


Sustainable supply of non-food biomass for a resource efficient bioeconomy

A review paper on the state-of-the-art

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The S2Biom project

The S2Biom project - Delivery of sustainable supply of non-food biomass to support a “resource-efficient” Bioeconomy in Europe - supports the sustainable delivery of non-food biomass feedstock at local, regional and pan-European level through developing strategies and roadmaps that will be informed by a “computerized and easy to use” toolset (and respective databases) with updated harmonized datasets at local, regional, national and pan-European level for EU-28, Western Balkans, Moldova, Turkey and Ukraine. Further information about the project and the partners involved are available under www.s2biom.eu.

The S2Biom project consortium:

Project coordinator

Scientific coordinator

Project partners

Summary

The European Union aims at raising the share of energy consumption produced from renewable resources to 20% in 2020 as compared to 1990. Moreover, the European Commission adopted a strategy "Innovating for Sustainable Growth: a Bioeconomy for Europe" to shift the European economy towards greater and more sustainable use of renewable resources. A resource efficient bioeconomy requires that the supply of biomass remains sustainable while achieving the EU target.

The aim of this paper is to give an overview about various studies which investigated the present and potential sustainable supply of non-food biomass in the EU. It will be a baseline for the update, comparison and refining of the datasets compiled throughout the S2Biom project.

The gross inland energy consumption of renewable energy sources within EU-28 in 2012 was 7,750 PJ (185 million toe) - an 11% share of total gross inland energy consumption. Biomass and renewable wastes provided 7.3% (5,150 PJ) representing around two thirds of this share.

Forest biomass is currently the most important source of renewable energy and accounts for around half of EU total renewable energy consumption (3,850 PJ in 2012). Many studies estimated the potential supply from forest for bioenergy. There is a significant difference between reported values caused mainly by different policy and sustainability scenarios. The estimated minimum and maximum values are approximately 5,000 PJ and 7,600 PJ for 2020 and 3,300 PJ and 7,500 PJ for 2030.

Currently, approximately 5.5 million ha of agricultural land are used for bioenergy cropping in the EU. This amounts to 3.2% of the total cropping area. Non-food lignocellulosic crops today play a minor role (1%), accounting for only about 50,000 – 60,000 ha of land. The lack of information and the lack of specificity of certain data sources present a significant challenge to the accurate identification of land areas with potential for non-food lignocellulosic crop cultivation. Nevertheless, some studies estimated the potential of abandoned non-arable land. In addition, estimations were done on the possibility to grow non-food lignocellulosic crops on a part of the arable land. If the potential from the two categories are summed up, the total minimum potential for the present is approximately 2,200 PJ and the maximum 6,400 PJ. For 2020, the potential is between 3,450 and 9,100 PJ and for 2030, between 3,600 and 8,700 PJ.

Agricultural residues are strongly promoted to contribute to the achievement of renewable energy targets. Currently, there is no specific data on the share from agricultural residues for bioenergy production. The potential of agricultural residues was investigated by category: crop residues, pruning residues, livestock residues, other primary residues, secondary crop residues and secondary animal residues. The estimated minimum and maximum values for the total categories are approximately 2,650 PJ and 3,100 PJ for 2020 and 5,200 PJ and 5,400 PJ for 2030.

Residual biomass from waste is another source of biomass supply for bioenergy production in the EU. This includes the biodegradable fraction of municipal solid waste, common sludges and kitchen oils and fats. The gross energy consumption of the biodegradable fraction of municipal solid waste was 370 PJ in 2012 in EU-28. The estimated minimum and maximum values for the total categories are approximately 900 PJ and 1,850 PJ for 2020 and 850 PJ and 1,850 PJ for 2030.

These estimations show that the EU is able to provide between 6,900 PJ and 16,600 PJ from biomass for its energy consumption today. These estimates could increase to 10,600 PJ and 21,350 PJ in 2020, and to 10,850 PJ and 22,700 PJ in 2030.

The current supply of biomass for energy is not exhausted and biomass can supply more in the future. However the lack of precise data makes it challenging to estimate these figures. In addition, the estimates vary to a large extent due to different definitions of potential and due to different methods applied. Nevertheless most of the studies reviewed agree that:

- Biomass potentials from forestry and waste are relatively stable over time
- Waste and agricultural residues has a potential that is currently barely exploited for energy generation
- Large uncertainty exists on how much biomass from agriculture can be supplied.
- For the future, non-food lignocellulosic crops and agricultural residues seem to be the key for a genuine expansion of biomass supply once biomass from forestry and waste are stable.

The S2Biom project aims at fulfilling the gaps of uncertainties by providing updated harmonized datasets on the sustainable delivery of non-food lignocellulosic biomass at local, regional and pan-European level. Moreover it develops strategies and roadmaps that are informed by a “computerized and easy to use” toolset.

1. Introduction

The targets of the EU climate change and energy policy for 2020 are to decrease greenhouse gas emissions (GHG) by 20%, to increase energy efficiency by 20% and to raise the share of energy consumption produced from renewable resources to 20% as compared to 1990. For 2030, the targets are set for a 40% GHG reduction and a 27% share of energy consumption produced from renewable resources compared to 1990.

The primary production of renewable energy within the EU-28 in 2012 was 177 million tonnes of oil equivalent (toe) (7,400 PJ) - a 22.3% share of total primary energy production from all sources. Among renewable energies, the most important source in the EU-28 was biomass and renewable waste, accounting for 65.5% of primary renewables production in 2012 [1].

The gross inland energy consumption[1] of renewable energy sources within the EU-28 in 2012 was approximately 185 million toe (7,750 PJ) - an 11% share of total gross inland energy consumption. Biomass and renewable wastes provided 7.3% (123 million toe or 5,150 PJ) representing around two thirds of this share [1].

According to the National Renewable Energy Action Plans it is expected that the use of other types of renewable energies increases in comparison to bioenergy in 2020, but the use of bioenergy is still expected to further increase to about 140 million toe (5,900 PJ) in 2020 [2].

The European Commission has adopted a strategy “Innovating for Sustainable Growth: a Bioeconomy for Europe” to shift the European economy towards greater and more sustainable use of renewable resources. The goal is a more innovative and low-emissions economy, reconciling demands for sustainable agriculture and fisheries, food security, and the sustainable use of renewable biological resources for industrial purposes, while ensuring biodiversity and environmental protection.

A resource efficient bioeconomy requires that the supply of biomass remains sustainable while achieving the EU target. The first step to achieve this target is to investigate the availability of biomass supply for bioenergy production. This review paper gives an overview about the state-of-the-art of the present use and potential of sustainable supply of non-food biomass in EU-28 including forest biomass, non-food lignocellulosic crops, agricultural residues, and residual biomass from waste.

[1] Gross inland energy consumption = primary production + recovered products + net imports + variations of stocks – bunkers.

2. Forest biomass in EU-28

Forests are defined by the FAO (Food and Agriculture Organization of the United Nations) as land with a tree canopy cover of more than 10% and an area of more than 0.5 ha, comprising trees able to reach a minimum height of 5 m at maturity in situ.

Other wooded land is land of more than 0.5 ha not classified as a forest. It has a canopy cover of 5% to 10%, comprising trees able to reach a height of 5 m at maturity in situ. Alternatively, it has a canopy cover of more than 10% comprising shrubs, bushes and trees. Neither forests nor other wooded land include land that is predominantly under agricultural or urban use.

Forests have a variety of ecological functions, serving as habitats for plant and animal species, helping to protect water and soil resources, as well as contributing to the fight against climate change by absorbing carbon dioxide that would otherwise remain in the atmosphere. They also safeguard our infrastructure and settlements by preventing landslides or avalanches in mountainous regions. In addition, forests are an important economic factor as suppliers of wood not only for wood products but also for bioenergy.

Forest biomass is currently the most important source of renewable energy and accounts for around half of the EU's total renewable energy consumption (92.5 million toe or 3,850 PJ in 2012). According to the National Renewable Energy Action Plans, biomass (mainly woody) used for heating, cooling and electricity is expected to supply about 42% of the 20% renewable energy target for 2020 [3].

2.1. Present use of forest biomass

According to Eurostat, the EU-28 had approximately 180 million ha of *forests* and *other wooded land* in 2010, corresponding to 42.4% of its land area [4]. The EU's forests and other wooded land cover approximately the same proportion of land area as that used for agriculture (Table 1).

Sweden recorded the largest area covered by forest and other wooded land in 2010 (31.2 million ha), followed by Spain (27.7 million ha), Finland (23.3 million ha), France (17.6 million ha), Germany (11.1 million ha) and Italy (10.9 million ha). The least densely wooded Member States were Malta, the Netherlands, Ireland and the United Kingdom.

Between 2000 and 2010, wooded area in the EU increased through natural expansion and afforestation by a total of 3.5 million ha, a rise of 2%. Only four of the EU Member States recorded a fall in their areas of wooded land, with Denmark recording the largest reduction (-5%) ahead of Portugal, Slovenia and Finland. In relative terms, the largest expansions in wooded area were recorded in Ireland (21.4%), while Bulgaria and Latvia both recorded increases in excess of 10%.

Just under 60% of the EU‑28 forests were privately owned in 2010. There were 11 Member States where the share of privately owned forest was above the EU‑28 average with 98.4% in Portugal. By contrast, the share of privately owned forest was below 20% in Poland and Bulgaria (where the lowest proportion was recorded, at 13.2%) (Table 1).

The growing stock (the living tree component of the standing volume) of forest and other wooded land in the EU−28 totalled some 24.4 billion m³ (over bark) in 2010: Germany had the highest share (14.3%), followed by Sweden (13.8%) and France (10.6%). Germany also had the largest growing stock in forests available for wood supply in 2010, some 3.5 billion m³, while Finland, Poland, France and Sweden each reported between 2.0 and 2.6 billion m³. The net annual increment (growth) in forests available for wood supply was also highest in Germany with 107 million m³ in 2010 (13.8% of the total increase for the EU-28), while Sweden, France and Finland each accounted for around 12% of the annual increment across the EU.

Table 1: EU-28 forest area, ownership and stock in 2010 [4].

Country	Land area without inland water	Forest and other wooded land	Forest	Forest ownership		Forest and other wooded land	Forest available for wood supply	
				Public	Private	Growing stock		Net annual increment
	(1 000 ha)			%	%	(1 000 m³ over bark)		
Belgium	3,033	706	678	44.3	55.7	167,900	164,288	5,289
Bulgaria	10,893	3,927	3,927	86.8	13.2	656,000	435,000	14,677
Czech Republic	7,723	2,657	2,657	76.8	23.2	769,300	737,650	23,086
Denmark	4,243	591	544	23.7	76.3	109,500	111,862	5,796
Germany	34,877	11,076	11,076	51.5	48.5	3,492,000	3,466,179	107,000
Estonia	4,343	2,350	2,217	39.0	61.0	455,200	398,300	11,201
Ireland	6,839	789	739	54.3	45.7	74,300	74,300	3,588
Greece	13,082	6,539	3,903	77.5	22.5	185,000	170,385	4,511
Spain	50,176	27,748	18,173	29.4	70.6	913,900	783,900	45,842
France	55,010	17,572	15,954	25.8	74.2	2,584,000	2,453,193	94,367
Croatia	5,659	2,474	1,920	72.7	27.3	415,590	334,400	7,423
Italy	29,511	10,916	9,149	33.6	66.4	1,448,300	1,285,330	32,543
Cyprus	921	387	173	68.7	31.3	8,829	3,269	38
Latvia	6,220	3,467	3,354	49.4	50.6	634,900	584,000	18,333
Lithuania	6,268	2,240	2,160	63.5	36.5	472,200	408,022	10,750
Luxembourg	259	88	87	47.1	52.9	25,950	25,756	650
Hungary	8,961	2,029	2,029	57.8	42.2	359,387	259,154	11,099
Malta	32	0	0	-	-	80	0	0
Netherlands	3,372	365	365	50.4	49.6	70,000	56,000	2,250
Austria	8,241	4,006	3,887	25.7	74.3	1,135,000	1,106,722	25,136
Poland	30,633	9,337	9,337	82.2	17.8	2,049,000	2,092,000	68,519
Portugal	9,068	3,611	3,456	1.6	98.4	187,800	154,000	19,087
Romania	23,016	6,733	6,573	67.7	32.3	1,390,200	1,098,328	33,984
Slovenia	2,014	1,274	1,253	23.2	76.8	417,000	389,927	9,165
Slovakia	4,810	1,933	1,933	50.6	49.4	514,100	477,600	13,193
Finland	30,389	23,269	22,157	30.3	69.7	2,199,391	2,024,000	91,038
Sweden	40,734	31,247	28,203	26.8	73.2	3,369,300	2,651,100	96,486
United Kingdom	24,251	2,901	2,881	33.3	66.7	380,000	340,000	20,700
EU-28	**424,578**	**180,232**	**158,785**	**40.3**	**59.7**	**24,484,127**	**22,084,665**	**775,750**

Forests available for wood supply are forests where no legal, economic, or environmental restrictions cause constraints on the sustainable supply of wood. They do not include protected forests.

The growing stock of the forest and other wooded land available for wood supply in EU-28 accounted for 22 billion m³ in 2010 (over bark) equivalent to around 90% of the total growing stock of forest and other wooded land (Table 1).

The primary energy production from forestry in the EU-27 in 2010 accounted for 9.8% of the total primary energy (80.8 million toe or 3,400 PJ) and for 48.5% of the total renewable energy according to [5]. In the forestry sector, the differences among Member States in the production of renewable energy are not very pronounced.

According to the project EUBIONET III [6] which assessed the wood use flow in Europe based on data from Eurostat, FAO and national partners in the project (Figure 1) (updated in 2012), the available stock of forests accounted for 25,717 million m^3 (solid wood) of which 246 million m^3 (0.95%) were used for bioenergy and 982 million m^3 (3.8%) for other purposes. The bioenergy flows are marked in red in Figure 1. The highest stream is supplied from the forest stock in form of firewood (82.1 million m^3), followed by black liquor from the pulp industry (66.1 million m^3) and sawmill industry (35.8 million m^3). The heating value of the wood used for bioenergy was estimated to be about 80 million toe (3,350 PJ).

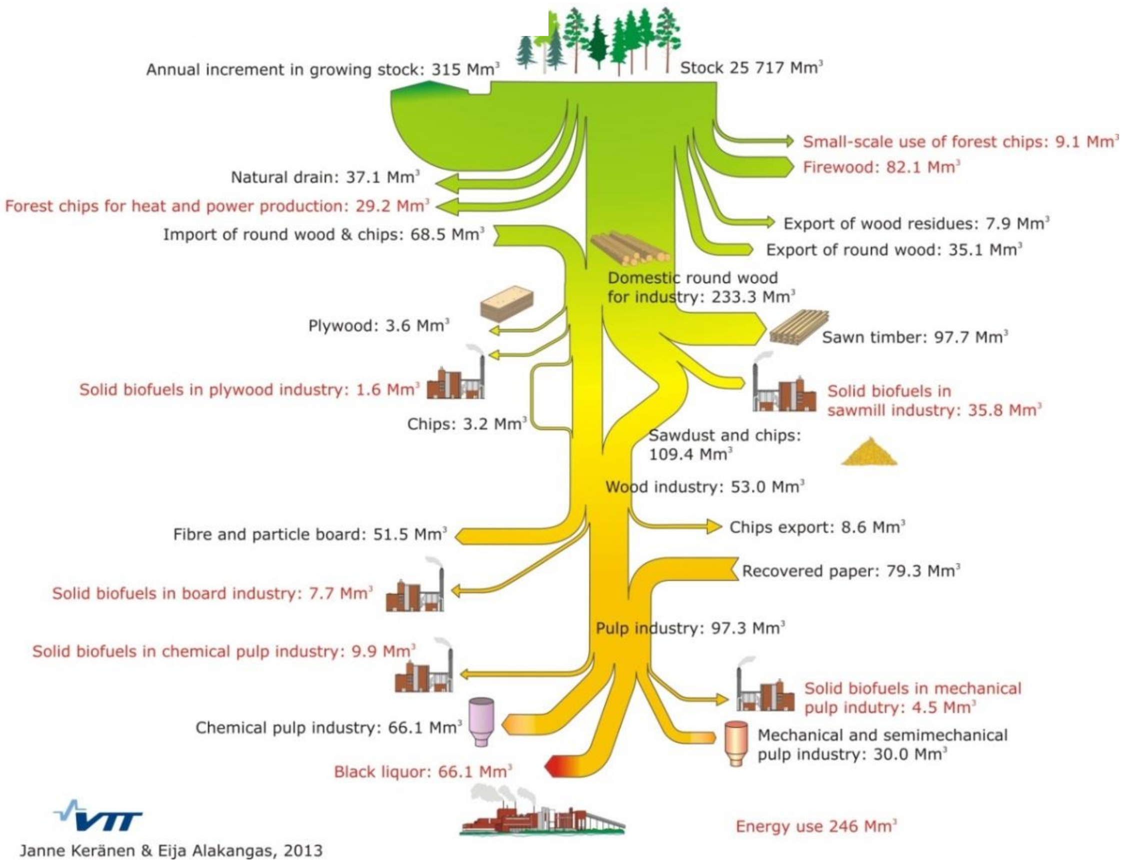

Figure 1: Wood use flow in EU-28 in 2012 [6].

2.2. Sustainable potential supply of forest biomass

In order to increase wood supply on short and long term from European forests the following measures can be implemented:

- Increasing the productivity of standing forest area which will increase the harvest level of the forest that is productively used. This can be done by taking silvicultural measures such as site preparation, fertilisation, weed control, protection measures, species and provenance selection, spacing, thinning intensity and better managing production time,
- Increasing the harvest area by starting to remove the annual increment from the unexploited forests,
- Removing a larger amount of logging and forest residues from the forest,
- Investing in the development of new technology in procurement and in the use of energy wood,
- Motivating forest owners to harvest in time and/or start exploiting parts of their forest that were unused.

However, all these measures might have constraints with respect to the sustainability of future forest biomass supply. Constraints can be technical (e.g. losses from harvesting and logging techniques, road infrastructure and logistics), social (e.g. forest owners unwillingness to manage forests), economic (e.g. increase of wood price) and environmental (e.g. biodiversity, nutrient losses).

Until today, there is no general agreement on the sustainable potential of wood supply for bioenergy production in Europe. Therefore an overview on different estimates is presented below.

The European Forest Sector Outlook Study (EFSOS) II [7] prepared by UNECE (United Nations Economic Commission for Europe) and FAO in 2011, presents varying scenarios for the European forest sector up to 2030, based on differing assumptions about priorities and policy choices. The reference scenario in this study was based on the Intergovernmental Panel on Climate Change (IPCC) B2 storyline which describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with continuously increasing global population, intermediate levels of economic development, and slow and diverse technological change.

The EFSOS II study shows that if no major policies or strategies are changed in the forest sector and trends outside it follow the lines described by the IPCC B2 storyline (*Reference scenario*), consumption of forest products and wood energy will grow steadily up to 1,167 million m^3 round wood equivalent (RWE) equivalent to approximately 156 million toe (6,550 PJ) and wood supply will expand to 1,179 million m^3 RWE to meet this demand (158 million toe or 6,600 PJ) (Figure 2). All components of supply will have to expand, especially harvest residues. However, due to the increased demand for wood for energy, wood prices are likely to increase.

Figure 2 shows the supply and demand of the reference scenario in comparison with three other scenarios. The main conclusions of these scenarios are the following:

1. *Maximising biomass carbon scenario (2030 Carbon):* To maximise the forest sector's contribution to climate change mitigation, the best strategy is to combine forest management focused on carbon accumulation in the forest, longer rotations and a greater share of thinnings, with a steady flow of wood for products and energy. In the long term however, the sequestration capacity limit of the forest will be reached, and the only potential for further mitigation will be regular harvesting, to store the carbon in harvested wood products or to avoid emissions from non-renewable materials and energy sources. The demand and supply in this scenario will stay more or less constant compared with the *Reference scenario*.

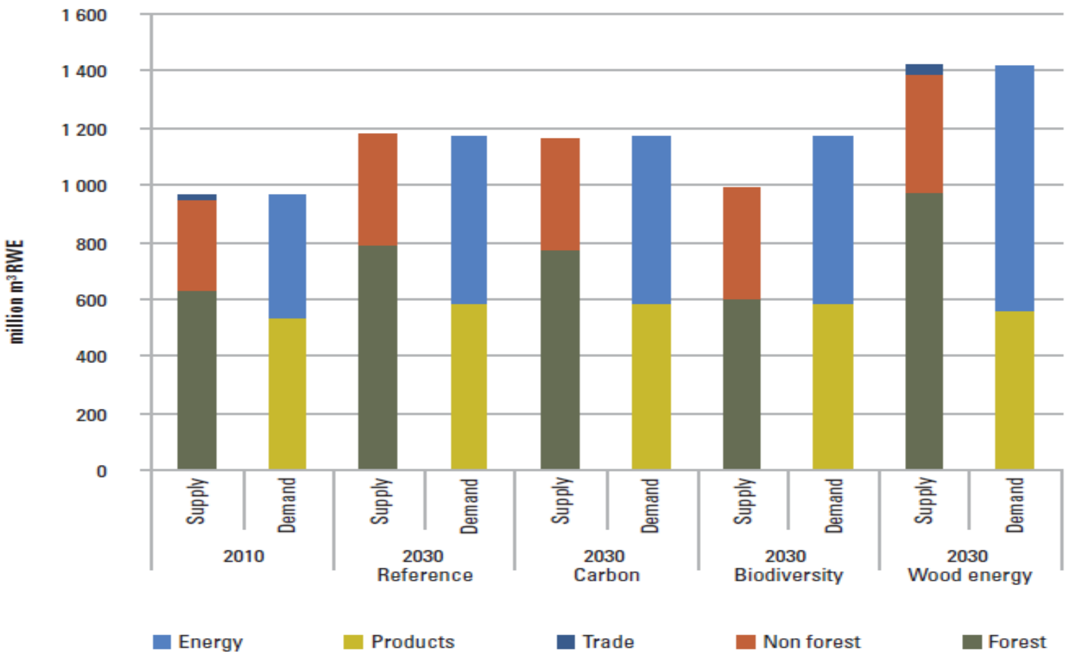

Figure 2: Supply/demand balance in the quantified scenarios, 2010-2030 [7].

2. *Priority to biodiversity scenario (2030 Biodiversity):* If biodiversity was given priority, for instance by setting aside more land for biodiversity conservation and changing forest management to favour biodiversity, the supply of wood from the European forest would be 12% less than in the *Reference scenario.* This necessitates reduced consumption of products and energy, and/or increased imports from other regions and/or intensified use of other sources like landscape care wood and wood originating from conservation management and short rotation coppice.
3. *Promoting wood energy scenario (2030 Wood energy):* If wood is to play its part in reaching the targets for renewable energy, with rather favourable assumptions about energy efficiency and increases for other renewable energies, and without expanding forest area, wood supply would have to be mobilised strongly, increasing by nearly 50% in twenty years. However the mobilisation of such high

volumes would have significant environmental, financial and institutional costs. To achieve this level of highly intensive silviculture and harvesting, strong political will would be necessary to modify many framework conditions for wood supply. The very high levels of extraction of residues and stumps would adversely affect nutrient flows, soil carbon content and thus water holding capacity and biodiversity. Forests would also be less attractive for recreation.

To increase European wood supply from outside the existing forest sector, it would be necessary to establish short rotation coppice on agricultural or other types of land. This could significantly reduce the pressure on the existing European forest and help to build the share of renewables in energy supply, but at the cost of trade-offs with other land uses and, depending on site selection processes, it will have both negative and positive effects on landscape, biodiversity, air, water, soil quality and ecosystem services.

Demand for energy wood is directly determined by the efficiency with which it is used. The most energy efficient ways in general are for heat production or in CHP installations. The distribution of the resource also influences the efficiency of the wood energy pathway, as transporting large volumes of bulky, moist wood is inefficient. Use efficiency is improved if transport distances are kept short, or if wood energy is transported in concentrated forms, such as pellets or biofuels. Efficient wood burning installations equipped with the necessary filters prevent the emission of fine particles which are harmful to human health.

A method developed for EFSOS II, which builds on the sustainability assessment of SoEF (State of Europe's Forests) 2011, has been used to review the sustainability of the *Reference scenario* and all three quantified policy scenarios. Most sustainability parameters, in this experimental method, are relatively satisfactory. The main concern is for biodiversity, as increased harvest pressure in all scenarios, except for the *Priority to biodiversity scenario* lowers the amount of deadwood and reduces the share of old stands. The *Promoting wood energy scenario* shows sustainability concerns with regards to forest resources and carbon, due to the heavy pressure of increased wood extraction to meet the renewable energy targets.

In comparison with the presented scenarios from EFSOS II, a more conservative view on potential future supply of forest biomass in Europe is expressed by several NGO. For example Birdlife International, European International Bureau and Transport and Environment have commissioned the International Institute for Sustainability Analysis and Strategy (IINAS) in cooperation with the European Forest Institute (EFI) and Joanneum Research (JR) to carry out a study on the sustainability of woody bioenergy in the EU [8]. The study underlines the following main observations:

- Europe's use of wood for material and energy purposes in 2010 was already relatively close to the estimated 2030 potential of wood, if we are to see only low environmental and climate risks. A significant increase in the use of wood compared to 2010 will probably lead to increased reliance on imports, displacement of wood use in other sectors and increased pressure on forests both in Europe and elsewhere. The domestic (low-risk) potential of wood in 2030 for material and energy use as estimated in this study (208 million toe or 8,700 PJ) would be exhausted if the use of wood for energy is increased by only 50% from the 2010 level of use.

- Only the use of woody residues for energy, either from forest harvesting, industrial processes or landscape care offer real climate benefits within a policy relevant time scale, since they are the only woody biomass feedstock with GHG intensities below those of fossil fuels.
- The potential for low-risk woody biomass in the EU is not enough to meet the expected demand (210 million toe or 8,800 PJ) as proposed by the European Commission for all uses by 2030.
- The sustainability scenario showed that woody bioenergy could contribute sustainably to the EU's energy needs with up to about 103 million toe (4,300 PJ) by 2030, satisfying 7% of all energy production demand with minimal environmental impacts and without relying on imports. This would require increased cascading use of wood for paper and packaging to reduce wood demand for materials, increased recycling of post-consumer wood from which some energy could be recovered, as well as increased use of short rotation coppice (SRC) instead of wood from forests. As a result of this, the overall consumption of wood from forests available for different uses would be well below amounts which would pose a risk to the climate and the environment.
- Current policies will lead to significant GHG emissions from the use of wood energy by 2030. Without additional measures, woody bioenergy use will not reach carbon neutrality even in a 100-year timeframe. With the correct policy choices promoting cascading use of wood and disincentivising the use of wood with high GHG intensity like stemwood, net biogenic GHG emissions of woody bioenergy use could be brought to nearly zero by 2030.

The Biomass Futures project also provided estimates on the supply of wood for energy use in EU-27 for 2010, 2020 and 2030 based on the EUWOOD project [9]. The results are presented in Table 2. The EUWOOD project estimated the amounts of wood energy supply for 2020 and 2030 at about 119 million toe (5,000 PJ) and 162 million toe (6,800 PJ), respectively [10].

Table 2: Estimation of total potential forest supply for 2010, 2020 and 2030 in EU-27 [9].

Forest products for bioenergy use	2010	2020	2030
	Energy potential (PJ)		
Additionally harvestable round wood	1,719	1,586	1,613
Primary forestry residues	849	1,724	1,752
Sawmill by-products	380	423	474
Saw-dust	188	209	234
Other industrial wood residues	194	229	272
Black liquor	261	701	366
Post-consumer wood	318	368	412
Total	**3,909**	**5,239**	**5,123**

The estimated energy potentials of wood supply from forest for 2010, 2020 and 2030 in the EU are summarised in Table 3.

Table 3: Studies estimating wood supply from forest for bioenergy use for 2010, 2020 and 2030 in EU-27.

Studies estimating wood supply from forest for bioenergy use	2010	2020	2030
	Energy potential (PJ)		
EFSOS II	2,434		
EFSOS II - Reference scenario			3,274
EFSOS II - biodiversity			3,274
EFSOS II - Promoting wood energy			4,084
EFSOS II - biomass carbon			3,274
Biomass Futures	3,909	5,239	5,123
EUWOOD	2,200	5,000	6,800
IINAS	3,000	3,650[2]	4,300

The different existing estimations of forest potential supply for bioenergy production, (minimum and maximum values) are illustrated in Figure 3. It is clear that there is a significant difference between these values caused primarily by different policy and sustainability scenarios.

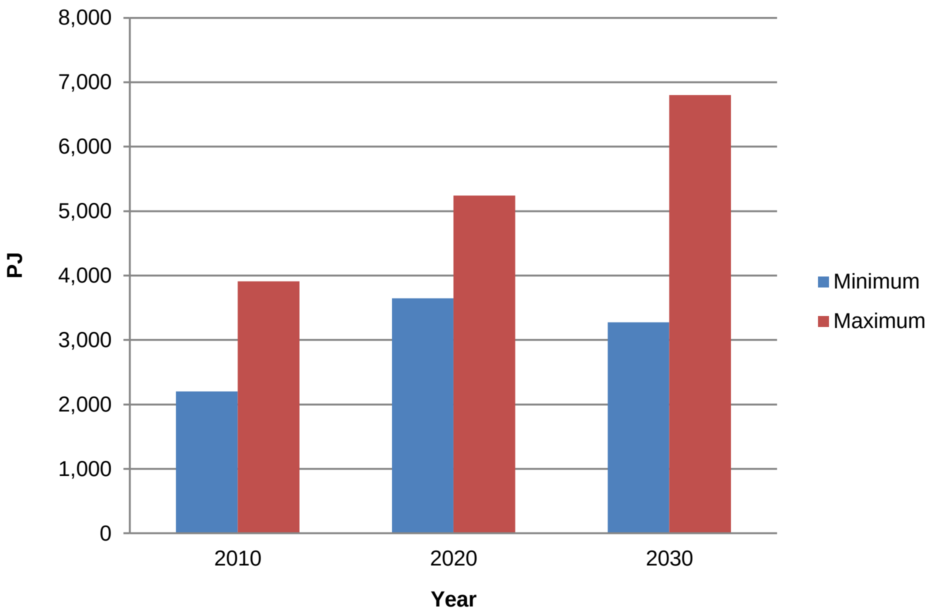

Figure 3: Minimum and maximum estimated bioenergy potential from forest biomass in the EU for 2010, 2020 and 2030.

The actual energy use from forest biomass was approximately 92.5 million toe (3,850 PJ) in 2012, but according to Biomass futures project which recorded the maximum estimated values there is still a large amount of wood from forest that could be exploited for bioenergy use under the 2010 policy requirements.

[2] This value is linearly extrapolated from the values of 2010 and 2030

2.3. EU policies for sustainable supply of forest biomass

The EU has a long history of contributing through its policies to implementing sustainable forest management and to Member States' decisions on forests although there is no common EU forest policy or guiding framework for forest-related issues. Important developments have taken place including the Europe 2020 strategy for growth and jobs, the Resource Efficiency Roadmap, Rural Development Policy, Industrial Policy, the EU Climate and Energy Package with its 2020 targets, the Plant Health and Reproductive Materials Strategy and the Biodiversity and Bioeconomy Strategies [11] [12].

Since 1990, FOREST EUROPE (The Ministerial Conference on the Protection of Forests in Europe) which is the pan-European political process for the sustainable management of the continent's forests has been developing common strategies for its 46 member countries and the European Union on how to protect and sustainably manage forests. The collaboration of the ministers responsible for forests in Europe has had a great economic, environmental and social impact on the national and international level. FOREST EUROPE has led to achievements such as the guidelines, criteria and indicators for sustainable forest management. The approach of Forest Europe follows two main pillars. The first pillar defines objectives for sustainable forest management and ensures and supports its implementation via policy measures in a range from informing actors to legislation and measures to prevent breach of sectorial law with focus on combatting illegal logging. The second pillar involves monitoring based on commonly agreed criteria and indicators that have evolved from environmental criteria to a set of criteria that currently covers the ecological, economic and socio-cultural dimensions [13].

In 1998 the EU made the first attempt to adopt an EU-wide framework for forestry by creating the 1998 Forestry Strategy [14] based on subsidiarity and shared responsibility. The strategy established a framework for forest-related actions that support sustainable forest management and are based on cooperative, beneficial links between EU and Member State policies and initiatives. The Forest Action Plan [15] 2007-2011 was an important instrument for implementing the strategy and addressed four objectives: competitiveness, environment, quality of life and coordination and communication. Co-financing of forestry measures under the Rural Development Regulation has been and will remain the main means of EU-level funding.

In 2013, the EU forest strategy has been renewed based on an ex-post evaluation of the Forest Action Plan. This strategy aims to put forests and the forest sector at the heart of the path towards a green economy and to value the benefits that forests can deliver sustainably, while ensuring their protection. The strategy, and its implementation, built on existing legislation and international initiatives, including work carried out under FOREST EUROPE [16], consider the special situation of small forest owners, and address market-based private-sector tools such as certification. The strategy also focuses on increasing sustainable wood mobilisation and the cascading principle, prioritising products of higher added value, creating more jobs and contributing to a better carbon balance. All parties involved need to show a strong long term commitment and political support. A review will be carried out by 2018 to assess progress in implementing the strategy.

The EU Renewable Energy Directive [17] (RED) lays down sustainability criteria for biofuels for transport and bio-liquids used in other sectors, but not for solid and gaseous biomass used for electricity, heating and cooling. In February 2010, as required by Article 17(9) of the RED, the EC published a Report on sustainability requirements for the use of solid and gaseous biomass sources in electricity, heating and cooling [18]. The EC decided not to introduce EU binding criteria but to adopt non-binding recommendations to Member States that had already introduced or planned to introduce national biomass sustainability requirements like Belgium, The Netherlands, the United Kingdom and Denmark [19].

In 2014, the EC published a report on the state of play on the sustainability of solid and gaseous biomass used for electricity, heating and cooling in the EU [20], here it analysed the key internal market and sustainability issues related to biomass for heat and power generation. The main conclusions of this report were the following:

- Since currently a limited number of Member States have adopted broadly consistent sustainability schemes and no apparent internal market barriers have been identified so far, it is considered that the risk of market distortion caused by national sustainability regulations can be effectively managed through the existing EU tools on technical standards.
- The EC has discussed the most important sustainability risks of large-scale biomass production and use for energy, and reviewed how they are currently being addressed at EU level. The vast majority of the biomass used today in the EU for heat and power are considered to provide significant GHG savings compared with fossil fuels even though a number of knowledge gaps still exist.
- Through the reporting requirements under the Renewable Energy Directive, and other policy initiatives related to the bioeconomy, the EC will closely monitor the origin and the end-use of biomass in the EU, with a view to taking appropriate corrective action, if needed. In this way, the Union and its Member States can ensure a stable and predictable regulatory framework for meeting the 2020 energy and climate targets, while at the same time taking action to minimize the risks of unintended sustainability impacts.

In The EU there are some sustainability certification schemes. In the SolidStandards project, an updated overview of these schemes (both existing and in preparation) in the EU-27 is described [21]. The overview includes factsheets of sustainability certification initiatives for solid biomass, a comparative analysis of sustainability certification initiatives for solid biomass and a contextual review of sustainability criteria recommended by the EC for solid biomass.

Annex I gives an overview of the voluntary sustainability certification schemes applied to solid biomass: FSC, PEFC, NTA 8080, GGL and Laborelec label.

Originally created as Industrial Wood Pellets Buyers (IWPB) to facilitate intercompany trading of solid woody biomass, the industry-led initiative Sustainable Biomass Partnership (SBP) [22] was formed in 2013. SBP is driven by major European utilities that use biomass, mostly in the form of wood pellets, in large thermal power plants. SBP's vision is an economically, environmentally and socially sustainable solid biomass supply-chain that contributes to a low-carbon economy. SBP is currently focusing on developing tools to provide assurance that woody biomass is sourced from legal and sustainable sources. SBP recognises fully the credibility of existing and well-proven forest certification schemes, FSC and PEFC, and does not wish to compete with or replicate them. Unfortunately there is limited uptake of certification in some key forest-source areas and the schemes themselves do not yet cover all the key requirements of biomass users.

Therefore, SBP is working to develop solutions, short-term and long-term, to address both these issues and is in discussion with both schemes on how these challenges might be overcome.

SBP immediate priority is to develop standards and processes allowing companies in the biomass sector to demonstrate compliance with legal, regulatory and sustainability requirements relating to woody biomass.

The SBP designed a Biomass Assurance Framework representing a clear statement of principles, standards and processes necessary to demonstrate such compliance. Wherever possible, use is made of the FSC and PEFC standards and processes already applied to other forest product streams. Further refinement and strengthening of these SBP standards will follow as necessary.

3. Non-food lignocellulosic crops in EU-28

Non-food lignocellulosic crops are crops that are unsuitable for human or animal food consumption and are grown exclusively or primarily for the purpose of producing biomass for energy and/or material purposes in an agricultural rather than a forestry context. Nearly all of the crops considered within this definition are perennial in nature, i.e. they can be cut and harvested for biomass over successive years without re-cultivation or sowing. The whole crop can be harvested and used for energy production. Two broad types of energy crops are considered, **perennial herbaceous crops** (Miscanthus, switchgrass, reed canary grass, giant reed, perennial rye grass) and woody crops known as **short rotation coppice** (SRC) (e.g. willow, poplar, eucalyptus, paulownia).

3.1. Present use of non-food lignocellulosic crops

Based on a compilation of a wide range of data sources it is estimated that at present there are approximately 5.5 million ha of agricultural land on which bioenergy cropping takes place. This amounts to 3.2% of the total cropping area [10].

Most of this land is cultivated with oil crops for biodiesel production (82%) or sugar and starch crops that are used for the production of bioethanol (11%), mostly in France and Germany but also in the UK, Poland and Romania. Crops grown as feedstock for biogas production (e.g. maize) also take up an important part of that land (7%), especially in Germany. Until today non-food lignocellulosic crops for electricity and heat generation play a minor role (1%), accounting for only about 50,000 – 60,000 ha of land. The largest areas of non-food lignocellulosic crops are in the UK (mainly miscanthus and willow), Sweden (willow, reed canary grass), Finland (reed canary grass), Germany (miscanthus, willow), Spain and Italy (miscanthus, poplar). Statistics of non-food lignocellulosic crops plantations are almost inexistent in many European countries.

3.2. Sustainable potential supply of non-food lignocellulosic crops

In order to assess the potential supply of non-food lignocellulosic crops for bioenergy, it is important to assess the areas where these crops can be potentially cultivated if arable land is not to be considered. These areas include: fallow land in agriculture, other unutilised land within the current agricultural land area, recently abandoned agricultural land, recently abandoned arable land and contaminated land.

The Institute for European Environmental Policy (IEEP) assessed the potential contribution of non-food lignocellulosic crops to Europe's future energy [23]. The study showed that the lack of information and the lack of specificity of certain data sources present a significant challenge to the accurate identification of land areas with potential for non-food lignocellulosic crop cultivation. The figures in Table 4 suggest a hypothetical area of land that could be investigated further for growing non-food lignocellulosic crops production of about 1.35 million ha. This is approximately one third of the area cultivated for biofuel feedstock production in 2010. The aggregated figure presented is formed through a combination of estimates of various land use types and areas. Whether or not these areas could or would be cultivated in practice remains a major question. Economic, environmental and social barriers to cultivation would need to be overcome, and the sustainability considered alongside local investment in collection and processing activities. These additional constraints could further limit the potential areas of land in the categories reviewed.

Table 4: Categories of land considered in IEEP study for non-food lignocellulosic crop production [23].

Agricultural land	Area (ha)
Recently abandoned cropland (<5 years old)	200,000
(Recently abandoned) Grassland moving out of agricultural use since 2009, most likely out of production, includes transitions to urban land	600,000
Fallow land in agricultural rotation, most of which is needed for agronomic purposes	200,000
Other underutilised land within the current UAA but not permanent grassland	300,000
Non-agricultural land	
Suitable contaminated sites (excluding areas suited only for afforestation	50,000
Total potentially available land based on optimistic assessments of area	**1,350,000**

If the 1.35 million ha of land were to be cultivated, a total of between 7.7 and 16.7 million dry tonnes of biomass could be produced annually with embedded energy content between 3.3 and 7.2 million toe (140 PJ and 300 PJ).

In the EEA-ETC/SIA study [25] and the Biomass Futures project [26] a different approach was taken to estimating land availability for dedicated cropping. The focus was on future land availability and tries to identify abandoned agriculture land between 2004 and 2020. The land estimates in the study builds on CAPRI model results. The use of the CAPRI results is very logical as it is the only available model which predicts the EU markets and production responses at the regional level for the whole EU-27. It simulates the most probable land use changes in European agricultural sector. For the EEA and Biomass Futures study the CAPRI baseline was used. It takes into account the most recent Common Agricultural Policy (CAP) Health Check reform, the 2020 RES Targets and the most recent OECD-FAO projections on agricultural prices, population and welfare developments [27]. In the EEA and Biomass Futures assessment it is expected that dedicated cropping with perennials for bioenergy production is most likely to take place on land that is neither needed for the production of food and feed nor for biofuel crops. The EEA-ETC/SIA study and the Biomass Futures study made the same analysis but used different scenarios.

The results of the EEA-ETC/SIA study assessment for 2020 showed that land availability for dedicated perennial biomass crops in EU-27 ranges between 6.8 and 12 million ha. The biomass produced on this land is estimated to be between 86 and 118 million dry tonnes. The primary energy produced from this biomass is estimated to be between 33 million toe (1,400 PJ) and 45 million toe (1,900 PJ) considering a heating factor of 16 PJ/million tonnes.

In the Biomass Futures study where only some environmental constraints in the cropping phase were taken into account, the primary energy potential for non-food lingocellulosic crops is assessed to be approximately between 51.6 million toe (2,150 PJ) and 70 million toe (2,950 PJ) in 2020 and between 36.8 million toe (1,550 PJ) and 60.8 million toe (2,550 PJ) in 2030.

Overall it is clear that there are plenty of land resources in the EU available that are not going to be used for food and feed production and where non-food lignocellulosic crops can be grown. Part of these lands will have an agricultural status but many will have a marginal status and not included any longer in any agricultural or forest land statistic. Ownership of some of these lands may also be unclear. Whether these lands can be brought into dedicated cropping land is very much dependent of future market forces, stimulation measure and sustainability requirements applied nationally and locally.

If in addition a part from arable land would be used for non-food lignocellulosic crops production, the estimations will be much higher. In order to estimate how much arable land is available, first it is necessary to estimate the area needed for food production. In the EU-27 this is calculated to be about 111 million ha of arable land and about 69 million ha of permanent grassland. The population of EU-27 is unlikely to increase rapidly in the near future. Nielsen et al. estimated that assuming a moderate diet (mixed vegetable-animal products), about 62% of the arable land would be needed to feed the population of EU-27 [24]. According to the study, if 10%, 20% and 30% of arable land were used for bioenergy crops in EU-27, the potential bioenergy produced will account for about 49 million toe (2,050 PJ), 98 million toe (4,100 PJ) and 146 million toe (6,100 PJ), respectively assuming yields of 10 tonnes dry matter per ha.

If the potential from land suitable for non-food lignocellulosic crops mentioned above and additional arable lands are summed up, the total minimum estimated potential for the present will be approximately 52 million toe (2,200 PJ) and the maximum 153 million toe (6,400 PJ). For 2020, the potential will be between 82 and 217 million toe (3,450 and 9,100 PJ) and for 2030, between 86 and 208 million toe (3,600 and 8,700 PJ).

3.3. EU policies for sustainable supply of non-food lignocellulosic crops

Perennial herbaceous crops and **short rotation coppice** grown on agricultural land in the EU have to meet a series of statutory environmental rules regarding the quality of water, soils and air as any other agricultural biomass, whether used for food, feed, material or energy (see CAP cross compliance rules).

Non-food lignocellulosic crops can undergo two lines of energy conversion pathways: the production of second generation transport biofuels or the production of heat and power, knowing that currently the second option is more common.

In case the end product is transport biofuel, it needs to comply with the sustainability criteria set out in the Renewable Energy Directive 2009/28/EC in order to be eligible for the targets or any other public support. If the crops are used for heat and power generation, no sustainability criteria for solid biomass were set by the European Commission, as it is the case for solid biomass produced from forestry.

Policy makers have begun to address the impact of land use change, both direct and indirect, associated with the use of conventional (food and feed) crops for conversion into biofuels. As the debate has progressed there has been an increasing perception that non-food lignocellulosic crops, which can be grown on marginal and degraded land, offer one option to limit the impacts of displacing food and feed production from current farmland. If non-food lignocellulosic crops are grown on agricultural land, the impact of land use is again in question.

The reformed Common Agricultural Policy (CAP) affects the use of land for bioenergy production through two pillars: **Direct Payment** and **Rural Development** [28] [29].

The first pillar - **Direct Payments** - will move away from allocations per Member State and per farmer within the Member State based on historical references. This will mean a clear and genuine convergence of payments not only between Member States, but also within Member States. Direct payments are largely decoupled: there will be no direct incentives supporting the production of bioenergy from energy crops.

Moreover, Greening Payment is introduced meaning that a significant share of the subsidy will in future be linked to rewarding farmers for the provision of environmental public goods.

The second pillar of the CAP, through its **Rural Development** measures, encourages the supply of bioenergy from agriculture and forestry and the use of bioenergy on farms and in rural areas. It will be up to Member States / regions to decide which measures they use (and how) in order to achieve targets set against six broad "priorities" and their more detailed "focus areas" (sub-priorities). The six priorities cover:

- Fostering knowledge transfer and innovation;
- Enhancing competitiveness of all types of agriculture and the sustainable management of forests;
- Promoting food chain organisation, including processing and marketing and risk management;
- Restoring, preserving and enhancing ecosystems;
- Promoting resource efficiency and the transition to a low-carbon economy;
- Promoting social inclusion, poverty reduction and economic development in rural areas

Beyond 2020 the policy landscape surrounding biofuels and bioenergy could change dramatically. On 22 January 2014, the EC set out its vision for EU climate and energy policy up to 2030 proposing significant changes from the current status. The EC envisages no ‘public support’ for biofuels produced from food–based feedstocks, and no longer foresees any transport specific targets for renewables post 2020. This may, depending on how it would be implemented, offer an opportunity for non-food lignocellulosic crops to expand in area [30].

4. Agricultural residues in EU-28

Agricultural residues are generally divided into two categories: **primary agricultural residues** which are residues resulting from primary agricultural operations (e.g. straw, manure) and **secondary agricultural residues** which are produced during the processing of crops into food or other products (e.g. bagasse). Both primary and secondary agricultural residues can be used for energy production. They can be classified in two categories depending on their moisture content: dry residues which have low moisture content (e.g. straw) and are more suitable for combustion and gasification processes and wet residues (e.g. slurry) with high moisture content making them energetically inefficient to use for combustion or gasification, and financially and energetically costly to transport. Wet residues are therefore more suitable for biogas production. Second generation bioethanol can be produced from dry or wet residues with high ligno-cellulose content (e.g. straw, grass).

Many agricultural residues may have alternative uses or markets such as soil nutrient recycling and improvement purposes, and any decision to use them for energy must be made in the context of these alternatives.

Agricultural residues are strongly promoted to contribute to the achievement of renewable energy targets since competition for resources and land is largely avoided.

4.1. Present use of agricultural residues

According to Eurostat in 2010 the primary renewable energy production from agriculture in the EU-27 represented 2.1% of the total primary energy produced (17.6 million toe or 750 PJ) and accounted for 10.6% of the total renewable energy production [5]. Most of this share comes from energy crops. There is no data on the share from agricultural residues for bioenergy production on EU level. Nevertheless, it is valuable to mention that in some member states e.g. Denmark, the annual consumption of straw for heat and power production accounted for 16% of the national renewable energy production in 2012 which is equivalent to approximately 0.5 million toe or 20 PJ [31].

4.2. Sustainable potential supply of agricultural residues

Agricultural residues are produced from different sources. In order to increase the accuracy in estimating the potential supply in this paper, agricultural residues have been divided and assessed according to the following categories:

- Primary agricultural residues
    - Crop residues
    - Pruning residues
    - Livestock residue
    - Other residues
- Secondary agricultural residues

4.2.1. Primary agricultural residues

4.2.1.1. Crop residues

Crop residues are parts of the crop that are not harvested during standard agricultural operations. In the European Union there are large differences between Member States in terms of cultivated area, types of crops and yields, due to climate conditions, specific soil condition and farming practices.

The use of agricultural crop residues for bioenergy production requires accurate data on their availability by crop type. Crop yields depend upon specific local agro-ecological conditions (climate and precipitation pattern, soil properties, etc.), plant varieties, farming techniques, etc.

Data on crop yields are directly available, while data on their residues are not, since the aim of agricultural production was mainly to maximize the yield of main food/feed product in the past. Crop residue yields are very variable and depend on plant variety, crop yield, climate and soil conditions, whether the crop is irrigated or rain-fed, farming practices, harvesting techniques and the cutting height. The availability of residues depends on the amount that can be removed from land keeping land fertility maintained and on their competitive use for agricultural or industrial purposes.

There are many studies which estimated crop residue availability in the EU. A study by ICCT (International Council on Clean Transportation) assessed the total crop residue production at 367 million tonnes per year and the current net availability of crop residues for bioenergy at 122 million tonnes per year based on FAOSTAT data on yields and total annual production of these crops from 2002–2011 (Table 5) [32]. This is equivalent to approximtely 2,150 PJ.

Table 5: Projected production and availability of crop residues in 2011, 2020 and 2030 [32].

Crop type	2011 Total residue production	2011 Residue availability	2020 Total residue production	2020 Residue availability	2030 Total residue production	2030 Residue availability
	Million tonnes					
Barley	65	22	70	23	74	25
Maize	62	21	66	22	70	23
Oats	10	3	11	4	12	4
Rapeseed	18	6	20	7	22	7
Rice	2	1	2	1	2	1
Rye	11	4	12	4	12	4
Soybeans	2	1	2	1	2	1
Sunflower	9	3	10	3	12	4
Triticale	13	4	13	4	14	5
Wheat	144	48	154	51	163	54
Sugar beet	30	10	31	10	32	11
EU-28	**367**	**122**	**393**	**131**	**417**	**139**

For 2030, the ICCT study estimated the availability of crop residues following the European Commission's (2012) projections of agricultural production to 2022. Changes in crop production to 2030 were then linearly extrapolated. The projected residue availability for 2030 is only slightly higher than the figure for 2011 estimated at 139 million tonnes (Table 5). In terms of energy this figure is equivalent to approximately 2,450 PJ.

A study by the Bloomberg New Energy Finance [33] estimated residue production available for bioenergy production at 151 million t/year in 2030 equivalent to 2,650 PJ approximately assuming 82.5% of residues are required for soil quality.

Many other studies have estimated the potential of crop residues for bioenergy in addition to other residues. Figure 4 illustrate the crop residues share in these studies in EU-27.

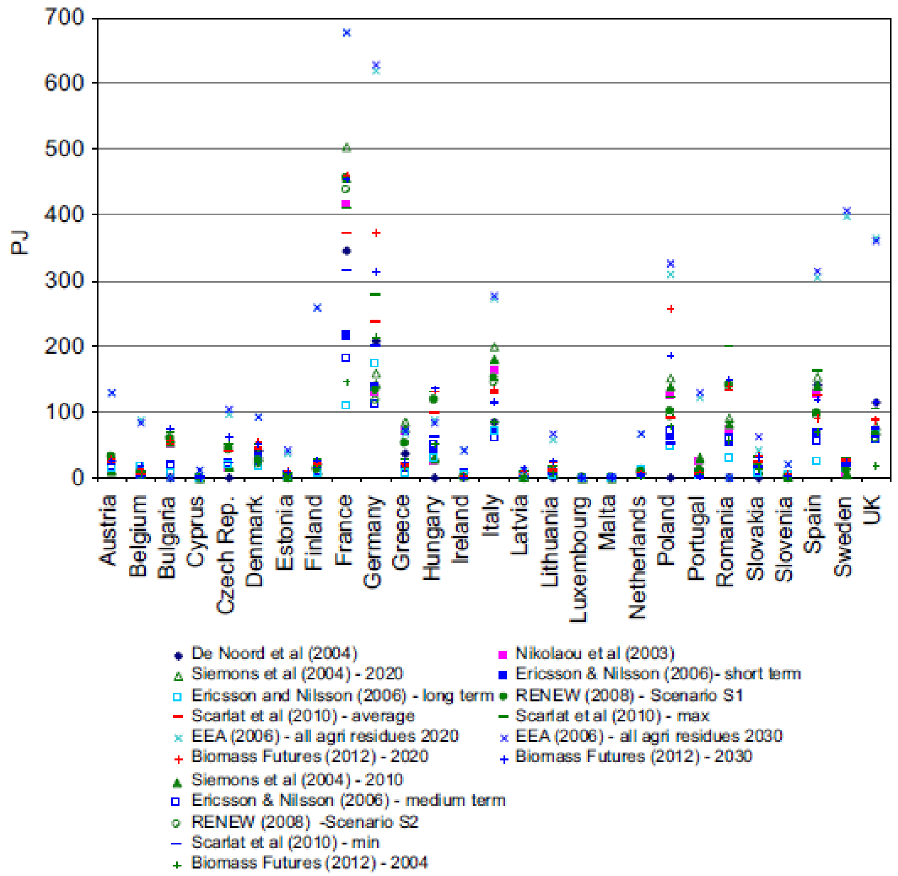

Figure 4: Various assessments for crop residue potential and availability in EU-27 [34].

The graph shows that there are significant differences between the estimated results, depending on the different assumptions considered. These relate to the variability in relation to crop type cultivation, changing market conditions, as well as competitive uses of agricultural residues, including the different energy uses of biomass (heat, electricity generation, and biofuels), biochemical and other bio-products.

A study conducted by JRC [35] assessed the availability of 8 crop residues (wheat, barley, oats, rye, rice, maize, sunflower and rapeseed) in the EU-27. In order to provide estimates of the crop residues that can be used for bioenergy production, the study took into account the crop and residue production, environmental constraints for collection and competitive uses in the livestock sector or for horticulture/mushroom production.

The total amount of crop residues produced in EU-27 every year was estimated at 258 million dry tonnes per year on average based on residue yields and crop areas. The share of the 8 different crop residues in EU-27 is shown in Figure 5. For the 10-year period (1998-2007), a variation of crop residue production between 200 and 305 million dry tonnes per year at EU level was identified.

The analysis of sustainable removal rates concluded that, on average, about 40% of wheat, barley, rye, oat residues and 50% of the maize, rapeseed and sunflower residues can be collected, if environmental and harvesting constraints are taken into account.

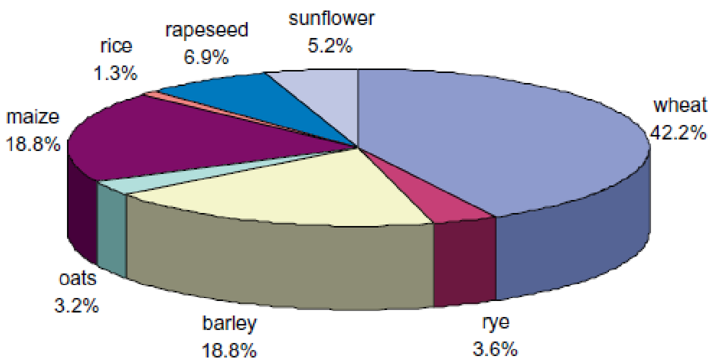

Figure 5: Share of 8 crop residues produced in EU-27 [35].

Based on the sustainable removal rates of crop residues, residue-to-crop yield and seed and straw moisture content, the amount of collectable crop residues was estimated at an average of 111 million tonnes dry matter of crop residues/year in EU-27. However, this amount can vary between 86 and 133 million tonnes dry matter/year depending on crop residue production.

The average consumption of straw for animal breeding and mushroom production was estimated at 28 million tonnes per year. Therefore, the sustainable total average amount of crop residues available for bioenergy production in EU-27 is 83 million tonnes per year. In terms of energy the estimated value is equivalent to approximately 37 million toe (1,550 PJ). The estimation was based on Lower Heating Value (LHV) of 17.5 PJ/t dry matter for crop residues. The data also show a higher temporal variability of available residues in the EU, from 26 million toe (1,090 PJ) to a maximum of 45 million toe per year (1,900 PJ), depending on the various conditions considered. This yearly variation ranges between +23% and -28% compared with average data.

Thus, at EU-27 level, the use of agricultural crop residues alone could in average contribute 3.2% of final energy consumption. However, this figure ranges from minimum 2.3% to maximum 4%, depending on the availability of residues in different years.

As a summary, the minimum and maximum values of energy potential from crop residues according to the studies above for 2011 and 2030 are presented in Figure 6. Crop residues potential estimation for 2020 was calculated as an average of the values of 2010 and 2030. Secondary crop residues were estimated to supply the same amount of energy for 2020 and 2030 as it was for 2011.

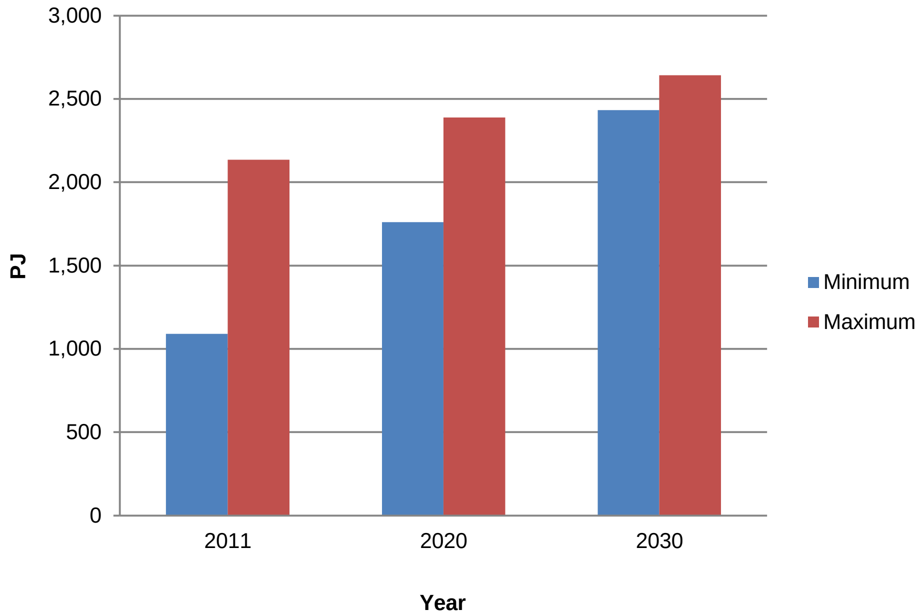

Figure 6: Minimum and maximum estimated bioenergy potential from crop residues in the EU for 2011, 2020 and 2030.

4.2.1.2. Pruning residues

Woody material from pruning and cutting can deliver a large potential of biomass. In some regions of the EU, plantations of soft fruit, citrus, olives and vineyards cover quite a significant area. The Biomass Futures project assessed the potential supply of these residues by combining the permanent cropping areas with average harvest ratios per type of permanent crop. The harvest ratios were derived from several publications (Table 6).

In the Mediterranean region, pruning residues could be an important resource with Spain as the largest contributor followed by Italy, Greece and Portugal (Table 7). The largest potential is delivered by vineyards and olives.

Table 6: Average residue harvest ratios per type of permanent crop [10].

Land use category	Residue yields tonnes dry matter / ha / year
Fruit and berry plantations - total	2.15
Temperate climate fruit and berry plantations	
Subtropical climate fruit and berry plantations	
Nuts fruit and berry plantations	2.15
Citrus plantations	2.75
Olive plantations - table olives	1.77
Olive plantations - oil production	
Vineyards - quality wine	2.81
Vineyards - other wines	
Vineyards - table grapes	
Vineyards - raisins	

Table 7: Potential from woody residues of fruit trees, nuts and berry plantations, olives, citrus and vineyards (ktoe) in 2004, 2020 and 2030 [10].

Country	2004	2020	2030
	ktoe		
Austria	68	48	39
Belgium/Luxembourg	14	18	26
Bulgaria	81	242	106
Cyprus	33	31	17
Czech Republic	33	10	29
Denmark	6	6	6
Estonia	2	2	1
Finland	3	8	7
France	1,133	996	760
Germany	162	135	129
Greece	858	801	1,163
Hungary	150	255	130
Ireland	1	0	2
Italy	1,966	2,067	1,624
Latvia	20	7	1
Lithuania	23	14	18
Luxembourg	0	0	0
Malta	1	0	3
Netherlands	16	13	14
Poland	260	323	360
Portugal	564	586	512
Romania	318	314	150
Slovakia	26	9	5
Slovenia	27	20	18
Spain	3,570	4,164	3,680
Sweden	2	22	5
United Kingdom	25	15	31
EU27	**9,362**	**10,106**	**8,836**

The potential supply of pruning residues seems to remain relatively stable according to Biomass Futures assessment. It was estimated at about 10 million toe (423 PJ) in 2020 and 9 million toe (370 PJ) in 2030.

With respect to potential applications for bioenergy production, primary residues face constraints due to their relatively high ash content resulting from the high share of bark and the presence of agrochemicals on the biomass surface influencing the flue gases emissions. Therefore, pruning residues are considered low quality fuel and can be used for combustion technologies aimed for low quality fuels.

4.2.1.3. Livestock residues

Livestock residues or residues from animal husbandry include primarily animal manure. According to the inventory of manure processing activities in the EU conducted by the European Commission in 2011 [36], the entire manure production in the EU that is potentially available for manure processing, for energy recovery and other purposes is estimated at 1.4 billion tonnes (wet) (Table 8). The largest production is in France, followed by Germany.

Table 8: Estimated amount of livestock manure produced from pigs, cattle and chicken in the EU Member States by major livestock manure types [36].

Country	Pig	Cattle	Poultry	Total
	1,000 tonnes / year			
Austria	3,538	24,648	1,378	29,564
Belgium	7,189	31,289	2,762	41,241
Bulgaria	904	6,971	1,668	9,545
Cyprus	537	685	276	1,499
Czech Republic	2,203	16,652	2,286	21,142
Denmark	14,279	19,010	1,828	35,117
Estonia	422	2,937	167	3,524
Finland	1,595	11,333	468	13,395
France	17,098	229,436	16,732	263,264
Germany	31,039	159,756	11,218	202,013
Greece	1,087	7,652	3,023	11,762
Hungary	3,905	8,652	2,963	15,519
Ireland	1,696	82,885	-	84,580
Italy	10,681	75,578	2,472	88,731
Latvia	442	4,693	380	5,515
Lithuania	1,036	9,515	840	11,390
Luxembourg	93	2,425	9	2,527
Malta	76	219	47	343
Netherlands	13,978	49,315	9,222	72,515
Poland	16,485	70,344	11,801	98,630
Portugal	2,701	17,756	3,707	24,164
Romania	7,127	33,123	8,021	48,272
Slovakia	855	5,971	1,260	8,086
Slovenia	499	5,800	418	6,716
Spain	30,351	74,297	13,120	117,766
Sweden	1,764	18,985	680	21,430
United Kingdom	5,312	122,190	16,161	143,663
EU-27	**176,893**	**1,092,112**	**112,905**	**1,381,911**

The figures make it possible to assess the share of livestock manure processing for the individual Member State and for EU as a whole. Currently 7.8% of the livestock manure in the EU is being processed which is equal to about 108 million tonnes, but the study does not estimate the bioenergy production from these figures.

Biogas production is one of the important manure processing technologies having considerable positive effects on the environment, the climate, the waste handling and the renewable energy production, but there are many other processing technologies which are implemented and researched in Europe.

Biomass Futures estimated the energy potential from manure in EU-27 for 2004, 2020 and 2030 at 57 million toe (2,400 PJ), 47 million toe (1,950 PJ) and 50 million toe (2,100 PJ), respectively indicating that manure production is going to decrease because of reduced livestock numbers.

The BioBoost project estimated the total theoretical potential of residues from livestock production in Europe at about 1,450 PJ. However, despite the high theoretical potential, there were no possibilities of obtaining this type of biomass in most regions, considering the needs of soil conservation. The total technical potential was assessed at 21 PJ only [37].

4.2.1.4. Other primary residues

There are many other primary residues from agriculture that can supply biomass for bioenergy such as mowing from permanent grasslands occurring in agricultural land areas, in areas like recreational or nature conservation areas or dykes and abandoned grasslands. Management of abandoned areas through mowing could often be beneficial for biodiversity as low levels of human disturbance stimulate larger diversity because it prevents one plant species from becoming dominant over others and thus creates new ecological niches for a range of species.

According to Biomass Futures project, the potential of abandoned grassland cuttings in EU-27 seems to be non-negligent in 2020 (3.65 million toe or 153 PJ), but towards 2030 it is expected that most of these lands will be converted to productive use again for grazing or cropping production, which brings down the potential to 0.26 million toe (11 PJ). The figures provide a limited quantification of the biomass potential from grasslands as they exclude the potential from non-agricultural lands.

Roadside verge grass can be another source of biomass supply. In Biomass Futures project the supply was estimated at approximately 1.09 million toe (46 PJ) in 2010 in EU-27. Roadside verge grass may be an interesting resource to complement the woody-feedstock potential in regions where large biomass conversion installations are based. The estimated potential towards 2020 and 2030 is 1.14 million toe (48 PJ) and 1.16 million toe (49 PJ) indicating a limited, but stable biomass source.

4.2.2. Secondary agricultural residues

Secondary agricultural residues are by-products of industrial processing of crops and animals into food or other products. They may be referred to as agro-industrial residues. Unlike crop residues, which are available on the field and must be collected over a wide area, agro-industrial residues are easy to collect at the processing site and their logistics are thus greatly simplified.

4.2.2.1. Secondary crop residues

The availability of agro-industrial residues on a European level has not been widely studied. The actual amount of residues produced by a given process depends not only on the quality of the incoming raw material but also on the process itself. Some reported values of crop residues are [38]:

- Olive husks representing approximately 23% of olive oil production. The moisture is variable depending on the process and can be up to 30% - though usually it is much lower
- Rice husks representing approximately 16% of rice production, with a moisture content of 10%
- Cotton ginning residues representing approximately 10% of cotton production, with a moisture content of 17%

The EUBIONET III project estimated the unexploited agro-industrial residues potential of crops in 17 European countries (Latvia, Estonia, Lithuania, Slovenia, Czech Republic, Slovakia, The Netherlands, Austria, Germany, Italy, Greece, Portugal, Spain, Sweden, Norway, Finland and Denmark) at more than 2.4 million toe (100 PJ) excluding animal excrements and straw [39] (Table 9).

Table 9: Estimated energy production potential from unexploited agro-industrial crop residues [39].

Country	2011
	PJ/y
Austria	18.97
Czech Republic	12.00
Denmark	10.89
Estonia	0
Finland	2.5
Germany	4.40
Greece	10.20
Italy	24.28
Latvia	0.876
Lithuania	0.670
Netherlands	0
Portugal	1.39
Slovakia	8.09
Slovenia	0.31
Spain	2.67
Sweden	6.08
Total	**103.36**

4.2.2.2. Secondary animal residues

The residues mapped in this category are defined by Eurostat as “Animal waste of food preparation and products”.

In the Biomass Futures project, the total current potential of energy from animal agro-industry was estimated at about 2.8 million toe (115 PJ) in EU-27. However, whether this potential is really completely available for bioenergy generation is very much in question. In many EU countries, particularly Germany, Sweden, Finland and Ireland, this type of waste is already recovered, but not only for energy conversion. The potential towards 2020 and 2030 are both estimated at about 2.9 million toe (120 PJ).

4.2.3. Total potential supply from agricultural residues

Figure 7 sums up the values of the potential of all agricultural residues for bioenergy production and shows the minimum and maximum values estimated for 2010[3], 2020 and 2030[4].

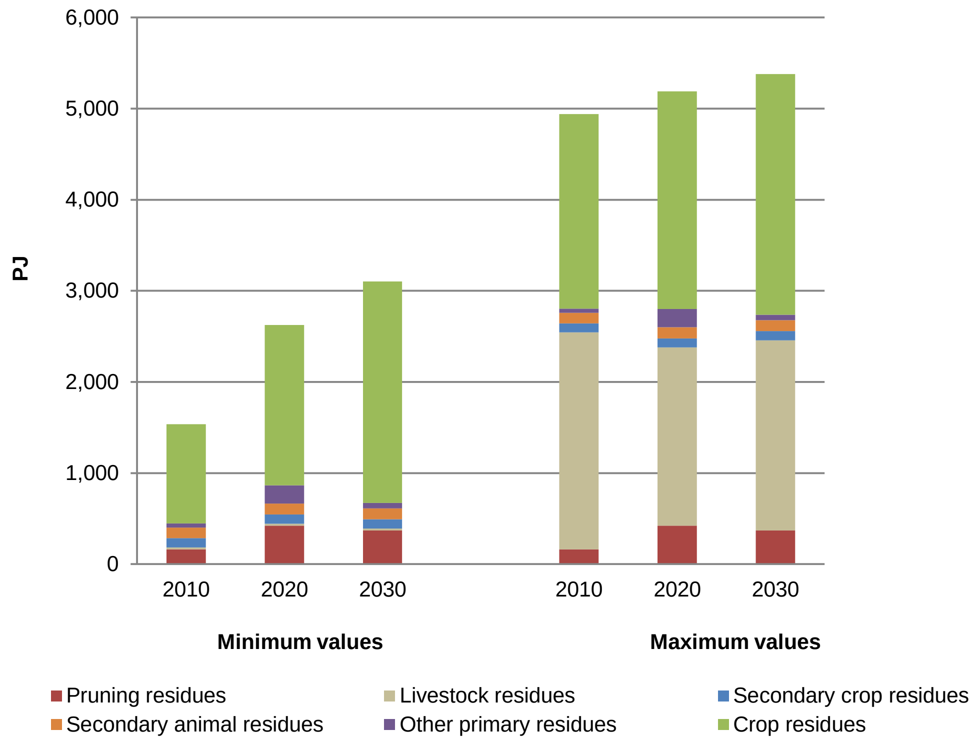

Figure 7: Minimum and maximum estimated bioenergy potential from agricultural residues in the EU for 2010, 2020 and 2030.

4.3. EU policies for sustainable supply of agricultural residues

Policies on the land use for agriculture follow the CAP (please see section 3.3).

[3] Data existing for 2011 for some categories were used for 2010
[4] Minimum values of livestock residues potential for 2020 and 2030 were estimated the same as those of 2010

5. Residual biomass from waste in EU-28

Waste is most commonly, and according to the EU Waste Framework Directive, defined as material which an entity wishes to dispose of. National perception of this definition varies to a large extent. In the context of biomass, waste will occur in the forestry and agricultural businesses as well as in biodegradable municipal waste (BMW). As forestry and agriculture have already been covered, this section covers only BMW and common sludges.

Biowaste is a putrescible, generally wet waste. There are two major streams – green waste from parks, gardens etc. and kitchen waste. The former includes usually 50-60% water and more wood (lignocellulose) and the latter contains no wood but up to 80% water. Waste management options for bio-waste include, in addition to prevention at source, collection (separately or with mixed waste), anaerobic digestion and composting, incineration with and without energy recovery, and landfilling. Waste management processes which can produce energy are anaerobic digestion and incineration

5.1. Present use of residual biomass from waste

The overall potential for separately collected bio-waste is estimated at up to 150kg/inhabitant/year, including kitchen and garden waste from households, park and garden waste from public estates, and waste from the food industry (80 million tonnes for EU-27). About 30% of this potential (24 million tonnes) is collected separately and treated biologically [40].

In 2012, total Municipal Solid Waste (MSW) in the EU was treated in different ways: 33% was landfilled, 24% incinerated, 27% recycled and 14% composted. In 2001 56% was landfilled, 17% incinerated, 17% recycled and 10% composted in 2001 [41]. Total MSW includes the biodegradable portion in addition to solid waste (plastics etc). In the EU bio-waste constitutes usually between 30% and 40% (but ranges from 18% up to 60%) of MSW. According to Eurostat the gross energy consumption of the renewable part of MSW was about 8.84 million toe (370 PJ) in 2012 in EU-28.

5.2. Sustainable potential supply of residual biomass from waste

5.2.1. Biodegradable Municipal Waste

Biodegradable municipal waste (BMW) is defined by the Council Directive (1999/31/EC)72 as any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, and paper and paperboard.

A study by the EEA (2006) [42] estimated the total potential of BMW for 2010, 2020 and 2030. The estimation is based on the assumption that BMW currently incinerated or landfilled without energy recovery is available for incineration with energy recovery. Similarly waste that is currently composted is assumed to be first anaerobically digested in order to allow energy recovery. The digestate is then composted.

The EEA study also assumed that waste generation can be reduced by 25 % by 2030, due to household waste prevention measures. The fraction of waste that is biodegradable is assumed to remain constant in the future.

Results showed that the potential of bioenergy production from BMW is approximately 19 million toe (795 PJ) for 2010, 17 million toe (715 PJ) for 2020 and 16 million toe (670 PJ) for 2030.

Siemons et al. (2004) estimated the total potential of BMW for 2010 and 2020 assuming the following [43]:

- Member states will fulfil their obligations at the lastest time possible. Thus, a reduction to 35 % of the 1995 number is assumed for 2020
- All EU-27 comply fully with the Landfill Directive
- In case countries presently produce less BMW for landfill than stated in the Landfill Directive, these countries will limit the amount of landfilled waste at the present level, and not increase these quantities
- All BMW that does not go to landfill is available for incineration
- The moisture content of BMW was estimated at 35% (wet basis).

The results show that the energy recovered from BMW from landfill gas and from incineration with energy recovery amounts to approximately 24 million toe (1,000 PJ) in 2010 and 36 million toe (1,500 PJ) in 2020 (Table 10). For the energy potential of landfill gas, the maximum quantity of gas that can be extracted from a given quantity of dumped waste is taken, using a calorific value of 3.71 GJ/tonne dry BMW.

Table 10: Availability of BMW for bioenergy production in EU-27 for 2010 and 2020 [43].

	2010	2020
	million toe	
Landfill gas	4.68	2.49
Incineration with energy recovery	19.01	33.71
Total	23.69	36.20

Other types of waste that can be considered under this category are used oils and fats. The Biomass Futures project has estimated the potential of this category at 2.10 million toe (88 PJ), 2.17 million toe (91 PJ) and 2.16 million toe (90 PJ) for 2010, 2020 and 2030, respectively.

5.2.2. Common sludge

The category common sludge which is defined by Eurostat as “Industrial effluent sludge” includes all kinds of sludge originating from wastes, waste water treatment and water preparation. Biomass Futures project estimated the total current potential of common sludges at about 7.8 million toe (325 PJ), particularly concentrated in the

UK, France, Italy and Spain. For 2020 and 2030, the estimation is 8.1million toe (340 PJ) and 8.2 million toe (340 PJ), respectively.

Siemons et al. estimated the potential of common sludges at about 2.4 million toe (100 PJ) in 2010 and 2.6 million toe (110 PJ) in 2020 [43]. The quantities of sewage sludge were taken as a measure for the amount of biogas that could be produced. It was assumed that 1 dry tonne of sewage sludge could produce 9 GJ of energy.

The present recovery rate of this category is still very low in most EU countries. This is related to the limited possibilities to recover this waste other than into energy. Today most of the sludge is incinerated and/or deposited on the land (e.g. agriculture) and only a small part is already used for energy recovery (e.g. biogas production), like in Germany, France and Finland.

Figure 8 presents the minimum and maximum estimated values of residual biomass waste potential for bioenergy production in the EU. The maximum value for energy supply from municipal waste and the minimum value from sludge for 2030 were estimated to be the same as the values for 2020.

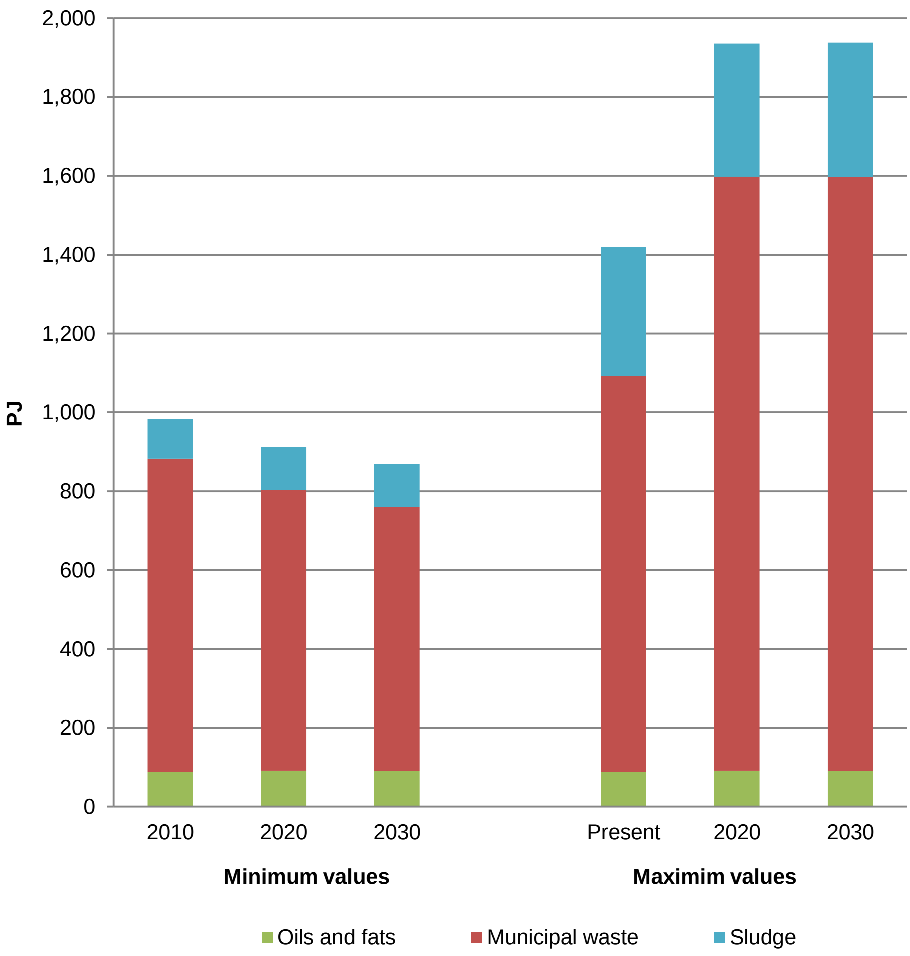

Figure 8: Minimum and maximum estimated bioenergy potential from residual waste biomass for 2010, 2020 and 2030 in the EU.

5.3. EU policies for sustainable supply of biomass from waste

About 33% of municipal waste in the EU was landfilled in 2012. The European Landfill Directive 1999/31/EC sets strict diversion targets for the landfilling of biodegradable waste. Article 5 states that in 2016 the biodegradable municipal waste going to landfills must be reduced to 35% of the total amount (by weight) of biodegradable municipal waste produced in 1995.

Article 1 of the Waste Framework Directive 2008/98/EC says that Member States shall take measures to promote high quality recycling and, to this end, shall set up separate collections of waste where technically, environmentally and economically practicable and appropriate to meet the necessary quality standards for the relevant recycling sectors.

Member States shall take measures, as appropriate, and in accordance with Articles 4 and 13, to encourage:

- the separate collection of bio-waste with a view to composting and digestion of bio-waste;
- the treatment of bio-waste in a way that fulfils a high level of environmental protection;
- the use of environmentally safe materials produced from bio-waste.

An important issue that would affect the handling and fate of bio-waste is the end-of-waste criteria. The JRC-IPTS reported its contribution to the development of the end-of-waste criteria for biodegradable waste subject to biological treatment (compost/digestate) in accordance with Article 6 of Directive 2008/98/EC of the European Parliament and of the Council on waste (the Waste Framework Directive) [44]. The report “End-of-waste criteria for biodegradable waste subjected to biological treatment (compost and digestate)” includes a possible set of end-of-waste criteria and shows how the proposals were developed based on a comprehensive technoeconomic analysis of the biodegradable waste derived compost/digestate production chain and an analysis of the economic, environmental and legal impacts when such compost/digestate ceases to be waste.

The report proposes that the end-of-waste material should be hygienised and stabilized compost and digestate materials should be obtained through a biological waste treatment process using input materials originating exclusively from:

a. the separate collection of bio-waste and/or;
b. manure and/or;
c. living or dead organisms or parts thereof, provided the latter are unprocessed or processed only by manual, mechanical or gravitational means, by dissolution in water, by flotation, by extraction with water, by steam distillation or by heating solely to remove water, or which are extracted from air by any means and/or;

d. processed living or dead organisms or parts thereof other than c., as well as biodegradable packaging materials, provided all such materials are certified biodegradable according to EN 13432, EN 14995 or equivalent and 90% biodegradability in 6 months has been demonstrated in a single or combined composting and/or anaerobic digestion process and/or;
e. any material listed in points a., b., c. and/or d. that has previously been composted and/or digested;

Input materials must not be contaminated. Contaminated is defined as having a level of chemical, biological or physical contamination that may cause difficulties in meeting the end-of-waste output product quality requirements or that may result in other adverse environmental or human health impacts from the normal use of the output compost/digestate material.

The material excludes compost and digestate materials partially or completely derived from

a. the organic fraction of mixed municipal household waste separated through mechanical, physicochemical, biological and/or manual treatment and/or;
b. sewage sludge and/or;
c. sludges derived from the paper industry and/or;
d. sludges derived from materials other than those included in the scope and/or;
e. animal by-product category 1 materials according to ABP Regulation (EC) No 1069/2009 and/or;
f. animal by-product category 2 and/or 3 materials for which composting and/or digestion is not allowed according to ABP Regulation (EC) No 1069/2009 and implementing Regulation (EU) 142/2011.

Compost or digestate materials partially or completely derived from contaminated input materials, regardless of their origin, are also excluded.

The JRC –IPCT report mentions also the limits of heavy metals and pollutants.

The industrial emissions directive (2010/75/EC) covers management and emissions from large composting and digestion plants dealing with waste. The permit conditions including emission limit values must be based on the Best Available Techniques (BAT), as defined in the IPPC Directive. For biological treatments, the limits are the following:

- Disposal of non-hazardous waste with a capacity exceeding 50 tonnes per day
- Recovery, or a mix of recovery and disposal, of non-hazardous waste with a capacity exceeding 75 tonnes per day
- When the only waste treatment activity carried out is anaerobic digestion, the capacity threshold for this activity shall be 100 tonnes per day.

6. Conclusion

Currently biomass is providing more than 60% of renewable energies in the EU and is expected to provide more in terms of toe for 2020 and 2030. At the same time sustainable biomass is a limited resource. This review paper has investigated the present use, the current potential and projections for the future of biomass supply for bioenergy production in the EU and the policies which have a direct effect on the potential. The review is based on existing publications without additional data analyses. Figure 9 presents a summary of these estimates showing the minimum and maximum values of potential biomass supply in comparison with the RES gross inland energy consumption of the EU in 2012 (7,750 PJ) which represents around 11% of the total gross inland energy consumption.

The estimates show that the EU has a potential to provide between 6,900 PJ and 16,600 PJ from biomass for its energy consumption today. These estimates could increase to 10,600 PJ and 21,350 PJ in 2020 and 10,850 PJ and 22,700 PJ in 2030.

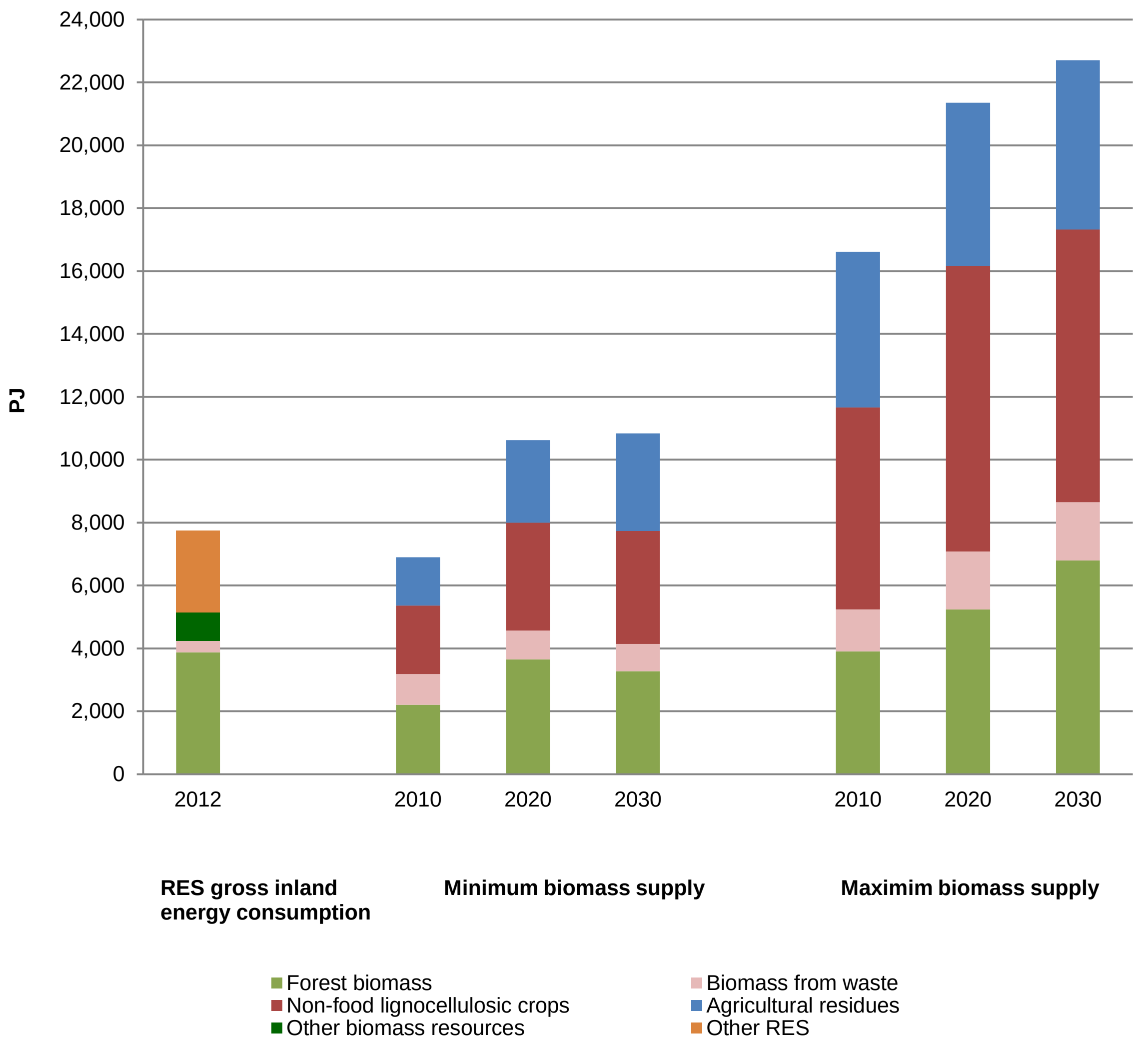

Figure 9: Minimum and maximum estimation values of biomass potential supply for bioenergy use in the EU for 2010, 2020 and 2030.

In 2012 the gross inland energy consumption from biomass accounted for 7.3% of the total consumption (5,150 PJ). More than 75% of the biomass was supplied by forest biomass.

In conclusion, the current supply of biomass for energy is not exhausted and biomass can supply more in the future. However, the lack of precise data makes it challenging to estimate these figures. In addition, the estimates vary to a large extent due to different definitions of potential and due to different methods applied. Nevertheless most of the studies reviewed agree that:

- Biomass potentials from forestry and waste are relatively stable over time
- Waste and agricultural residues has a potential that is currently barely exploited for energy generation
- Large uncertainty exists on how much biomass from agriculture can be supplied.
- For the future, non-food lignocellulosic crops and agricultural residues seem to be the key for a genuine expansion of biomass supply once biomass from forestry and waste are stable.

Within the BEE project a study on the status of biomass resource assessment was done in 2010 [45]. At that time a huge diversity of results has been also observed. The assessment showed that the potential of energy from biomass was much greater for dedicated energy crops on agricultural land than that for residues from forestry and agricultural systems and organic waste. Some years later, as shows this review paper, the updated assessment of bioenergy potential from different sources still shows big differences.

The S2Biom project aims at filling the gaps of uncertainties by providing updated harmonized datasets on the sustainable delivery of non-food lignocellulosic biomass at local, regional and pan-European level for energy and material use. Moreover it develops strategies and roadmaps that are informed by a “computerized and easy to use” toolset.

In the S2Biom project, the research work foreseen covers the entire biomass delivery chain from primary biomass to end-use of non-food products and from logistics, pre-treatment to conversion technologies. All these aspects are being assessed in order to facilitate the integrated design and evaluation of optimal biomass delivery chains and networks at European, national, regional and local scales. This approach will support the design of strategies for the development of a viable bio-based economy. The project activities are implemented in three individual but strongly interrelated Themes:

- Theme 1 focuses on methodological approaches, data collection and estimation of sustainable biomass potentials, resource efficient pathways and optimal logistical supply routes as well as the development of a computerised toolset. The work outputs, apart from the toolset will include fully populated databases at local, regional and pan-European levels as well as manuals for their operation, maintenance and updates.

- Theme 2 makes use of the findings of Theme 1 and develops a Vision, Strategies and a R&D roadmap for the delivery of sustainable non-food biomass feedstocks at local, regional and pan-European level.
- Theme 3 validates the findings from Themes 1 and 2 and ensures the project outreach. This is performed through selected case studies which efficiently capture the different scales of applications for biomass supply chains in a sufficient number of regions across Europe.

S2Biom

Abbreviations

BMW	: Biodegradable Municipal Waste
CAP	: Common Agricultural Policy
EC	: European Commission
EFSOS	: The European Forest Sector Outlook Study
EU	: European Union
FAO	: Food and Agriculture Organisation
FSC	: Forest Stewardship Council
GGL	: Green Gold Label
GHG	: Greenhouse gases
ha	: Hectare
IPCC	: Intergovernmental Panel on Climate Change
ktoe	: Kilo tonnes of oil equivalent
m	: Metre
m^3	: Cubic metre
MSW	: Municipal Solid Waste
NGO	: Non-governmental organization
NTA	: Dutch technical agreement
PEFC	: Programme for endorsement of Forest Certification Scheme
PJ	: Petajoule
RED	: Renewable Energy Directive
RWE	: Round wood equivalent
SBP	: Sustainable Biomass Partnership
SRC	: Short Rotation Coppices
toe	: Tonnes of oil equivalent

Conversion rates

1 million toe = 41.87 PJ

1 million m^3 solid wood = 1.43 million m^3 RWE

1 million m^3 solid wood = 8 PJ

1 million tonnes of agricultural residues = 17.5 PJ.

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Annex I: Overview of voluntary sustainability certification schemes applied to solid biomass: FSC, PEFC, NTA 8080, GGL and Laborelec label

		FSC	PEFC	GGL[5]	Laborelec Label	NTA 8080
	Website	www.fsc.org	www.pefc.org	www.greengoldcertified.org	www.laborelec.be	www.sustainable-biomass.org/
A.	**General aspects**					
1	**Description of organization (owner) and scheme**	FSC is an independent, non-governmental, not-for-profit organization. The FSC Principles and Criteria (P&C) set out best practices for forest management.	PEFC is an international not-for-profit membership organization endorses national forest certification schemes PEFC International describes the requirements for standardising bodies in the development and revision of forest management and scheme-specific chain of custody standards.	Owned by Green Gold Label Foundation which was established by RWE and Control Union. GGL is certification system for sustainable biomass covering production, processing, transport and final energy transformation.	Owned by GDF-SUEZ / Electrabel EPA, developed by Laborelec. Laborelec label is a biomass verification procedure used by Electrabel (mainly for co-firing in power plants).	The Netherlands Standardization Institute (NEN) is a private, non-profit organization. NEN is the independent owner of NTA 8080. NTA 8080 is a certification system describes the requirements for sustainably produced biomass for energy applications (power, heat & cold and transportation fuels).
2	**Applied since**	1993	2000	2002	N/A	2011
3	**Biomass focus**	Biomass feedstock from forests and forest plantations It covers all product raw materials produced in forests, including timber and non-timber forest products (NTFPs)	Biomass feedstock from forests and forest plantations It covers all product raw materials produced in forests, including timber and non-timber forest products (NTFPs)	Biomass / biofuel / bio-liquids for energy production and biofuel conversion. It covers agricultural / forestry products and also residual products.	Mainly for wood pellets	All biomass for all types of biomass end-uses (electricity, heat & cold and transportation fuels)
4	**Objective**	To promote the responsible management of the world's forests	To promote the sustainable forest management especially among small forest managers	To ensure importation of sustainable biomass for energy, power production and chemical purposes	To offer a scheme that adds up the wishes of all regional authorities in Belgium for green certificates	To offer a way for suppliers and buyers of biomass to distinguish sustainable products, based on verifiable requirements translated from Dutch and European sustainability criteria
5	**Recognition by**	No bilateral recognition. See Document WP D5.1-1	Mutual recognition between PEFC endorsed schemes.	The UK: Approved by Ofgem in March 2012.	N/A	The EC has recognized the 'NTA 8080' scheme for demonstrating compliance with the sustainability criteria under Directives 98/70/EC and 2009/28/EC of the European Parliament and the Council in July 2012. The Decision is valid for a period of five years after it enters into force

[5] The GGL foundation is used as the new governance structure for the new sustainability standard based on the Initiative Wood Pellets Buyers (IWPB) principles. IWPB is a working panel grouping the major European utilities firing wood pellets in large power plants GDF SUEZ, RWE, E.On, Vattenfall, Drax Plc, and Dong, as well as certifying companies SGS, Inspectorate, and Control Union. Laborelec participates in this work panel as a technical expert. The IWPB is developing a common sustainability approach for solid biomass in large scale power plants. See Document WP D5.1-1 for details.

		FSC	PEFC	GGL[5]	Laborelec Label	NTA 8080
B.	**Functions and coverage**					
1	**Management**	(Elected) The board of directors and the Director General	(Elected) The board of directors and the Secretary General	The Executive Board, the Advisory Board and the Technical Committee.	GDF-SUEZ/Electrabel TPM/Fuel Procurement is in charge of the daily application of the verification procedure	NEN Scheme Ownership - an integrated division of the NEN Office
2	**Membership and Decision-making**	FSC membership is open to a wide range of organizations and individuals (NGOs, unions, market actors and etc.). The decision-making body is made up of the three membership chambers (environmental, social and economic), which are further split into North and South sub-chambers. The purpose is to maintain the balance of voting power between different interests without having to limit the number of members.	There are two categories of membership with voting rights: (1) National members (or "National Governing Bodies") are independent, national organizations established to develop and implement a PEFC system within their country, (2) International Stakeholder members are international entities including NGOs, companies, and associations committed to supporting PEFC's principles.	The Executive Board (elected by existing members) is responsible for strategic decision making and is ultimately responsible for the initiative, with the advices from the Advisory Board (evenly represented by all stakeholders).	The system was designed by SGS Belgium and Laborelec.	A Committee of Experts has been set up to draft, establish and maintain the certification scheme, through consultation process in the form of working groups, consultation rounds, etc. The committee is responsible for involving the stakeholders in the maintenance of the scheme.
3	**Target groups and coverage**	(i) Forest management units (ii) Actors along the supply chain taking ownership of FSC certified biomass (processing, transformation, manufacturing and distribution) It could be for individual, or in the form of projects - one-off and complex products FSC certified without each involved participant having to become individually FSC certified	PEFC's target group is national forest certification schemes. The target groups of these national schemes are generally similar to those of FSC (see left column). Individual national schemes may additionally include other target groups.	Suppliers (producers, processors, traders) and buyers of biomass.	Suppliers (producers, processors, traders) and buyers of biomass Mainly for wood pellets.	Suppliers (producers, processors, traders) and buyers of biomass. It covers solid, liquid and gaseous biomass. Note that NTA 8080 and CAN/CSA-Z809 are the only two standards with sustainability criteria for solid biomass (noting that CSA is not developed for bioenergy)
4	**Geographical coverage (2012)**	Producers: No. of countries: 80 Total area: 155 million ha (43% in Europe; 40% in USA) No. of certificates: 1124 CoC: Total countries: 106 Total certificates: 23462 (49% in Europe) (As of 15 June 2012)	Producers: No. of countries: 29 Total area: 243 million ha (60% in USA; 33% in Europe) CoC: Total countries: 61 Total certificates: 9069 (84% in Europe) (As of 15 June 2012)	Producers: Canada, USA, Portugal, Baltic States Consumers: The Netherlands and the UK	Consumers: Belgium	International

		FSC	PEFC	GGL[5]	Laborelec Label	NTA 8080
5	**Actual utilization**	(Certified areas) By types of forest certified: Natural forest: 63.7% Semi-Natural and Mixed Plantation & Natural forest: 28% Plantation: 8.3% By biomes: Boreal: 52.3% Tropical/Subtropical: 11.7% Temperate: 36.1% By ownership: Public: 53.7% Private: 28.51% Government: 13.5% Community: 3.6% Others: 0.6% By tenure management: Private: 63.6% Public: 24.3% Others: 12.1%	No detailed information available	In 2012, 25 companies have been certified. More than 5 million tonnes of biomass were certified with the Green Gold Label in 9 years-time. In 2012, approximately 3 milliontonnes were certified	In 2010, 30 pellet suppliers have participated for verification	19 certificates have been issued as of August, 2012
C.	**Schemes characteristics**					
1	**Schemes structure**	"Top-down" - It has drawn up 10 principles and the accompanying criteria which are to be used worldwide. The principles were translated to country-specific criteria and indicators. 10 principles and accompanying criteria ↓ Translated to country-specific criteria and indicator (C & I) ↓ National FSC Standards	"Bottom-up" – It is based on inter-governmental principles that are developed for different forest regions of the world. It recognizes (as umbrella standard) existing national forestry standards, such as SFI, CSA, ATFS, etc., when certain conditions are met. Benchmarking ↑ Assessments ↑ National standards for sustainability forest management	Offers two programmes: 1. Green Gold Label (GGL) (for sustainable biomass (covering production, processing, transport and final energy transformation) 2. Clean Raw Material (CRM) is a specific clean wood certificate for pre-treated biomass, based on the Dutch standard NTA 8003 "Classification of biomass for energy production" codes 101-169.	Biomass verification procedures (9 documents): General: DOC 01 For supply chain inspection: DOC 02 to DOC 07 For producers: DOC 08 and 09	The NTA 8080 certification system includes two levels of certification: 'NTA 8080 approved' for organisations that comply with the NTA 8080 requirements and 'NTA RED' for organisations that do not yet meet the NTA 8080 requirements but comply with all the RED criteria. In order to become recognized by the EC, NTA 8080 have included in the interpretation document the 'RED language' (for biofuels and bioliquids).
2	**Regional differences**	Based on the Principles and Criteria, provide locally appropriate indicators for each criterion to show compliance can be demonstrated in that national situation.	Large differences between the single national systems. See Document WP D5.1-1 for details.	Not relevant	N/A	Not relevant

		FSC	PEFC	GGL[5]	Laborelec Label	NTA 8080
D.	**Certification systems set-up**					
1	**Standard setting**	All FSC standards and policies are developed by the Policy and Standards Unit based at the FSC International Center in Bonn.	Standard Setting (PEFC ST 1001:2010) describes the requirements for standardising bodies in the development and revision of forest management and scheme-specific chain of custody standards.	Various Working Groups where specific topics are addressed, for example the development of the Green Gold Label standards, accreditation procedures, communication, engagement with governments etc. The Working Groups are multi-stakeholder governing bodies.	The system was designed by Laborelec and SGS Belgium	See B-2.
2	**Standards documents**	www.fsc.org/standards.340.htm	www.pefc.org/standards/technical-documentation/pefc-international-standards-2010	www.greengoldcertified.org/site/pagina.php?id=11	www.laborelec.be/ENG/biomass-verification-procedure/	http://www.sustainable-biomass.org/publicaties/3941
3	**Forest management: Principles and Standards**	10 principles as in (a) a. FSC STD 01 001 V4-0 EN FSC Principles and Criteria for Forest Stewardship b. FSC-STD-01-002 V1-0 EN Glossary of Terms c. FSC STD 01 003 V1 0 EN SLIMF Eligibility Criteria d. FSC STD 01 003a EN SLIMF Eligibility Criteria Addendum 2010-09-07 e. FSC-STD-01 005 V1-0 EN Dispute resolution system f. FSC STD 30 005 V1-0 EN Standard for Group Entities in Forest Management Groups	Sustainability principles and criteria vary significantly between PEFC endorsed schemes in number, structure and contents, but SFM standards must fulfill a set of minimum requirements laid out in the International PEFC standard: PEFC ST 1003:2010	GGLS5: Forestry standards - derived from existing and internationally recognised forest management standard; Following may also comply: 1. FSC – (incl. FSC Controlled) 2. PEFC 3. CSA-SFM (incl. SFI Fiber Sourcing, but only with individual chain of custody data) 4. SFI 5. FFCS 6. Approved pre-scope certificate of one of the endorsed forest management certification systems, with the intention of full certification	DOC 08: Inspection Procedure for Forestry Based Company - 10 principles First principle on GHG and energy balance is mainly assessed following the experienced procedure of Laborelec-SGS. For the other principles, the assessment will be based on the QUALIFOR and NTA inputs. If any FSC certificate covering the surfaces where the wood to be processed was harvested is provided, no further verification of the Principles 2 to 10 is needed.	NTA 8080 describes the sustainability criteria that are based on the so-called Cramer criteria: • GHG (emissions & carbon stock); • competition with other applications; • biodiversity; • environment (soil, water and air); • prosperity; • social well-being. NTA 8081 describes the certification requirements including those applicable to group certification and the use of residues and waste. An interpretation document further elaborates on the requirements in NTA 8080
4	**Agricultural standards**	Not applicable	Not applicable	GGLS2: Agricultural criteria - based on the United Nations sustainable development program Agenda 21. This standard is to be used for approval of the agricultural source when no other certification system is available. Following may also comply: 1. GlobalGAP 2. All programmes that certify organics as per EU, Japanese and/or US regulations	N/A	See D-3

		FSC	PEFC	GGL[5]	Laborelec Label	NTA 8080
5	**Chain of Custody (CoC)**	*Policy:* FSC guidelines for certification bodies fsc-pol-40-002 (2004) EN: Group chain of custody (CoC) certification *Standard:* a. FSC STD 40 003 V1-0 EN Multi site Chain of Custody b. FSC STD 40 004 V2-1 EN Chain of Custody Certification c. FSC STD 40 004a V2-0 EN FSC Product Classification d. FSC STD 40 004b V1-0 EN FSC Species Terminology e. FSC STD 40 006 V1-0 EN Project Certification f. FSC STD 40 007 V2-0 EN Sourcing Reclaimed Materials	PEFC ST 2002:2010: Chain of Custody	GGLS1: Chain of Custody and Processing – Trader GGLS4: Transaction and Product Certificate CRM1: Chain of custody and processing standards - CRM is the counterpart of GGL1 for CRM material. Where GGL focuses on sustainability, CRM is used to prove that clean wood is used for the production of e.g. torrefied material. CRM 2: Transaction Certificate - the counterpart of GGL4 for CRM material, covering a specifically described amount of clean wood, leading to a CRM Transaction Certificate.	DOC02: Pellet Supplier Declaration Form DOC 03: Pellet Supplier Audit Procedure DOC 04: Pellet Transport Declaration Form DOC 05: Energy and Carbon Balance Form DOC 06: Pellet Supplier Declaration Form	See Document WP D5.1-1
6	**Other standards**	Standards that apply to multiple types of certificate holders: a. FSC STD 50 001 V1-2 EN Certificate Holder Trademark Requirements b. FSC TMK 50 201 V1-0 EN Requirements for promotional use of FSC trademarks (also applies to non-certified commercial organizations) Standards that apply to FSC accredited certification bodies: a. FSC STD 20 001 V3-0 EN General Requirements for FSC Certification Bodies - application of ISO/IEC Guide 65:1996 (E) FSC Controlled Wood controls the non-certified material in FSC products avoid timber from the most destructive and harmful practices, such as illegal logging or human rights abuses: a. FSC STD 30 010 V2-0 EN Controlled Wood standard for FM enterprises	Standards for multiple types of certificate holders: a. Group Forest Management Certification (PEFC ST 1002:2010) b. PEFC Logo Usage Rules (PEFC ST 2001:2008 v2) c. Annex 7 - Endorsement and Mutual Recognition of National Schemes and their Revision Standards that apply to certification bodies: Certification Body Requirements – Chain of Custody (PEFC ST 2003:2012) PEFC Due Diligence System (DDS) for avoidance of raw material from controversial sources (Included in CoC)	GGLS6: Use at power plant - specifically for power plants; follows the conversion process of the biomass into electricity and lays down requirements for policy, administration, safety, mass balance calculation, etc. GGLS7: Stewardship criteria – For raw materials from other sources (from high conservation value areas as well as material coming from parks, public gardens and green spaces) GGLS8 GHGs and energy balance calculation - an inventory is made of all components that influence GHG emissions within the chain, such as energy use for processing and storage, fuels used in transport.	DOC 09 Inspection Procedure for Sawmill Industry requires at least: - the evaluation of the overall energy balance for the supply of each biomass feedstock - the full traceability of the resources that were used for manufacturing the biomass and the evidence that those resources are managed in a sustained way	See D-3

		FSC	PEFC	GGL[5]	Laborelec Label	NTA 8080
		b. FSC STD 40 005 V2-1 EN Company Evaluation of Controlled Wood				
E.	**Others**					
1	**Certification bodies**	Only FSC accredited certification bodies are authorized to issue FSC certificates. See Document WP D5.1-1 Certification bodies are accredited by ASI according to FSC STD 20 001 V3-0 EN General Requirements for FSC Certification Bodies - application of ISO/IEC Guide 65:1996 (E).	Varies among nationally endorsed schemes, but there is a total of 374 certification bodies accredited for PEFC certification	Control Union	SGS Belgium (Inspection and independent reporting)	Certification is done by certifying bodies that have entered into an agreement with NEN. See Document WP D5.1-1 for the list.
2	**Cost**	See Document WP D5.1-1	See Document WP D5.1-1	Approximately €0,10 per metric tonne of biomass	The costs is less than 0.05 € of the biomass fuel cost	Certificate cost for operators: Annual fee per certificate [€50-€200] annual membership fee [€50-€5,000, depending on turnover] OR fee per metric ton [€0.03]. The annual fee is collected by the CB and subsequently transferred to the scheme manager.
3	**Policy relation**	Forest management shall respect all national and local laws and administrative requirements. In signatory countries, the provisions of all binding international agreements such as CITES, ILO Conventions, ITTA, and Convention on Biological Diversity, shall be respected.	Forest management shall comply with legislation applicable to forest management issues including forest management practices; nature and environmental protection; protected and endangered species; property, tenure and land-use rights for indigenous people; health, labour and safety issues; and the payment of royalties and taxes. For a country which has signed a FLEGT Voluntary Partnership Agreement (VPA) between the European Union and the producing country, the “legislation applicable to forest management” is defined by the VPA agreement.	European level: A decision from the European Commission is pending for the approval of the newly developed GGL – RED standard under the Renewable Energy Directive (RED). The UK: Currently, the GGL - RED standard is the only voluntary system that has been approved by Ofgem.	Applied to all Belgium Green certificates (5 different Green Certificates mechanisms are running in Belgium: 2 different in Flanders (1 Green, 1 Cogen), 1 in Wallonia, 1 in Brussels and 1 at the Federal level)	The Dutch government wishes to incorporate sustainability criteria for biomass into the relevant policy instruments. In the short term this regards the Dutch subsidy arrangement for electricity production and the obligation for biofuels for road transport. In the longer term the Dutch government wishes to promote a wider application of these sustainability criteria. The EC has recognized the ‘NTA 8080’ scheme for demonstrating compliance with the sustainability criteria under Directives 98/70/EC and 2009/28/EC of the European Parliament and of the Council in July 2012. The Decision is valid for a period of five years after it enters into force.