the biomass supply chains suitable as feedstock for the development of the CONVERGE technology at commercial scale has necessarily to take into account the system's complexity (wider understanding and integration of relevant players) of the regional bioeconomy ecosystem (Fig. 10) and to differentiate the needs of implementation at three different levels, according to the EUROPEAN BIOECONOMY STAKEHOLDERS MANIFESTO[8]:

1. Policy and decision-makers (involving various administrative levels and different competences on economic development/industry, agriculture/fisheries, and research and education);
2. Primary production communities, assuring the availability of biofeedstock ;
3. Local/ regional value cycles within a logistically defined area that connect consumers, producers, resource/waste managers, logistics and retailers.

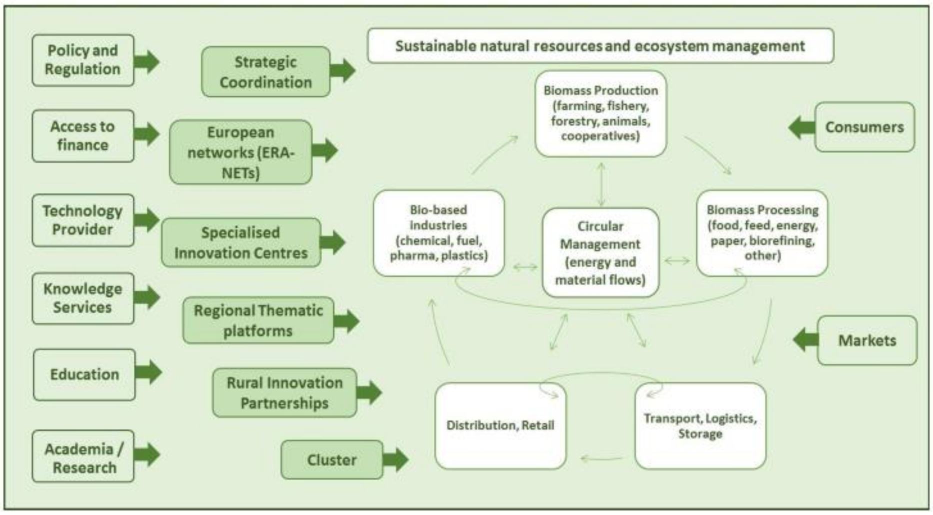

Figure 10 - Model of a regional bioeconomy ecosystem (Source: Spatial Foresight et al., 2017)

Bioeconomy related research and innovation (R&I) is a priority for most of European countries and regions in the time period 2014-2020. According to the study "*Mapping of EU Member States' / regions' Research and Innovation plans & Strategies for Smart Specialisation (RIS3) on Bioeconomy for 2014-2020*"[9] out of 210 analysed territorial units (22 NUTS0 = countries, 25 NUTS1 regions, 125 NUTS2 regions, 38 NUTS3 regions), **207 (98.6%) include bioeconomy related aspects in their 2014-2020 R&I priorities and plans** (Spatial Foresight et al. 2017).

In the first European Bioeconomy Strategy (European Commission 2012) European Commission defined **bioeconomy** as the *synthesis and combination of the production of renewable biological resources and their conversion into food, feed, bio-based products and bioenergy*. It includes primary production from

[8] The EUROPEAN BIOECONOMY STAKEHOLDERS MANIFESTO was launched in Utrecht in April 2016 at the Fourth Bioeconomy Stakeholders' Conference

[9] The study project was commissioned by DG Research & Innovation, Directorate F – Bioeconomy (Unit F.1 – Strategy) and carried out by a consortium led by SWECO and Spatial Foresight with the support of ÖIR, t33, Nordregio, Berman Group and INFYDE.

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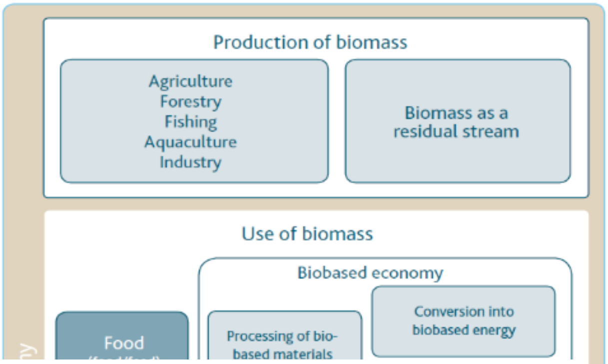
agriculture, forestry and fisheries, food and pulp and paper production, as well as parts of chemical, biotechnological and energy industries (Fig. 11).



Source: Vlaamse Overheid (2013:9), based on Minaraad and SALV recommendation 'Sustainable use of biomass in a bioeconomy' (2012), in Spatial Foresight et al. 2017

Figure 11 - The bioeconomy and the bio-based economy

The activities carried out by CONVERGE are considered core-bioeconomic ones as shown by the following Figure 12. In fact they can be related to primary production and the direct use of primary resources: agriculture, fishing and forestry, food industry and bioenergy.

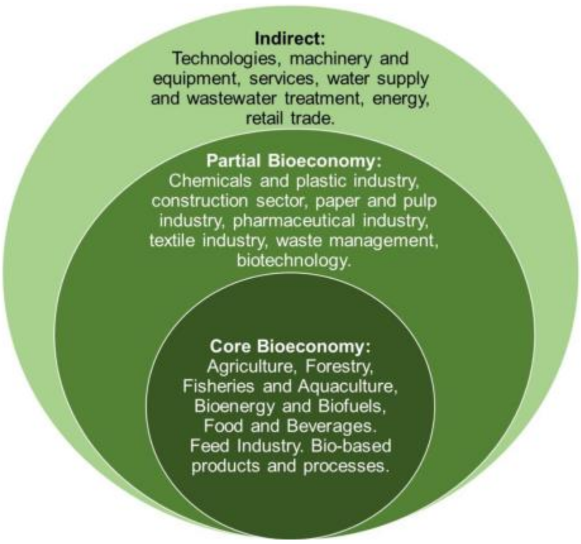


Figure 12 - Economic sectors in the bioeconomy Source: Spatial Foresight et al., 2017

In general, there is no clear **territorial pattern** for bioeconomy R&I, although some trends in specialization can be observed as for instance regions and countries with a thematic focus on "bio-based fuels and bioenergy" (Spatial Foresight et al. 2017).

An investigation in the European Cluster Collaboration Platform, conducted by Ca.Re. For. Engineering, shows the following scenario in term of thematic cluster (Fig. 13).

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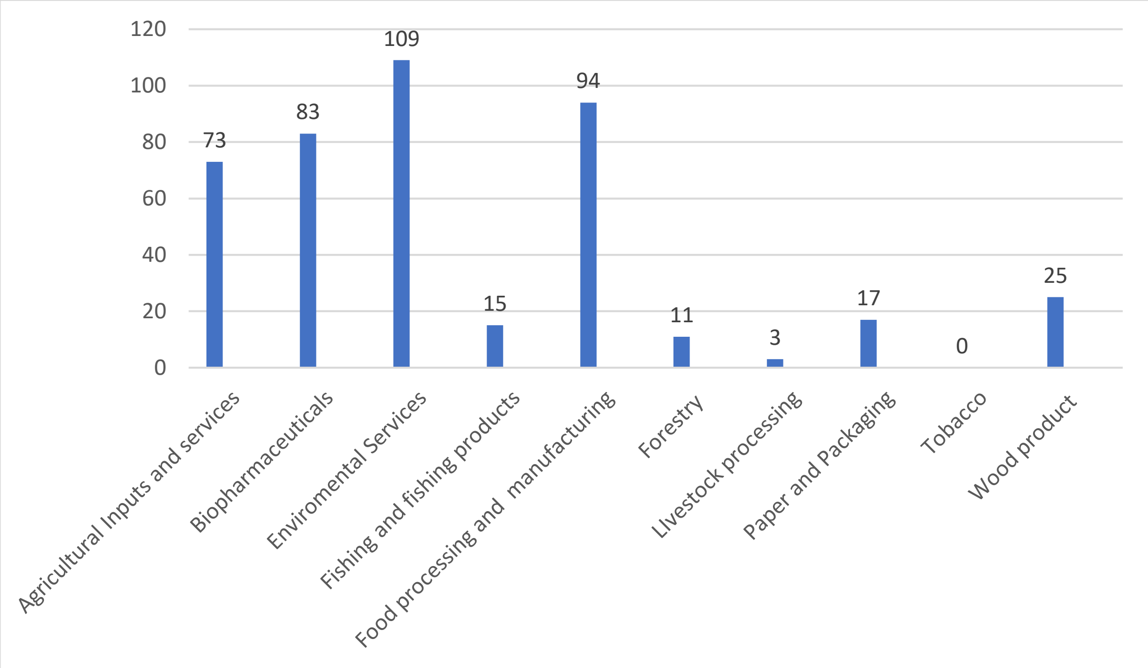

Figure 13 - Distribution of biocluster for industrial sector

Among them, several ‘thematic’ clusters have emerged in Europe as relevant for the CONVERGE development at regional level. Examples of these are:

- **Cluster organised around biological resources**, e.g. Cork Cluster in Extremadura (ES), Paper Province Värmland (SE), Croatian Wood Cluster (HR), Cluster Inno’vin Bordeux-Aquitaine (FR).
- **Agrofood cluster**, e.g. Pôle Industries & Agro-Ressources (IAR) (FR), Food+i (North of Spain), Agri-Tech East (UK), Food Nordwest (DE), Food Cluster of Lower Austria (AT).
- **Bioenergy cluster**, e.g. Canterbury Bioenergy Cluster (UK), Cluster of Bioenergy and Environment of Western Macedonia (Greece), Dynamic Bioenergy Cluster Central Finland (FI).

Moreover, the following clusters (Tab.7), which have given proof of Cluster Excellence in term of management and organizational structures, could be considered as reference point for the development of CONVERGE technologies at commercial scale:

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Table 7 – Reference Clusters in the different EU CONVERGE Districts

EU CONVERGE District	Reference Cluster
Scandinavia	Paper Province https://paperprovince.com/en/
North Sea	Flandersfood https://www.flandersfood.com/
Central Europe	AgroTransilvania Cluster http://agrocluster.ro/en/ Cluster Mobilier Transilvan http://www.transylvanianfurniture.com/
Mediterranean Regions	FEMAC - The Catalan Cluster of Agricultural Production Means http://www.femac.org/introduction/ Clustermadeira http://clustermadeira.com/cma/que-hacemos/?lang=en Agroindustrial Cluster of the Portugal Center. http://www.inovcluster.com/

8.3.2 Spatialization of the data, thematic focus and value chains of the European bioeconomy cluster in EU regions

As we have seen previously (par. 8.2.1) a key factor to select the biomass supply chain suitable for CONVERGE technology is the spazialization of the data on biomass availability and their evaluation.
Sultana and Kumar (2012) use the GIS to determine optimal locations, sizes and number of bio-energy facilities (pellet plants) in Alberta (Canada) while optimising the transportation cost.
The existence of bioeconomy clusters, together with their thematic focus and level of maturity, will represent key factors for the localization at area NUTS2 level of the suitable sites of implementation of the CONVERGE technology on a commercial scale.
In order to refer feedstock availability assessment to regional level we may consider the thematic specialisation of the bioeconomy in European regions, according to a EU-wide (EU-28) data gathering on bioeconomy related activities across Europe available in the *Bioeconomy development in EU regions*. Mapping of EU Member States'/regions' Research and Innovation plans & Strategies for Smart Specialisation (RIS3) on Bioeconomy for 2014-2020 (Spatial Foresight, 2017).

Considering the thematic areas that are tackled by EU regions and countries it is possible refer to the following themes:

- Forestry and wood;
- Crop production;
- Flower, seeds, plants;
- Food processing;

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- Wood based biomass;
- Agricultural residues and bioenergy corps;
- Waste as biomass;
- Fibres and lignocellulosic biomass.

For each of them it is possible to distinguish relevant regions and countries but no clear territorial patterns for identification of the biomass supply chains emerge. However, some trends in specialisation can be observed.
If the analysis of a value chains from bioeconomy perspective is considered, “biomass processing and conversion” is the most prominent approach in Europe.
The most frequent specific value chain approaches are “bio-energy and fuel from biomass” and/or “food and beverages” (Spatial Foresight et al. 2017).
Regions and countries with a thematic focus on “bio-based fuels and bioenergy” are mostly territories in Southern France, Southern Germany or Southern Poland, but also in Southern and Central Finland, Scotland, Ireland and Galicia (Spain).
Agro-Food is the broad thematic focus area most frequently ranked first among the regions studied. Regions with this profile are located in Portugal, Spain, North-West of France, North of Germany, Sweden, Latvia, Lithuania, Czech Republic, Slovakia, Hungary, Romania, Bulgaria, Greece, Croatia, Slovenia and the majority of Italian regions.

If the EU-28 Regions and Member States with Bioeconomy R&I priorities are analyzed, the following geographical scenario can be found out, for the thematic focus of CONVERGE interest (Fig. 14).

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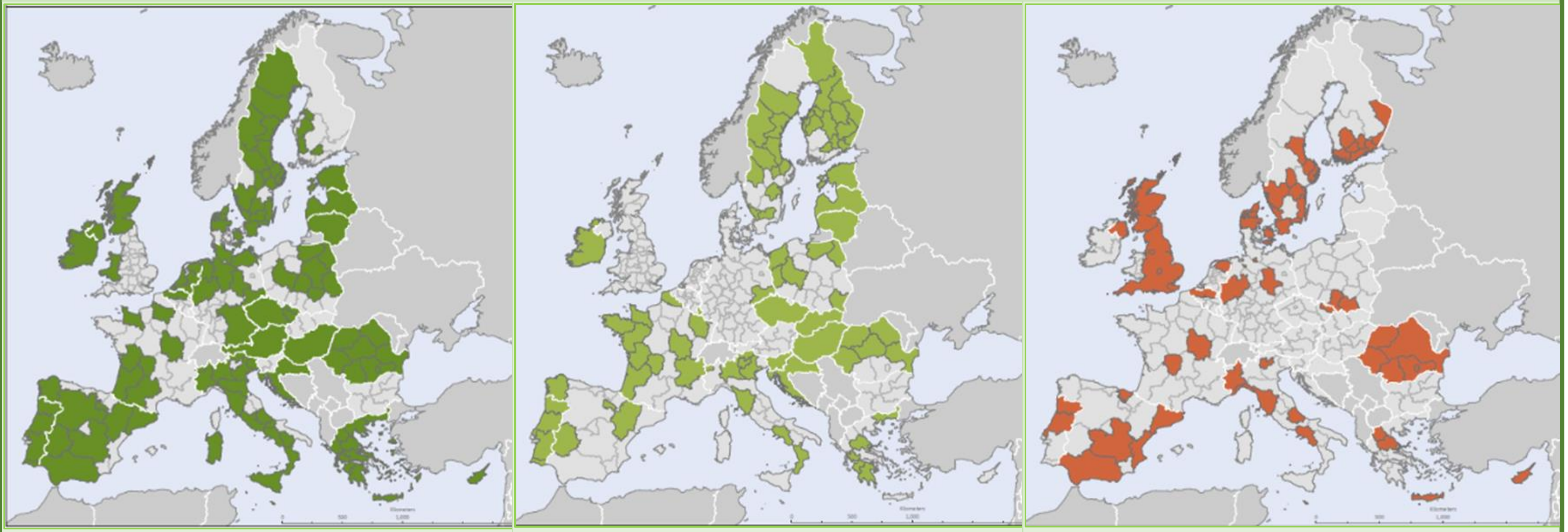
Figure 14 – EU-28 Regions and Member States with Bioeconomy R&I priorities (2014-2020).



A) related to AGRICULTURE | B) related to FOREST BASED BIOECONOMY | C) related to WASTE PROCESSING

Source: Spatial Foresight, 2017

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Combinations of thematic focus and value chain approaches permit to assess territorial specialization and highlights the first ranked bioeconomy value chain in European regions[10], as shown by the Figure 15. Given the overlapping occurrences of several value chains, this ranking indicates the tendency rather than the overall value chain specialisation.

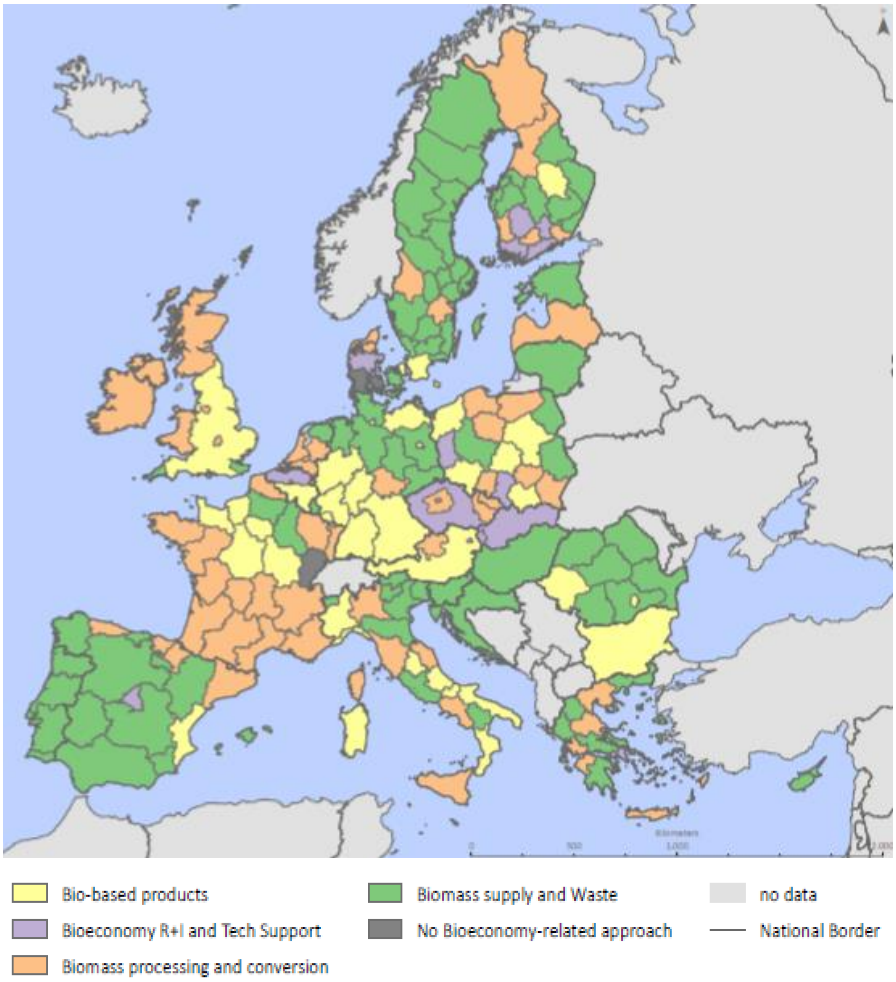

Figure 15: Territorial distribution of regions with similar bioeconomy value chain approaches. The regions are distingued by their first ranked value chain approach (Source: Spatial Foresight, 2017).

Another key of great utility for the selection of biomass supply chain is the MATURITY OF REGIONAL BIOECONOMY R&I measured by a specific index (the maturity index**)** of the bioeconomy profiles.
Maturity index is determined, a priori, on the basis of the combination of four variables on innovation in bioeconomy:

1- general regional innovation capacity and activity based on the classification of the region according to the Regional Innovation Scoreboard 2014 (e.g. innovation leaders and followers, moderate and modest innovators);
2- the existence of specific bioeconomy strategies;

[10] The thematic focus is strictly related to value chain approaches which sometimes indicates different orientation within a given thematic focus. E.g. a region can focus on agro-food, but within that it is oriented on biomass supply (crop, vegetables), or on biomass processing and conversion (the elaboration of food products or beverages) or on bio-based products (nutraceuticals or new functional foods).

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3- the existence of bioeconomy related clusters in a given region or country, as an indicator for the current deployment of the bioeconomy at political and business level;
4- the intensity level of bioeconomy related activities in a given region according to information in relevant documents.

The four variables are equally weighted in order to give a straightforward and replicable description of bioeconomy research and innovation maturity.

The map below (figure 16) shows the territorial distribution of regions according to bioeconomy maturity.

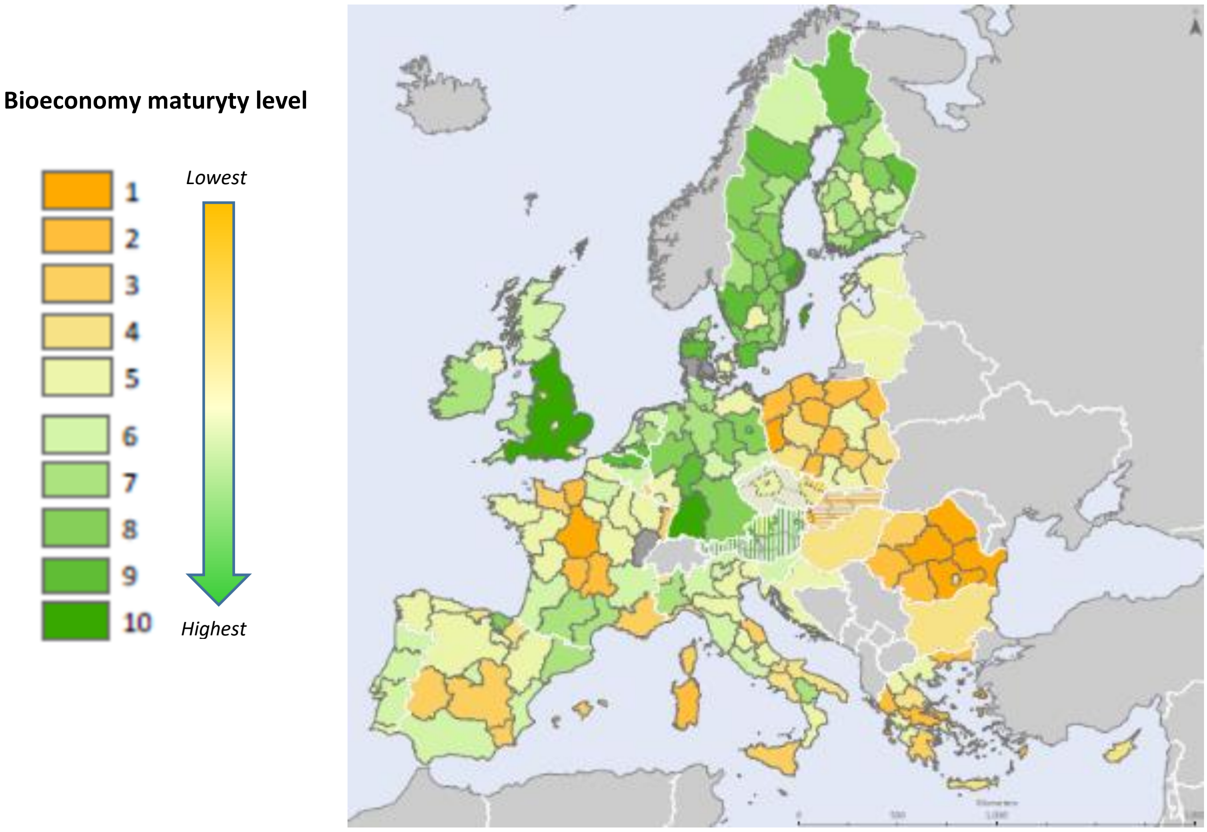

Figure 16 - territorial distribution of regions according to bioeconomy maturity (Source: Spatial Foresight, 2017) **.**

The picture of bioeconomy maturity is heterogeneous: most regions and countries have a middle score (5 points) on the bioeconomy maturity index, while fewer regions and countries particularly low or high. Three regions or countries have the highest bioeconomy maturity (10 points): England (UK), Baden-Württemberg (DE) and Stockholm (SE).
They are followed by 11 regions (9 points): Flemish Region (BE), Hessen (D), Central Jutland (DK), Helsinki Uusimaa, Pohjois-Karjala, Lappi (all FI), South Netherlands (NL), Uppsala län, Skåne län, Västra Götalands län, Västerbottens län (all SE) (see Annex document 8 for a list of all regions and countries).
75 regions (35.7%) have a low maturity (1-4 maturity points) and they tend to focus on value chain approaches "biomass supply and waste" and "biomass conversion and processing".
Therefore, we can conclude that there is no significant link between maturity levels and the bioeconomy value chain approach at first rank.
However at the present level of detail, the most part of the value chains related to "Biomass supply and waste", which can be profitably involved for purpose of the task 6.2, are located in rank between 3 and 8 level (Fig. 17).

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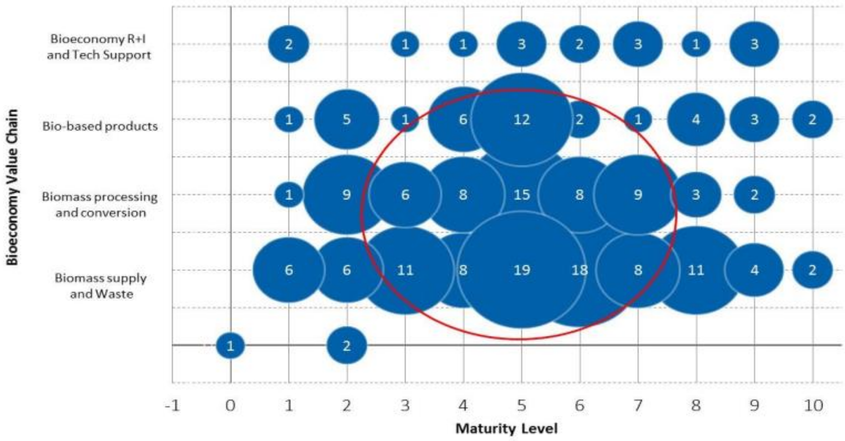

Figure 17 – Value chain approach and maturity level of the region (Source: Spatial Foresight, 2017)

9-Biomass requirements

The biomass supply chain for feeding the CONVERGE process shall ensure the provision of a renewable, consistent and regular supply of feedstock.
In compliance with the Directive (EU) 2018/2001, the selected biomass shall demonstrate high environmental performance and sustainability both in terms of emissions in atmosphere, water and soil, through the application of LCA methodology (see WP5), and counteracting depletion of the soil quality and soil erosion.
The biomass shall not have any land competition with food/feed industrial supply chain or with previous land use with higher carbon sink capability or naturalistic values.

9.1 The physical and chemical characteristics of the biomass suitable for CONVERGE process

In general terms, the gasification process is suited to multiple ad heterogeneous lignocellulosic and waste biomass feedstocks, such as forestry and agricultural residues, industrial waste and municipal solid waste. The suitability of a feedstock depends on the specific reactor design, with some designs more suited to heterogeneous waste feedstocks.
Feedstocks also impact the quality of the syngas and process efficiency.

Among the most relevant challenges for gasification and related synthesis where the syngas is produced from biomass residues and wastes are the capability of the gasification technology to operate reliably and efficiently with industrially relevant biomass and waste feedstocks, and achieving reliably high-quality syngas (very clean) that still always should meet the catalyst specification, even with variable feedstock inputs.

In such way suitability and quality of the biomass used as feedstock for the gasification process (and the specific involved reactor) are key challenges.
Advanced reactor designs, together with solutions that combine synthesis and cracking (thereby reducing the need for additional reactor vessels) to operate at commercial scale need high quality, homogeneous feedstocks to operate reliably and efficiently.

Therefore, for each type of biomass potentially selected in the case scenarios (task 6.2) a summary table will be produced (Tab.8) containing the most important information on biomass characteristics as well as on the specific operations that make up the biomass energy supply chain, such as type of crop, origin of processing residues, physical-chemical characteristics, characteristics at harvest (fresh state), operational solutions for transport, indications for storage, etc.
This data will be compared with the required physical and chemical characteristics of the suitable residual biomasses to use as feedstock for CONVERGE gasification process.

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Table 8 - Summary table of the synthetic information on biomass characteristics – Example of STRAW (Source: Fiala, 2012)

STRAW	CEREAL cultivation (soft wheat, durum wheat, barley, rye, oat)									
Source	**Chemical and physical characteristics**								**Main supply chains**	
Annual herbaceous cultivation	**LHV**	**Ash**	**C**	**H**	**O**	**N**	**S**	**Cl**	**1**	Animal husbandry (litter, food)
	kWh/kg_{dm}	$\%_{dm}$	$\%_{dm}$	$\%_{dm}$	$\%_{dm}$	$\%_{dm}$	$\%_{dm}$	$\%_{dm}$	**2**	Production of thermal energy and electricity
	4,3-4,6	11,4	43,2	5,0	39,4	0,61	0,11	0,28	**3**	Pulp and paper industry
	Product / residue ratio							0,6-0,8	**4**	Pellet production

Production Process	Harvesting of straw does not present any particular technical and operational difficulties, it takes place in June July after the grain is harvested. The operating machines are ordinarily owned in the machinery park by the cereal and forage producing companies: baling pickers (parallelepiped bales 1m on the ca side) or packing roto (cylindrical bales 1.5m). The only limitation is the reduced period for collecting straw (3 days) in the case of second-crop growing.

Yield	The amount of straw available varies widely: cultivation, cultivar, cultivation area, cultivation technique.	**Type of crop**	**Quantity (t_{ar}/ha)**
		Rye, tall wheat, in Northern Italy	5-6
		Durum wheat, dry, in southern Italy	1,5-2,5

Characteristics	**Moisture (%)**	10-20	**Baling**		**Cylindrical bales**	**Cuboid bales**	**Bulk**
			Density	Kg_{tq}/m^3	240-280	130-210	60-90
	PCN (kWh/kg_{tq}):	3,5-4	**Energy density.**	MJ/m^3	3150-4030	1640-3000	760-1300

Transportation and storage	The problems derive from the modest volume mass, inconvenient transportation costs are reduced by packaging in bales. Straw itself has reduced humidity and can be stored without problems as long as storage is protected from atmospheric agents.

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9.2 Traceability

Traceability is defined as the ability to discern, identify and follow the movement of a product or substance intended to be or expected to be incorporated into a product, through all stages of production, processing and distribution (FAO, 2017).

In particular, implementing a traceability system within a supply chain requires that all parties involved will link the physical flow of products with the flow of information about those products. Adopting regulations and industry standards for traceability processes ensures agreement about identification of the traceable items. This supports the visibility and continuity of information across the supply chain.

A traceability system is the totality of data and operations that is capable of maintaining the desired information about a product and its components through all or part of its production and utilization chain. Therefore it records and follows the trail as products and materials come from suppliers and are processed and distributed as end products. In fact, the basis of all traceability systems is the ability to identify things that move along the supply chain. The basic characteristics of traceability systems are

- identification of units / batches of all ingredients and products;
- registration of information on when and where units/batches are moved or transformed;
- a system linking these data and transferring all relevant traceability information with the product to the next stage or processing step.

In practice, traceability systems are record keeping systems that show the path of a particular product from suppliers through intermediate steps to consumers (ITC, 2015). As well as identifying the product, traceability systems may identify other information (e.g. country of origin, species and best by date) that is associated with the product.

The traceability has to be assured for each subject of the chain: farms and plantations, points of origins, first gathering points, central offices, collecting points, traders, storage facilities and processing units (see Fig. 18). Transport and any modes of transport (e.g. road, rail, air, river or sea) are not subject to certification. All relevant information regarding the transport of sustainable materials (e.g. delivery documents, means and distance of transport, etc.) are covered by the certification of the aforementioned economic operators.

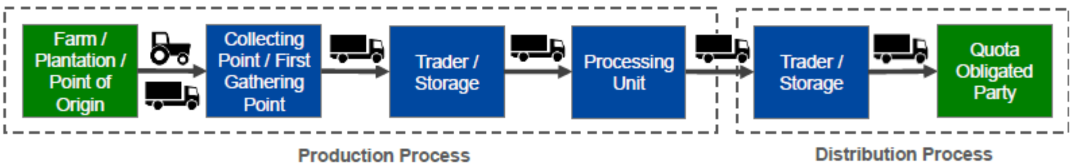

Figure 18 – Relevant subjects for chain of custody and traceability (Source: ISCC, 2016a).

Traceability of waste and residues starts at the point where the waste or residue occurs or is generated (point of origin) and covers the entire supply chain. Traceability is achieved by using systems for traceability (e.g. mass balance or segregation) as well as identification numbers and delivery documents, assuring that the country of origin (i.e. the country where the waste/residue was generated), the type of (raw) material, the amount and the respective GHG emissions of a material can be clearly identified on each level of the supply chain (ISCC, 2016b).

Finally, major factors affecting the effectiveness of traceability can be (ITC, 2015):

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- supply chain structure and organization (i.e. degree of collaboration between actors, number of actors, ability of actors to identify product origin, ability of actors to manage traceability systems, compatibility between actors);
- destination of a product;
- identification of traceable lot unit and time needed to trace a product;
- credibility of traceability method;
- data identification methods and data standardization.

9.2.1 Traceability of agricultural residues

Agricultural residues directly deriving from or generated by agriculture (agricultural crop residues, e.g. straw, bagasse, husks) do not include residues from related industries or processing.
In the case of residues directly deriving from or generated by agriculture (e.g. straw, bagasse, husks), the point of origin is a farm or plantation where sustainable biomass is cultivated and harvested. Farms or plantations do not need to be certified individually, but anyway have to conduct a self-assessment and complete and sign a self-declaration which must be provided to the certified first gathering point.
In order to assure the traceability and consequently the point of origin of the residues, the farm/plantation has to be clearly and transparently identified.
For the farm identification it is necessary to use the Business Identification (BID) or an alternative Farm ID. The BID is allocated by the Ministry of Agriculture or any other designated government agency which maintains the National Farm Registry (FAO, 2017).
Farmers have to identify all the plots in every farm they manage and if possible, all the crops in every plot. This shall give the opportunity to confirm the quantities of the residues and to verify the respect of the sustainability criteria (see RED II). All the information related to the previous conditioning (e.g. shredding, baling, etc.) and harvesting from plots must be recorded. These records should be organized chronologically by dates in a Farm Book (e.g. electronic or paper notes, etc.). The Farm Book is a simple notebook (e.g. a copybook) wherein a farmer records cultural practices, plant protection treatments and additional information that may be considered of importance in relation to crop/residues management.
Moreover, each time a farmer sells residues to a trading partner or directly to the customer, the following data must be recorded in order to ensure that the traceability link is maintained (FAO, 2017):

- Supplier/Seller name and contact information
- Customer name/identification number (e.g. VAT number)
- Product Description (Brand name if applicable, including variety)
- Lot number or other batch identifier of the good (i.e. harvesting date)
- Quantity and packaging information
- Date of transaction
- Origin Address: Address from where the good was delivered
- Destination Address: Address of receiving location/trading partner
- Name and contact information of the transporter
- Any other information deemed appropriate by the Competent Authority

All this information must be reported in the delivery documents.

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9.2.2 Traceability of agro-industrial residues

A processing residue is a substance that is not the end product that a production process directly seeks to produce; the production of the residue or substance is not the primary aim of the production process and the process has not been deliberately modified to produce it.
If the waste definition is not applicable to these residues, they do not have an associated CER number and are not interested by the laws concerning wastes transports.

9.2.3 Traceability of MSW

For wastes transport and delivery all the related European laws and rules must be applied. In particular the declaration format (see the Italian MUD) is needed for assuring the legal transportation of the wastes and their traceability with at least the following information:

- typology of the waste through the correct CER number;
- quantity and eventual packaging information;
- indication of the point of origin (name and identification of the producer);
- indication of the point of destination (name and identification of the destination subject);
- name and contact information of the transporter.

9.2.4 Traceability of forestry residues

Forestry residues directly deriving from or generated by forest do not include residues from related industries or processing. In the case of residues directly deriving from or generated by forestry, the point of origin is a forest management unit where sustainable biomass is cultivated and harvested. Forest management units do not need to be certified individually, but anyway have to conduct a self-assessment and complete and sign a self-declaration which must be provided to the certified first gathering point (ISCC, 2016b).
A forestry biomass supply chain consists of the following four main stages (Proforbiomed, 2014):

- source of forestry biomass;
- biomass processing (chipping, milling, cutting, etc.);
- intermediate transport and/or storage of the forestry biomass;
- delivery point.

The supply chain includes all the parties (i.e. organisations), material flows and services that contribute to the production, storage and transport of forestry biomass. In particular, residual forest biomass harvest activities involve the following actions:

- cutting of trees and shrubs;
- collecting and stacking wood waste;
- removal of crop residues for deposit.

In order to assure the traceability, origin and source of raw material for residues production can be classified according to the standard EN 17225:2014 for wood chips. The three main categories of woody biomass are (I) forest, plantation and other virgin wood, (II) by-products and residues from wood processing industry and (III) used wood. Detailed information in product declarations/specifications about sources, origin and location (country/sub-national level) is valuable for declaring wood properties by means of typical values according to type of raw material. Based on the information about the origin and source of raw material specific properties of the end product can be estimated, e.g. if the raw material contains a higher share of bark, consequently the ash continent will also be higher.
A declaration of origin and source of raw material should be prepared; the document should contain at least the following data:

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- Supplier information (name and address of the company)
- Origin and source classification according to standard UNI EN ISO 17225:2014
- Country and location of raw material

9.3 Sustainability of the supply chains

According to RED methodology (Dir. EU 2018/2001, Annex V, Part C), compared with ‘conventional’ first generation feedstock, the use of these raw materials would imply greater sustainability and less competition for land used for food and feed production.
However, where the lignocellulosic feedstock is to be produced from specialist energy crops grown on arable land, several concerns remain over competing land use – although energy yields in terms of gigajoule per hectare (GJ/ha) are likely to be higher than in case of crops grown for first-generation biofuels are being produced on the same land.

Sustainability needs specific emphasis, because it is both a transversal driving force and a challenge for guaranteeing long-term biomass strategies.
Criteria involved are biomass sustainability, sustainability certification, ILUC and greenhouse gas saving.
At the same time, the definition of sustainable biomass value chains should not represent an unmanageable obstacle for farmers and industries to develop supply chains.

Concerning the sustainability criteria (see art.29), the RED II assumes that

1. biofuels, bioliquids and biomass fuels produced from waste and residues, other than agricultural, aquaculture, fisheries and forestry residues, are required to fulfil only the greenhouse gas emissions saving criteria;
2. biofuels, bioliquids and biomass fuels produced from waste and residues derived not from forestry but from agricultural land shall be considered only where operators or national authorities have monitoring or management plans in place in order to address the impacts on soil quality and soil carbon (see Article 30).

Table 9 reports different rules for assuring the environmental sustainability starting from different residues or wastes.

Table 9 – Environmental sustainability requirements for biofuels/bioliquids produced from residues/wastes.

	GHG savings	Sustainability criteria
Residues/wastes from agricultural land	Yes	- Land use rules for agricultural biomass - Impacts on soil quality and soil carbon
Residues/wastes from forestry land	Yes	- Land use rules for forestry biomass
Municipal Solid Wastes	yes/no(1)	-
Other wastes and residues	Yes	-

(1) in case of electricity production no GHG savings calculation is required

Moreover, in order to quantify the CO_2eq emissions associated with the particular biofuel/bioliquid, it is necessary to check in advance if the biomass is classifiable as waste/residue or by-product.
As stated in the Annex V of the RED II

- in the case of wastes and residues, the raw material used will not be associated with CO_2eq emissions attributable to the production phase. For biofuels and biogas for transports, the GHG

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savings are doubled if the feedstock is listed in the Annex IX. Particularly, wastes and residues, including tree tops and branches, straw, husks, cobs and nut shells, and residues from processing, including crude glycerine (glycerine that is not refined) and bagasse, shall be considered to have **zero life-cycle greenhouse gas emissions** up to the process of collection of those materials irrespectively of whether they are processed to interim products before being transformed into the final product;

- in the case of a by-product, instead, it will be necessary to associate the raw material used with a portion of the CO_2eq emissions attributable to the production phase (allocation).

9.3.1 Sustainability criteria for residues/wastes from agricultural land

Biofuels, bioliquids and biomass fuels produced from waste and residues derived not from forestry but from agricultural land shall be taken into account only where operators or national authorities have monitoring or management plans in place in order to address the impacts on soil quality and soil carbon (Art. 29, point 2).

Biofuels, bioliquids and biomass fuels produced from agricultural biomass shall not be made from raw material obtained:

- from land with a high biodiversity value, namely land that had one of the following statuses in or after January 2008, whether or not the land continues to have the status of primary forest and other wooded land, highly biodiverse forest and other wooded land, areas designated for nature protection or conservation purposes, highly biodiverse grassland spanning more than one hectare (Art. 29, point 3);
- from land with high-carbon stock, namely land that had one of the following statuses in January 2008 and no longer has the status of wetlands, continuously forested areas spanning more than one hectare with trees higher than five metres and a canopy cover of more than 30 %, land spanning more than one hectare with trees higher than five metres and a canopy cover of between 10 % and 30 % (Art. 29, point 4);
- from land that was peatland in January 2008, unless evidence is provided that the cultivation and harvesting of that raw material does not involve drainage of previously undrained soil (Art. 29, point 5) .

9.3.2 Sustainability criteria for residues/wastes from forestry land

Biofuels, bioliquids and biomass fuels produced from forest biomass shall meet the following criteria to minimise the risk of using forest biomass derived from unsustainable production (Art. 29, point 6):

- the legality of harvesting operations;
- forest regeneration of harvested areas;
- that areas designated by international or national law or by the relevant competent authority for nature protection purposes, including in wetlands and peatlands, are protected;
- that harvesting is carried out considering maintenance of soil quality and biodiversity with the aim of minimising negative impacts;
- that harvesting maintains or improves the long-term production capacity of the forest.

9.3.3 GHG savings threshold

The greenhouse gas emission savings from the use of biofuels, bioliquids and biomass fuels shall be (Art. 29, point 10):

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- at least 50 % for biofuels, biogas consumed in the transport sector, and bioliquids produced in installations in operation on or before 5 October 2015;
- at least 60 % for biofuels, biogas consumed in the transport sector, and bioliquids produced in installations starting operation from 6 October 2015 until 31 December 2020;
- at least 65 % for biofuels, biogas consumed in the transport sector, and bioliquids produced in installations starting operation from 1 January 2021;
- at least 70 % for electricity, heating and cooling production from biomass fuels used in installations starting operation from 1 January 2021 until 31 December 2025, and 80 % for installations starting operation from 1 January 2026.

9.3.4 Methodology for GHG savings calculation

Greenhouse gas emissions from the production and use of transport fuels, biofuels and bioliquids shall be calculated as follows (Annex V part C):

$$E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr}$$

where
E = total emissions from the use of the fuel;
e_{ec} = emissions from the extraction or cultivation of raw materials;
e_l = annualised emissions from carbon stock changes caused by land-use change;
e_p = emissions from processing;
e_{td} = emissions from transport and distribution;
e_u = emissions from the fuel in use;
e_{sca} = emission savings from soil carbon accumulation via improved agricultural management;
e_{ccs} = emission savings from CO_2 capture and geological storage;
e_{ccr} = emission savings from CO_2 capture and replacement.
Emissions from the manufacture of machinery and equipment shall not be taken into account.
Greenhouse gas emissions from biofuels and bioliquids shall be expressed as follows:

- greenhouse gas emissions from biofuels, E, shall be expressed in terms of grams of CO_2 equivalent per MJ of fuel, g CO_2eq/MJ;
- greenhouse gas emissions from bioliquids, EC, in terms of grams of CO_2 equivalent per MJ of final energy commodity (heat or electricity), g CO_2eq/MJ.

Greenhouse gas emissions savings from biofuels shall be calculated as follows:

$$SAVING = \frac{EF(t) - EB}{EF(t)}$$

where
EB = total emissions from the biofuel;
EF(t) = total emissions from the fossil fuel comparator for transport
For biofuels, for the purposes of the calculation, the fossil fuel comparator EF(t) shall be 94 g CO_2eq/MJ.

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10- Conclusion

The assessment of the biomass supply chain is a fundamental issue in the field of renewable energies, in particular for the substitution of alternative energy sources, such as advanced biofuels, for fossil fuels (Fiorese & Guariso 2010).
The present deliverable provides the methodology to define the criteria that will be applied in the task 6.2 and follows, to set up case scenarios of low-carbon, resource-efficient and sustainable secondary biomass supply chains suitable for the commercial application of CONVERGE technology.
The analysis of the biomass sector in holistic terms is quite complex in respect of the proposed objectives and scale of results.
A Geographic Information Systems (GIS) approach appears to represent an appropriate tool for attaining this goal. Several studies have analysed GIS and spatial analysis instruments as tools for biomass chain evaluation at the European, national and local levels (Sacchelli et al., 2013).

Referring to the framework depicted in the present document, assumed the strong competition from today up to 2030, the industrial plant will be focused to small and medium scale and not-feedstock specific; this means with short supply chains as an option for profitable and sustainable models and capable of using the greatest number of different types of biomass.
Processes that work with heterogeneous lignocellulosic materials will make the technology less dependent on local competition for feedstock (Valdivia et al., 2016).
As described in the chapter 5, the consumption of wood feedstock for energy production is continuously increasing. According to Kirsanovs and Žandeckis (2015) non-wood material could be used to satisfy the demand for biomass, especially in certain EU geographical districts, on the condition that it doesn't alter the produced syngas' characteristics and quality, taking into account that biomass type and condition significantly influence the final composition of the syngas, given a certain type of gasifier and operating condition (Couto et al., 2013).

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BIBLIOGRAPHY

Bernetti I. , Sacchelli S., Alampi Sottini V., Marinelli N., Marone E. and Menghini S. (2013): *Optimisation of the regional energy supply network: a multi-objective analysis in the province of Florence (Italy)*, International Journal of Sustainable Energy, DOI:10.1080/14786451.2013.811412

BERST 7thFP Project (2015): *Catalogue of bioeconomy clusters in Good Practices and BERST regions*, Final Report Summary

BIOSIT (2003): Gis based methodology and algorithm, Life00 ENV/IT/oooo54.

COM(2007) 59, Communication from the Commission to the Council and the European Parliament on the *Interpretative Communication on waste and by-products*

Ćosić B. et al. (2016): *Database/inventory of the current agricultural value chains - Cereals AWCB value chain*, in Sustainable techno-economic solutions for the agricultural value chain, H2020-WASTE-2015-two-stage GA Nº 690142

Couto N., Rouboa A., Silva V. and Monteiro E. (2013): *Influence of the biomass gasification processes on the fina composition of syngas,* TerraGreen13 International Conference, Energy Procedia 36: 596 – 606

De Mol, R. M., Jogems M. A. H., Van Beek P., and Gigler J. K. (1997): *Simulation and Optimization of the Logistics of Biomass Fuel Collection*, Netherlands Journal of Agricultural Science 45 (1): 219–228

Directive (EU) 2018/2001 of the European Parliament and of the Council

E4tech (2017): *Advanced drop-in biofuels. UK production capacity outlook to 2030,* Final Report SPATS Work Package 1-045, PPRO 04/75/17

EIP-AGRI (2015): *European Innovation Partnership 'Agricultural Productivity and Sustainability'*, Workshop: Building new biomass supply chains for the bio-based economy, FINAL REPORT 27-28 MAY 2015

ENAMA (2010): *Biomasse ed Energia*, Roma.

European Commission (2012): COMMUNICATION FROM THE COMMISSION on *EU Bioeconomy Strategy & Action Plan "Innovating for Sustainable Growth: A Bioeconomy for Europe"*, COM(2012) 60

Fagarazzi C. and Tirinnanzi A. (2015): *Strumenti per lo sviluppo di filiere biomassa energia di qualità.* Provincia di Lucca. ISBN 978-88-7781-907-9

FAO (2017): Food Traceability Guidance, Santiago, ISBN 978-92-5-109876-9

Fiala M. (2012): *Energia da Biomasse Agricole. Produzione e utilizzo*. Maggioli S.p.A.

Fiorese G., Guariso G. (2010): *A GIS-based approach to evaluate biomass potential from energy crops at regional scale,* Environmental Modelling and Software 25: 702-711. DOI:10.1016/j.envsoft.2009.11.008

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 818135

Froese H.J. (2015): *National Policy Strategy on bioeconomy in GERMANY and its implementation*, EIP-AGRI Workshop, 27-28 MAY 2015

Gronalt, M., and Rauch P. (2007): *Designing a Regional Forest Fuel Supply Network,* Biomass and Bioenergy 31 (6): 393–402. doi:10.1016/j.biombioe.2007.01.007.

Hood, J. (2016): *Biomethane transport fuel, Department for Transport. Available at www.cngservices.co.uk/images/BiomethaneDay/2016/09Jonathan-Hood-DfT-Biomethane-Day-2016.pdf*

IPCC (2006): *Integrated Pollution Prevention and Control, Reference Document on Best Available Techniques in the Food, Drink and Milk Industries*, August 2006.

ISCC (2016a), ISCC 201-1 Waste and Residues, version 3.0.

ISCC (2016b), ISCC 203 Traceability and Chain of Custody, version 3.0.

ITC International Trade Center (2015): *Traceability in food and agricultural products*, Bullettin n.91/2015.

Kanzian, K., Holzleitner F., Stampfer K., and Ashton S. (2009): *Regional Energy Wood Logistics – Optimizing Local Fuel Supply,* Silva Fennica 43 (1): 113–128

Kirsanovs V. and Žandeckis A. (2015): *Investigation of fuel effect on biomass gasification process using equilibrium mode*,. Agronomy Research 13(2), 500–510

Matthew A. and McDermott F.(2012), *Domestic Energy Crops; Potential and Constraints Review*, NNFCC, Project Number: 12-021, URN: 12D/081

Ministère des Forêts, de la Faune et des Parcs du Québec (2009): *Developing the Value of Forest Biomass: An Action Plan,* ISBN 978-2-550-56564-2

Moller, B., and Nielsen P. S. (2007): *Analyzing Transport Cost of Danish Forest Wood Chip Resources by Means of Continuous Cost Surfaces,* Biomass and Bioenergy 31 (5): 291–298. DOI:10.1016/j.biombioe.2007.01.018.

Panichelli, L. and Gnansounou E. (2008): *GIS-Based Approach for Defining Bioenergy Facilities Location: A Case Study in Northern Spain Based on Marginal Delivery Costs and Resources Competition Between Facilities,* Biomass and Bioenergy 32 (4): 289–300. DOI:10.1016/j.biombioe.2007.10.008.

Proforbiomed (2014): *Development of a system of traceability of the forest biomass. Setting up of integrated strategies for the development of renewable energies*, Final Report of Pilot Action 1.5, MED project 'Promotion of residual forestry biomass in the Mediterranean basin' (acronym: Proforbiomed), September 2014.

PwC (2011): *Regional Biotechnology. Establishing a methodology and performance indicators for assessing bioclusters and bioregions relevant to the KBBE area,* Report by PwC for DG Research and Innovation.

Recchia L. (2006): *Strumenti GIS per un uso energetico della biomassa agro-forestale*, Rivista di Ingegneria Agraria, n.4: 19-26, ISSN: 0304-0593.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 818135

Recchia L., Cini E., Corsi S. (2009): *Multicriteria analysis to evaluate the energetic reuse of riparian vegetation*, Applied Energy, vol. 87: 310-319, 2010, ISSN: 0306-2619, doi: 10.1016/j.apenergy.2009.08.034.

Ricardo AEA Ltd (2017): *Biomass Feedstock Availability*, ED 662421043 | Issue Number 3

Sacchelli S., Zambelli P., Zatelli P. and Ciolli M. (2013): *Biomasfor: an open-source holistic model for the assessment of sustainable forest bioenergy,* iForest 6: 285-293. - doi: 10.3832/ifor0897-006

Spatial Foresight, SWECO, ÖIR, t33, Nordregio, Berman Group, Infyde (2017): *Bioeconomy development in EU regions*. Mapping of EU Member States'/regions' Research and Innovation plans & Strategies for Smart Specialisation (RIS3) on Bioeconomy, Final Report, Framework Contract: 2014.CE.16.BAT Lot 2, Specific Contract: RTD/F1/PP-03681-2015

Sultana, A. and Kumar A. (2012): *Optimal Siting and Size of Bioenergy Facilities Using Geographic Information System,* Applied Energy 94: 192–201.

Tallaksen J. (2009): *Biomass Gasification: A Comprehensive Demonstration of a Community-Scale Biomass Energy System* B, USDA Final Report. Grant 68-3A75-5-232

Ugolini M. and Barbati A. (2001): *Gestione dell'informazione ambientale per la valutazione del rischio inecndio boschivo in Povincia di Mantova*, Atti della 5° Conferenza Nazionale ASITA, Rimini 9-12 Ottobre 2001, Vol.2: 1407-1412.

Valdivia M., Laffarga J., Galan J. L. and Juan-Luis Ramos (2016): *Biofuels 2020: Biorefineries based on lignocellulosic materials,* Microbial Biotechnology (2016) 9(5), 585–594 doi:10.1111/1751-7915.12387.

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