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FLEXible operation of FB plants co-Firing LOw rank coal with renewable fuels compensating vRES

FLEX FLORES

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Deliverable 1.1– Evaluation report on availability, cost and characteristics of alternative supporting fuels

Lead Beneficiary: CERTH

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1 Executive summary

Deliverable 1.1 describes the work undertaken by CERTH, PPC and SFW in the framework of Task 1.1. The aim of this task is to investigate selected biomass resources that have high potential for co-firing with lignite in a fluidized bed boiler (FBC). Initially, a general overview of the lignite sector in Europe in 2016 is provided, and the countries with the highest lignite production are identified; these include Germany, Poland, Czech. Republic, Greece, Hungary, Romania, Bulgaria, Slovenia and Slovak. Republic. Then, lignite originating from two out of these nine countries, i.e. Greek lignite provided by PPC and German (Hambach) lignite provided by RWE, are selected as the primary fuel for co-firing. As a secondary fuel, biomass originating from either the forest or agricultural sector will be used. Concerning the biomass availability across Europe in the upcoming years, emphasis is placed mostly on the sustainable biomass potential in the European countries with the highest lignite production; however, general data are provided for all European countries, as well. The analysis conducted in undertaken at both a NUTS0 and NUTS2 statistical level. All data presented, concerning the primary and secondary fuel availability, are based on literature surveys, statistical data retrieved mostly from Eurocoal and Eurostat and previous EU projects (e.g. the FP7 S2Biom and Biomasud projects). Additionally, from PPC and RWE are delivered data as regards the lignite elemental analysis, whilst additional data are presented concerning properties of different biomass crops. The biomass resources surveyed contain currently unexploited, "difficult / dirty / opportunity" biomass fuels coming mostly from the **agricultural, agro-industrial or waste treatment sectors –including refuse derived fuel (RDF)**. The main outcome of Task 1.1 includes: a) **fuel availability** –both lignite and biomass and b) estimation of biomass roadside cost for specific logistic concepts, mostly based on S2biom platform. As regards, the latter, additional data regarding the **plant-gate cost** at different counties are obtained from various literature resources. CERTH is responsible for the activities in terms of the available biomass quality. PPC contributes to the **South and South-East Europe** area, whilst CERTH investigates the **Central and North Europe** area, having knowledge from past and on-going European projects in which they participate. For the first area a typical dirty/difficult (e.g. **agricultural residues**) biomass is selected, while for the second one a typical biomass genre originating from **forest residues** is identified. More specifically, as regards the former, **cereal straw**, which is a difficult fuel mostly due to its high ash content, has been selected for co-firing, whilst as regards the latter, **wood pellets from stemwood** have been identified to have a high sustainable potential. Amongst these two, cereal straw is considered as a challenging, opportunity fuel to be primarily investigated for its co-firing at different fuel blends with lignite in large-scale units. On the contrary, woody biomass, which is already commercialized in various European countries, is not considered as a difficult to burn fuel. Therefore, investigating its co-firing with lignite inside a fluidized bed boiler is considered of minor importance, when compared to cereal straw. Apart from these two, exhausted olive cake is another rather difficult to burn fuel and is worthwhile investigating; however, due to its low availability –it can be mostly found in Mediterranean countries in limited amounts 100-800 ktnonnes/year dry- it should be only considered for co-firing in small-scale units, or at low rates in the fuel blend. Finally, refuse-derived-fuel is a rather promising option that can be co-fired in a fluidized bed combustor (FBC). Based on this study, PPC and SFW along with CERTH have concluded on the two most promising biogenic fuels that will be tested for their co-combustion with both a German and a Greek lignite during the experimental campaigns at low thermal load conditions, as described in WP4. These two include cereal straw and RDF.

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Outline of this report

This report consists of eight chapters including the Executive summary and the Appendix sections. In the Introductory chapter, a general overview of the lignite sector in Europe is provided. Additional information is delivered as regards lignite elemental analysis from two different countries, i.e. Greece and Germany and biomass characteristics. In the next chapter (Chapter 3), the sustainable biomass-potential across Europe originating from the agricultural, forest and waste sectors is presented for 2020 and 2030 reference years. In each sub-chapter, a brief analysis of the biomass potential in Europe is delivered at a NUTS0 level. Then, Chapter 4 focuses on the European countries with the highest lignite production. At this point, the analysis is conducted at a NUTS2 level. Apart from this, additional information is given for the forest biomass potential in northern European countries -Finland and Sweden, in specific. Finally, Chapter 5 provides information concerning roadside and plant-gate cost of different biomass feedstocks, whilst Chapter 6 discusses integration of biomass co-firing at specific European lignite mining areas. The biomass sources covered in the chapters are summarized in the Tables given in the Appendix section.

2 Introduction

2.1 Lignite sector in Europe

Coal – hard coal and lignite- is the leading energy source in global power generation, with a high share of almost 40% -reference year 2014 [1]. Lignite, usually referred to as brown coal, is the lowest rank of coal (LRC), due to its relatively low heat content; its gross calorific value is less than 4.165 kcal/kg and its carbon content is equal to 60-70 percent.

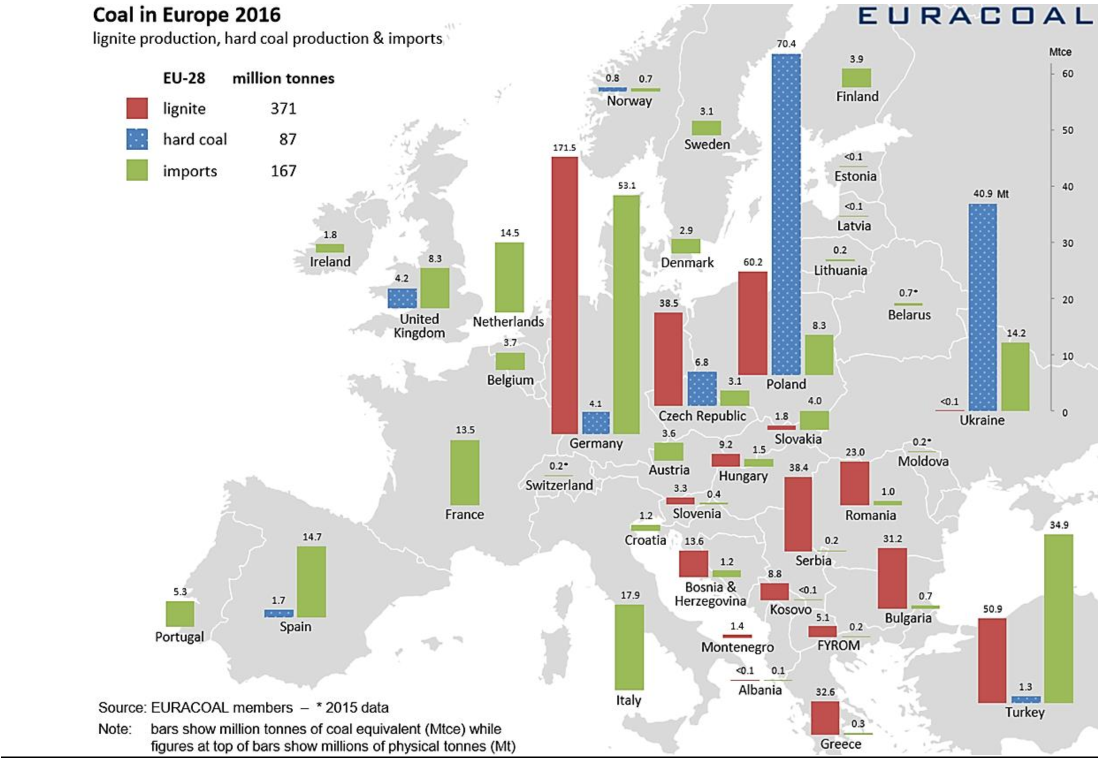


Figure 1. Coal in Europe 2016 (lignite production, hard coal production and imports) [2].

Overall, lignite constitutes an important energy source, with a 13% of the global coal production; its reserves account of almost 23% of the global coal recoverable reserves. The importance of lignite in many countries, such as **Germany, Greece, Serbia and Bulgaria**, is very high, sometimes even higher than hard coal, Figure 1. Therefore, the utilization of lignite is expected to play an important role in energy production in the forthcoming decades.

Country	Production 2016 (Mt)
Germany	171.5
Poland	60.2
Czech. Rep.	38.5
Greece	32.6
Romania	23.0
Hungary	9.2
Bulgaria	31.2
Slovak. Rep.	1.8
Slovenia	3.3
Turkey	50.9
Serbia	38.4

Table 1. Production of lignite in Europe in 2016 (in million metric ton) [2].

According to statistics, in 2016 the global lignite production was approx. 0.8 billion ton. Amongst the major producers, such as Europe, China and Russia, Europe accounts for almost 40% of global lignite reserves. Specifically, the availability of lignite is considerable in four EU countries -**Germany, Greece, Poland and the Czech Republic**, Table 1. Other European countries, which are not members of the EU, with significant lignite production are Turkey (50.9 Mt) and Serbia (38.4 Mt). Inside the EU, the largest lignite consumers are the power generation companies (90% to 95% of the production).

2.2 Lignite composition and handling in Europe

Lignite has relatively high water content (40 to 60%) and a lower calorific value compared to hard coal. Due to its high moisture content is unsuitable for trade, unless the distances involved are not too high. Apart from this, lignite may ignite spontaneously when stockpiled. Therefore, producers and consumers avoid accumulating large lignite stockpiles. Due to its difficult handling, the transportation cost is rather high and trade through the sea is considered unsuitable for both safety and economic reasons. Therefore, lignite is usually burned in power plants placed very close to the mines. Overall, 95% of lignite is consumed for power generation in electricity and combined heat power plants [3].

In Germany, for instance, almost 90% of lignite production is used for power generation (159.3 million ton in 2015), accounting for 23.9% of total power generation in Germany. Generally, lignite is mined through open cast mining technologies and transported by conveyor belts or train to power plants located near the deposits. Generally, Germany has been the world's largest lignite producer and consumer, since the beginning of the industrial lignite production [3], [2].

Rhineland (Hambach) lignite							
Grain size (Run - of - mine lignite)					mm		0-150
Proximate analysis (annual average)							
Moisture					% wt		54.0
Ash					% wt		2.5
Volatiles					% wt		23.5
Fixed carbon					% wt		20.0
Lower heating value					MJ / kg (Mcal / kg)		10.1 (2.41)
Typical range (month average values) 90% of the month average values are within this range					MJ / kg		9.9-10.6
Ultimate analysis (annual average)							
C		H		O	N		S
% wt		% wt		% wt	% wt		% wt
30.5		2.2		10.3	0.4		0.20
Oxide analysis of the ash (annual average) in compliance with standard DIN 51729 part 10 – ashing temperature 450°C (note: P_2O_5 < 0.2 % wt)							
SiO_2	Fe_2O_3	Al_2O_3	SO_3	CaO	MgO	Na_2O	K_2O
% wt	% wt	% wt	% wt	% wt	% wt	% wt	% wt
4.0	12.0	5.0	20.0	36.0	16.0	6.0	1.0
Ash fusibility (limit values)							
Softening temperature					°C		≥ 1.100
Flow temperature					°C		≥ 1.250

Table 2. German (Hambach) lignite analysis (**Data delivered from RWE**).

Lignite is mined in Germany in four fields: the Rhenish, the Lausitz, the central German and the Helmstedt lignite field. In the Rhenish lignite field, area to the west of Cologne, RWE Power AG operates four large opencast mines in the district – Hambach, Garzweiler, Inden and Bergheim, with a total production of almost 95.2 Mt [4]. Quality parameters delivered by RWE for the **Rhineland lignite (Hambach), which will be utilized for co-combustion with biomass in the framework of Flex Flores project (Task 1.4 and WP4)**, are listed in Table 2.

In Greece, lignite is the most important indigenous energy resource, accounting in 2015 for 23.4% of the country's primary energy supply of 33.7 Mtce [5]. On a global basis, Greece ranks seventh worldwide and fourth in the EU, Table 1. Lignite is mined by the PUBLIC POWER CORPORATION (PPC) exclusively in opencast mines, as in Germany. This company is itself the largest lignite producer in Greece. The most important deposits are located in the northern Greece, at Ptolemais-Amynteon and Florina (1.5 billion ton). These two deposits account for 80% of Greek lignite production. Other deposits can be found in Drama (900 Mton) and Elassona (170 Mton), as well as in southern Greece at Megalopolis (225 Mton). There is also a large peat deposit at Philippi in Eastern Macedonia [5].

The outlook of lignite consumption in Greece will be crucially determined by environmentally compatible generation of electricity [6]. Over the past 10 years, the share of lignite in meeting demand has clearly decreased, combined with a similar increase in the shares of renewable energy resources (RES), hydropower and imports. However, owing to its large deposits in Greece -only 30% of the total lignite reserves have been extracted to date and remaining reserves are good for over forty years at current production rates- lignite is expected to remain an important contributor in the country's energy production.

Greek lignite is characterized by very high moisture and ash contents, being, thus, one of the poorer solid fuels used in a global basis [7]. Its calorific value is lower compared to the German lignite (Table 2, Table 3). The quality of **Greek lignite, which will be used for co-combustion with biomass in the framework of Flex Flores** (Tasks 1.4 and WP4), can be characterized as follows:

Greek lignite								
	Moisture	Ash	LHV	C	H	N	S	O
	% w.t.	%w.t. as rec.	Kcal/kg	%w.t. as rec.	%w.t. as rec.	%w.t. as rec.	%w.t. as rec.	%w.t. as rec.
Type 1	52,82	14,32	1421	20,43	1,48	0,65	0,56	9,74
Type 2	46,81	22,85	1087	17,28	1,24	0,37	0,57	10,88

Table 3. Greek ignite analysis data of two, a "bad" and a "good" quality type are available (**Data delivered from PPC**).

In Poland lignite reserves amount to 1.4 billion ton with a further 22.1 billion ton of economic resources. Poland is the fourth worldwide producer and the second in the EU. Poland is characterized by the presence of more than 150 small to large lignite deposits. However, only a limited number of them is currently exploited and only at surface mines [8]. Its major contributors are located in central Poland (Bełchatów and Szczerców fields) and a third one lies in the south-west (hex. Turoszów lignite basin) of the country. Amongst them, Bełchatów mine is the largest contributor of the Poland's lignite production (42.1 million ton of lignite or 66.7% of Poland's total lignite production in 2015).

As can be deduced, currently, the lignite reserves are adequate to cover the European energy demand. Lignite is a convenient and cost-efficient way of producing energy. However, the depleting lignite supplies and growing greenhouse gas emissions, such as CO_2, originating from fossil fuels combustion, drive the global interest towards the development of **sustainable and environmentally friendly energy systems**.

2.3 Lignite co-firing with biomass

Co-firing (or co-combustion) is the simultaneous combustion of two or more fuels in the same boiler in order to produce one or more energy carriers [9]. Biomass co-firing is the utilization of a fuel blend comprising coal (e.g. lignite) as the primary fuel and biomass as the secondary fuel. The main advantage of biomass co-firing is its potential to reduce CO_2 and SO_2 emissions of the coal sector at low cost, low risk and short implementation time compared to other technologies, being thus a **sustainable and environmentally friendly option**.

Co-firing is an economic solution, since biomass co-firing does not require major capital investments and utilizes the existing coal-fired power plant infrastructure [10]. The reported investment costs for a biomass co-firing retrofit are within the range of 140 – 850 USD/kWe of biomass capacity, compared to 1,880 – 6,820 USD/kWe for dedicated biomass power plants [7, 11]. Additionally, co-firing is currently the biomass conversion technology with the highest electrical efficiency –within the range of 25% to 36. Conventional, sub-critical coal-fired power plants in OECD countries operate at efficiencies around 36%, with state-of-the-art units reaching at least 43% [9, 12]. This proves a rather modest impact of biomass co-firing on the generating efficiency of a coal power plant, which is mostly dependent on the biomass moisture content. Finally, blending biomass with coal can reduce greenhouse gas emissions and eliminate waste - wood waste, agricultural waste- and the environmental problem associated with its disposal [10].

Despite its advantages, biomass co-firing is not universally adopted, because it faces restrictions, due to policies and variable biomass availability across different countries. Most importantly, this technology encounters several **technical problems**, due to different characteristics between coal and biomass. Such problems pose different challenges for boiler process control and boiler design, fuel blend control and fuel handling systems, slagging/fouling and corrosion, emissions formation and gas cleaning equipment and, finally, ash utilization.

More specifically, the high biomass reactivity compared to coal and lignite, Table 4, induces several operational challenges, such as hot spots inside the reactor. Typically, the existence of biomass with a high volatile matter in coal/biomass blends deteriorates the uniformity of the already complex combustion process. Amongst the different types of coal, lignite and sub-bituminous coal have relatively more proximity with biomass in terms of volatiles content, and thus they are mostly preferred in co-firing/co-processing with biomass [13].

Coal		**Biomass**	
Type	**Volatiles (%)**	**Type**	**Volatiles (%)**
Anthracite	2-12	Woodchips	76-86
Bituminous	16-49	Bark	70-77
Sub-bituminous	34-54	Straw	70-81
Lignite	37-49	Miscanthus	78-84

Table 4. Volatile content in selected biomass species and coal (d.b.) [13].

Another important issue is the high ash content in some biomass types, especially the ones originating from agricultural crops, which might increase ash-related issues in the furnace, such as slagging/fouling. This is mainly because such biomass crops are characterized by high concentrations of problematic compounds such as chlorine and alkalis, Table 5. More specifically, corrosion can be mainly caused by high chlorine (Cl) content in the ash; Sulphur (S) in the biomass can counteract the corrosive effect of Cl. Especially, the risk of corrosion becomes high when the Cl/S ratio is above 4 [14]. However, as can be seen from Table 5 biomass does not contain a lot of sulphur. On the other hand, fouling in the reactor can be caused by ash agglomeration. In order to identify if there is a risk of ash agglomeration it is important to check the ash melting temperature ($T_{ash\ melting}$). Risk of ash melting becomes high when the ash melting temperature is less than 800 °C. For a safe boiler operation, the desirable melting temperature should be above 1,200 °C [14].

Finally, biomass fuels often have high moisture content which results in relatively low net calorific value, Table 5. It has been observed in the recent literature that the energy efficiency of a boiler can be increased by 5–10% if dried biomass is used instead of wet biomass [5]. This is because of increased combustion temperature due to use of dried biomass. Biomass drying equipment has been studied in detail in Deliverable 1.3 [15].

	Moisture	Ash	Net calorific value	Lignin	Cellulose	Hemi-cellulose	Cl	S	$T_{ash\ melting}$	Traded form
	% w.t.	%w.t. dry	MJ/kg dry	%w.t. dry	%w.t. dry	%w.t. dry	%w.t. dry	%w.t. dry	°C	
Cereal straw	15	6.5	17.67	18	37	27.6	0.3	0.12	892	Square bales
Maize stover	15	5.58	17.04	15	37	25	0.28	0.11	1277	Chopped straw
Sunflower straw/stalks	20	8.82	20.2	18	39	34	0.7	0.1	1000	Square bales
Rice straw	15	18.5	14.47	14	37	23	0.67	0.14	992	Square bales
Stemwood	48.3-53.9	0.5-0.9	19-19.3	23.4-28.6	38.7-43	29.2-29.8	0.01-0.07	0.01-0.02	1320-1230	Stemwood roundwood
Loggings	48.3-53.6	4	18.7-19.2	23.4-28.6	38.7-43	29.2-29.8	0.01	0.02	1175	Wood chips
Stumps	30	6	18.6	23.4-28.6	38.7-43	29.2-29.8	0.01	-	1175	Wood chips
Miscanthus	38.76	3.80	17.98	21.30	44.55	23.90	0.3	0.06	851	Pellets
Switchgrass	11.58	6.33	16.64	6.77	36.85	32.13	0.19	0.14	1098	Pellets
Eucalyptus	40	2	18.10	23.20	43	25.30	0.02	0.05	1330	Wood chips
Olive ston	8	3	20.34	45	24	28.3	0.125	0.08	700	Pellets
Cardoon	9.30	8.38	15.57	10.3	47.80	22.80	1.67	0.16	624	Pellets

Table 5. Typical properties of biomass fuels [16].

Woody residues, manure, agricultural leftovers, dedicated crops, herbaceous species, industrial and municipal solid wastes, food-processing residues, account for most of the biomass sources. Amongst them, **woody biomass** is highly preferred for co-firing due to high-energy potential associated with relatively low environmental impact due to negligible contents of sulfur, chlorine, and mineral matter. Woody biomass essentially refers to dead plant material containing thick cell walls with high lignin content, Table 5. As can be seen from Table 4, the content of volatile matter in wood-based biomass is generally close to 80%, whereas in coal it is around 30%. Wood char is highly reactive, which results in complete combustion of wood fuels in fluidized bed combustion. Due to low sulfur, chlorine etc. blending wood biomass with coal lowers emissions. Fluidized beds can burn a variety of wood fuel sources, like sawdust, logging residues –from conifer or no-conifer trees. Therefore, it is not considered as a dirty/opportunity fuel for co-firing with lignite.

A challenging fuel for co-combustion with lignite is **straw** (wheat, oil seed rape, rice etc.) as it has low bulk density and high chlorine and potassium content; especially, sunflower and rice straw can reach up to 0.7 % w.t. chlorine content, which in combination with their low sulfur content, can lead to a Cl/S ratio higher than 4. Such, high values of this ratio can cause corrosion problems inside the boiler, as abovementioned. Sodium and potassium lower the melting point of ash and, hence can increase ash deposition, fouling and corrosion in the boiler. Especially, in FBC when the steam temperatures are above 565°C, the lifetime of superheaters is unacceptably low, although problems start to occur even at lower temperatures. Such problems can become more pronounced when cereal straw is used for co-firing. For instance, in Denmark, Tech-wise has conducted a number of biomass co-firing experiments and demonstrations (Studstrup power station). In Studstrup, straw was co-fired up to 20% of the energy basis. Corrosion increased slightly, but the result would have been approximately the same if medium-corrosive coal had been used. Slagging increased when the proportion of straw was increased. Thus, if straw biomass is used for co-firing in large-scale boilers two questions should be answered: First, in which blending ratios straw should be co-fired with lignite, to avoid corrosion problems and second, does this biomass source present a sustainable potential across Europe and, especially near lignite mining areas. The second question will be answered in the framework of the present deliverable.

Finally, **exhausted olive cake** (or "kernel wood" or "pyrinoksylo" in Greek or alperujo in Spanish) is a type of residue originating from olive oil industry, during the two-phase or three-phase olive oil production. Olive cake comprises solid residues from olive oil extraction (ston, skin and flesh), moisture (>50 %), oil (2-4%) and ashes (>5%) [13]. The olive cake produced by two-phase systems is around 80% of the olives, with a typical moisture around 68%, while the three-phase system produce an olive cake which half of the weight of the incoming olives and with a lower moisture content of 52% [17]. Owing to its high moisture content and high alkaline content olive cake is quite a problematic fuel, which causes several operational problems in the boiler. First, the contained water is evaporated as the fuel enters the bed and this requires more heat for the fuel to be burned [18]. Second, high alkaline metal content often leads to low ash melting temperature, which might cause bed agglomeration in the boiler and deposit formation on heat transfer surfaces. Co-combustion of exhausted olive cake with coal has been studied for both bubbling and circulating fluidized bed boilers (CFB) [18, 19]. Depending the type of residue, the maximum share of the residue in the fuel blend can range between 25 and 50% of the weight.

Generally, the biomass fuel price at a lignite plant gate is higher than the cost of lignite itself; the difference can be bridged through CO_2 savings and additional financial support received for the production of electricity from biomass (feed-in tariffs and premiums, green certificates, etc.) [7]. Furthermore, in order to reduce the biomass transportation cost, the amounts of biomass needed for co-firing can be retrieved from fields near the power plant; therefore, there is a high necessity for high biomass availability near a lignite power plant that is targeted for co-combustion. However, even at low thermal shares, the implementation of co-firing requires large volumes of biomass due to the large installed capacity of lignite plants. **Low levels of local biomass availability place an additional restraint, especially considering that the low energy density of biomass can put a limit to its transport over long distances.**

For this reason, the research activity undertaken in the framework of Task 1.1 is mainly focused on the sustainable biomass potential in European countries, with the highest lignite production. Such countries are checked for their biomass availability for the forthcoming years (year 2020 and 2030) mostly for agricultural and forest biomass at NUTS0 (national) and NUTS2 (regional) level. Apart from this, additional data are delivered for secondary residues, waste residues and lignocellulosic biomass. Using crop model outputs at a national level, in combination with regional crop statistics to perform regional forecasts, can lead to higher forecasting accuracies for each country. NUTS3 (sub-regional) statistical level could be also used, however, NUTS2 level is considered accurate enough for the scope of this analysis. Data are retrieved from S2biom platform, developed in the framework of S2biom project [2].

3 Biomass availability per crop (NUTS0 level analysis)

3.1 Agro-biomass potential

In agriculture, two alternate sources of primary residues come from arable crops in the form of straw and stubbles and from maintenance of permanent crop plantations like fruit and berry trees, nuts, olives, vineyards, and citrus. All these crops presented in this work are summarized in Table 6.

Among these, **cereal straw** (CS) represents the major fraction of lignocellulosic agricultural wastes generated worldwide [20]. It originates from various cereal crops, such as rice, wheat, barley etc. Some of its advantages include, high availability, low cost – as it will be seen in this deliverable, high carbohydrate content and quick regeneration. CSs can be utilized for the production of bioethanol, biobutanol, biohydrogen and biogas/biomethane by specific microorganism/s only after efficient pretreatment through physical or chemical processes [20]. Straw used for fuel purposes usually contains 14 – 20% moisture content, 50% (d.b.) carbon, 6% (d.b.) hydrogen, 42% (d.b.) oxygen, and small amounts of nitrogen, sulphur, silicon and other minerals e.g. alkali (sodium and potassium) and chloride [21]. However, as previously mentioned in Introduction section, use of straw in boilers might possibly lead to corrosion problems on heat exchange surfaces. **Nevertheless, its selection for co-firing with lignite is a quite demanding task that needs further research.** Straw can be presented in chaffed, pellet or whole bale form depending on the boiler technology used for co-firing [21].

On the other hand, **maize stover** has been reported as the most useful crop for biogas and ethanol production. Added to this, maize has a higher dry matter content and a better C: N ratio than other crops [22]. However, even so it seems as a demanding fuel for co-firing likewise cereal straw, due to its high ash content, Table 5.

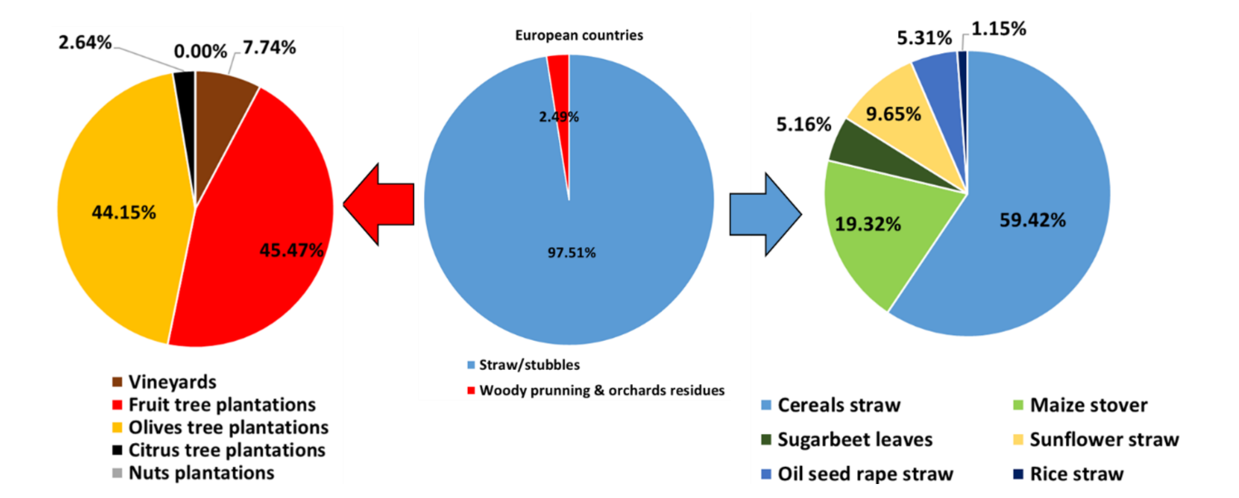
For this reason, this section will be mainly focused on cereal straw and maize stover availability in Europe on a NUTS0 statistical level, whilst additional data will be given for the rest of the agricultural crops.

Agricultural residues	
Straw/Stubbles	**Woody pruning & orchards residues**
Cereal straw	*Residues from vineyards*
Maize stover	*Residues from fruit tree plantations*
Sugar beet leaves	*Residues from olives tree plantations*
Sunflower straw	*Residues from citrus tree plantations*
Oil seed rape straw	*Residues from nuts plantations*
Rice straw	

Table 6. Investigated agro-biomass types (Straw/Stubbles, and pruning).

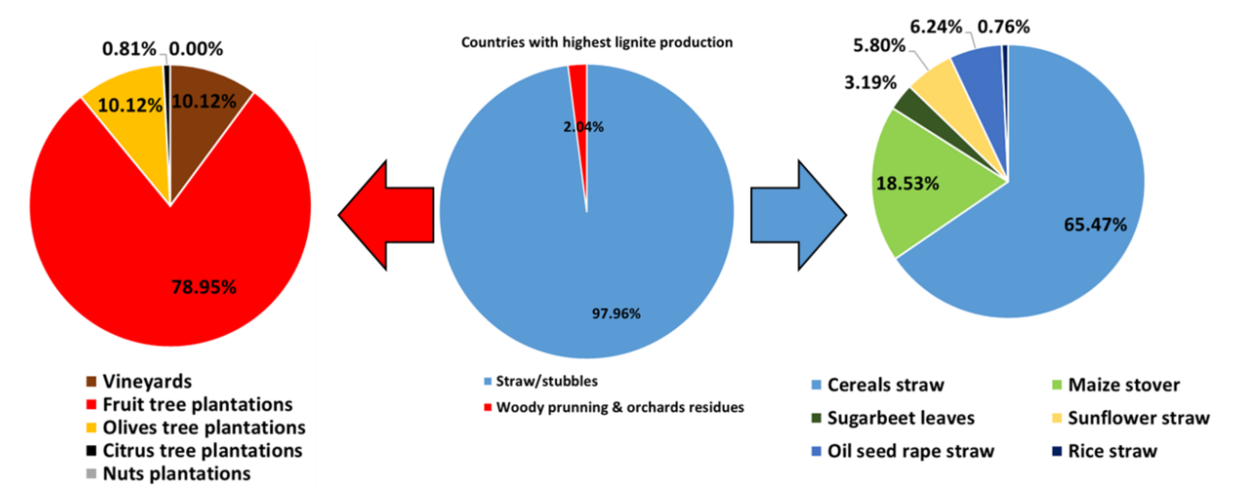
The estimated sustainable potential (Base potential) of the aboventioned crops, which will be used in the framework of this deliverable, has been calculated in S2biom project [2] by taking into account several technical and environmental constraints. According to them, only the biomass part can be removed that is not needed to keep the SOC stable. This is assessed according to carbon content that is removed with the residue and the SOC level in the soil that has to be maintained. An additional constrain is imposed to sugar beet leaves and tops: removal of leaves and tops from field is only allowed in Nitrate vulnerable zones where nitrogen surplus needs to be declined through removal of nitrogen rich biomass.

Based on the S2biom platform it is estimated that in 2020 (2030) there will be approximately 244 Mton (240 Mton) of agricultural biomass available across Europe- including countries outside European Union, (Table 10, Table 11 on Appendix). Out of it, 97.51 % will be from straw and stubbles and only a small share of equal to 2.49 % will be from woody pruning and orchards residues. Overall, the agriculture crops with the highest sustainable potential across Europe are **cereal straw** (59.42% of the available straw/stubbles crops), **maize stover** (19.32 %), **sugarbeet leaves** (5.16 %), **sunflower straw** (9.66 %) and **oil seed rape straw** (5.31 %), Graph 1. As regards woody pruning and orchards residues category, fruit tree and olives plantations have a moderate availability, but mostly in countries, such as Spain (~2.3 Mton), Italy (~0.4 Mton) and Poland (~0.55 Mton). The rest of the crops in this category are expected to have a rather small to zero availability across Europe within the next years. ***Thus, agricultural residues originating from woody pruning and orchards residues present a small potential to be utilized for co-combustion with lignite on a large scale.***



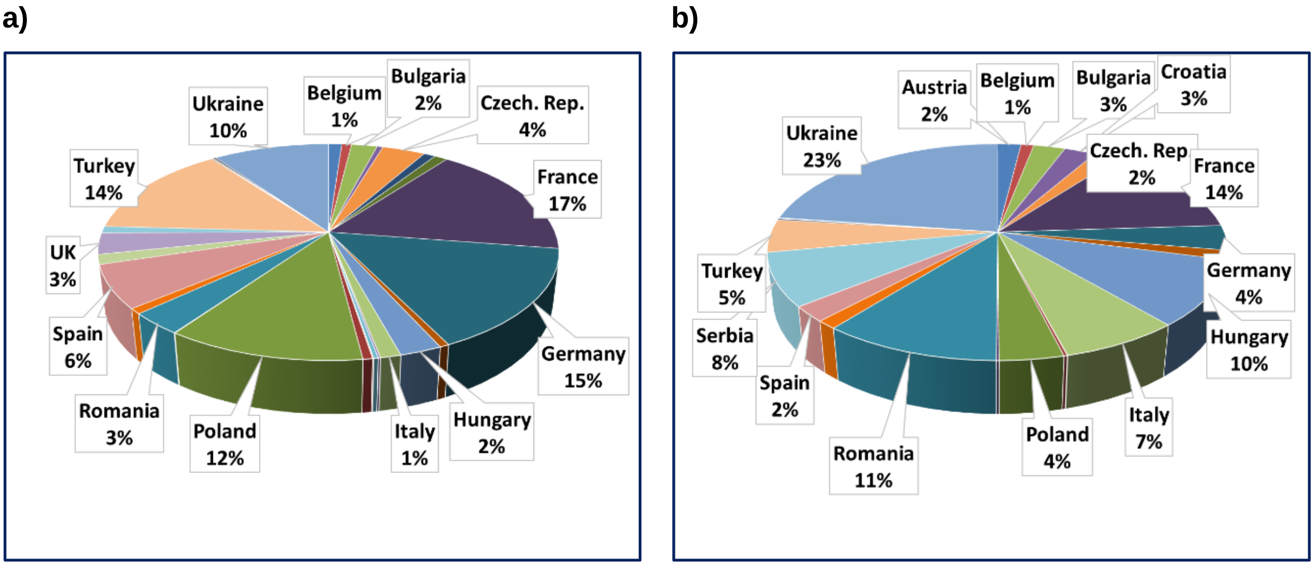
Graph 1. Sustainable agro-biomass potential shares for all the European countries- including countries outside European Union (reference year 2020).

In the areas of interest, i.e. European countries with highest lignite production, the agricultural crops that can be utilized in co-firing are mainly cereal straw and maize stover, Graph 2. In these areas cereal straw is expected to account for almost 60 % of the straw/stubbles crops and maize stover around 19 % in year 2020. This in absolute values is virtually equal to, 78 and 22 Mton, respectively.



Graph 2. Sustainable agro-biomass potential shares for the European countries with the highest lignite production (reference year 2020).

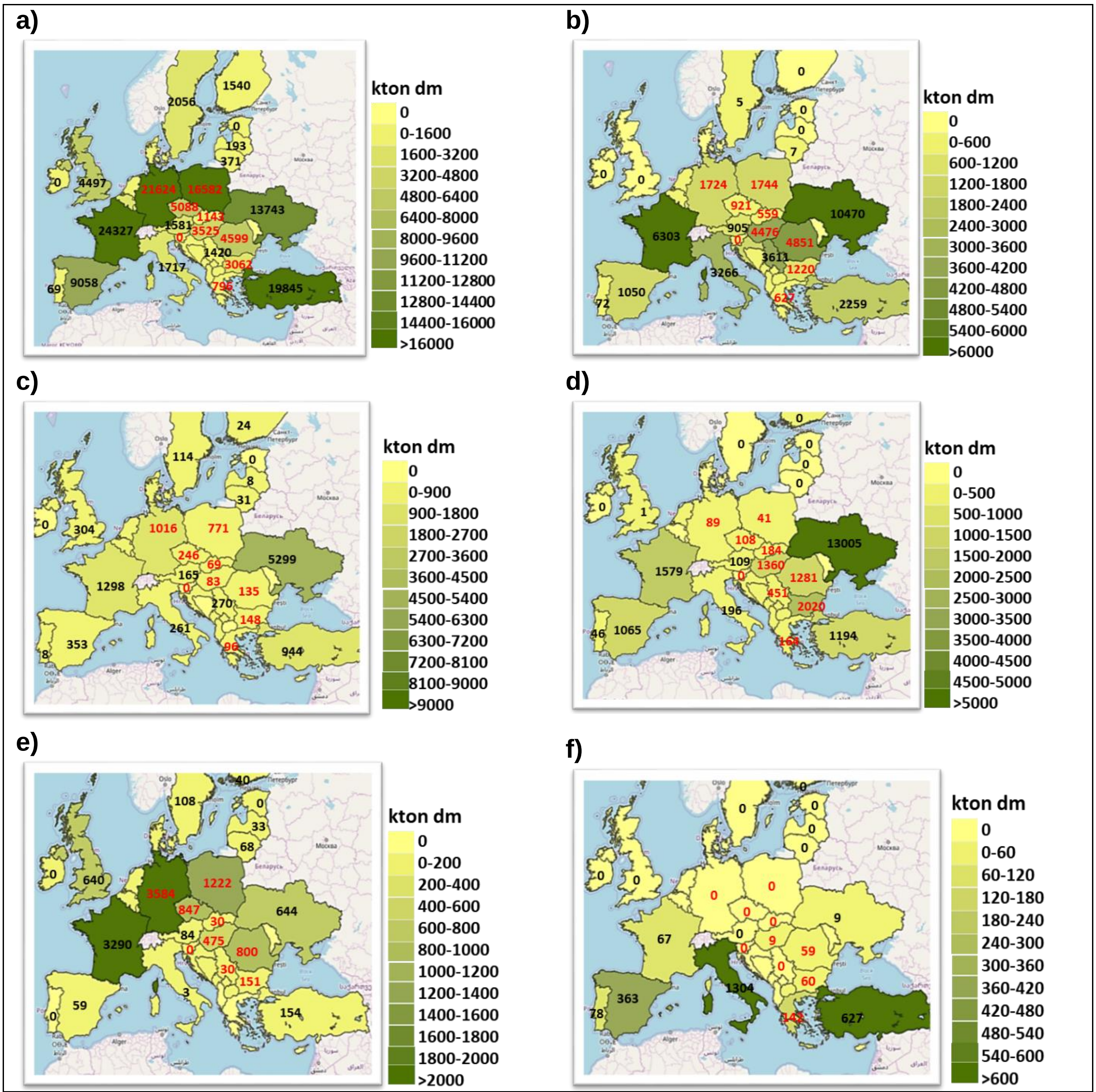
The regional distributions of the different agriculture crops as expected in **absolute levels** (kton dm) in Europe (year 2020) are depicted in Graph 3. As can be seen, the agriculture biomass, which is available for energy production varies significantly between the different countries and from crop to crop. The cereal straw potential is well spread over practically all of the Europe, but countries like France (17 %), Germany (15 %), Poland (12 %), Spain (6 %), Turkey (14 %) and Ukraine (10 %) have the largest potentials. Concerning maize stover, the largest shares are expected in Ukraine (23 %), France (14 %), Romania (11 %), Hungary (10 %), Serbia (8 %) and Italy (7 %).



Graph 3. European countries shares for their a) cereal straw and b) maize stover expected availability in 2020.

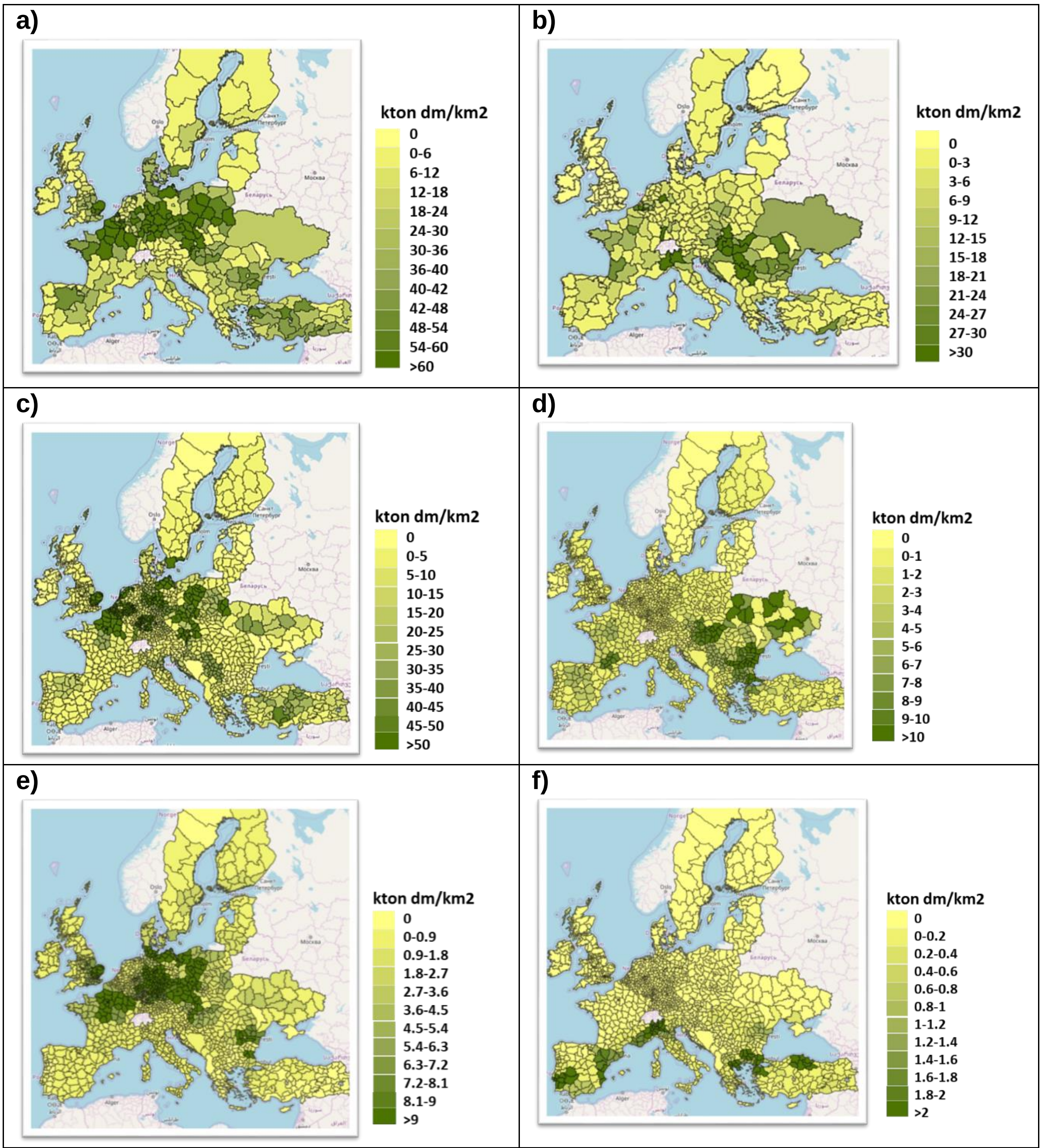
Among the countries of interest, -countries with the highest lignite production- Germany and Poland are the ones with the highest absolute cereal straw and maize stover production. More specifically, in Germany the cereal straw and maize stover availability are expected to be equal to 21.62 and 1.72 Mton, respectively. In Poland, these values are estimated to be equal 16.58 and 1.72 Mton. Finally, some moderate production of these two crops can be traced in Hungary, Romania, and Czech. Republic, Bulgaria and Greece.

Among the southeastern European countries, i.e. Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Kosovo, Macedonia, Montenegro, Romania, Serbia and Slovenia, only **Bulgaria, Greece, Croatia and Serbia** have a moderate potential for agricultural residues. Bulgaria has a total potential of 6.66 Mton for straw and stubbles, Greece of 1.83 Mton, Croatia of 2.1 Mton and Serbia of 5.75 Mton (year 2020).



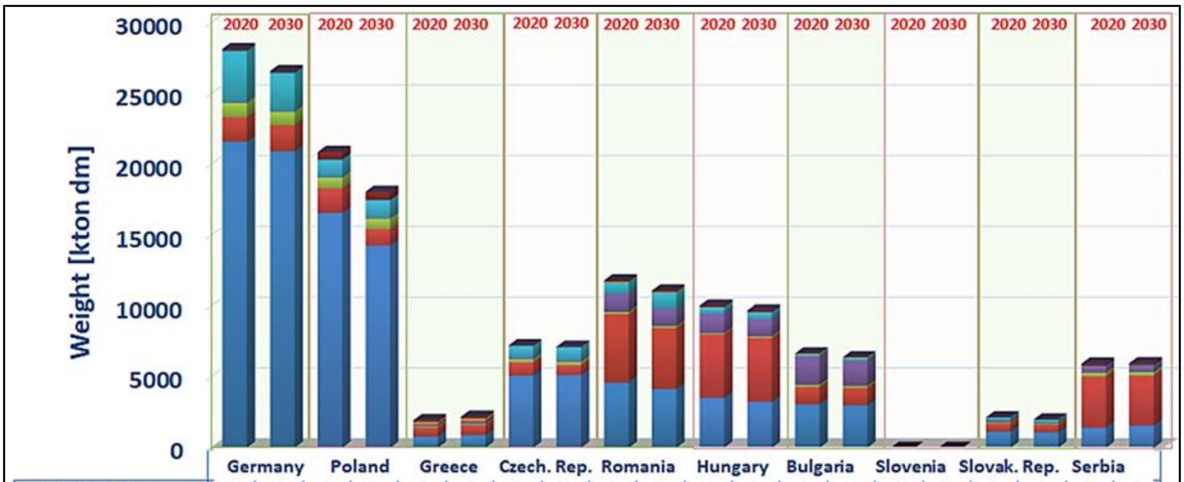
Map 1. Agro-biomass sustainable potential in 2020 in absolute level for a) cereal straw, b) maize stover, c) sugarbeet leaves, d) sunflower straw, e) oil seed rape straw and f) rice straw

Another conclusion to be drawn from this analysis is that the largest cereal and oil seed rape straw and sugarbeet leaves concentration areas are central Germany and central Poland, Map 1, Map 2. On the other hand, for maize stover, are Hungary and South-East Romania. Finally, most of the rice straw that can be potentially used for co-combustion is traced in Bulgaria, Northern Greece and Italy and southern Spain and France.



Map 2. Agro-biomass sustainable potential in 2020 in area weighted level for a) cereal straw and b) maize stover, c) sugarbeet leaves, d) sunflower straw, e) oil seed rape straw and f) rice straw (year 2020).

From Table 10 (Appendix) and Graph 4 it is deduced that the regional distribution of the 2020 and 2030 agriculture potential does not differ much in the European countries with the highest lignite production. As concerns, cereal straw in 2020 there is a total of 78 Mton and in 2030 76 Mton available. In 2020 the potential of maize stover is equal to 22 Mton and drops down slightly to 21 Mton in 2030. Countries, which show particularly large increases towards 2020 and 2030, are Poland, Hungary, Romania and Slovak. Republic.



	Germany 2020	Germany 2030	Poland 2020	Poland 2030	Greece 2020	Greece 2030	Czech. Rep. 2020	Czech. Rep. 2030	Romania 2020	Romania 2030	Hungary 2020	Hungary 2030	Bulgaria 2020	Bulgaria 2030	Slovenia 2020	Slovenia 2030	Slovak. Rep. 2020	Slovak. Rep. 2030	Serbia 2020	Serbia 2030
Nuts plantations	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Citrus tree plantations	0	0	0	0	14	14	0	0	0	0	0	0	0	0	0	0	0	0		
Fruit tree plantations	82	78	549	593	102	109	32	31	110	88	131	134	7	8	3	3	13	12	154	156
Vineyards	67	66	0	0	5	3	0	0	3	2	0	0	0	0	0	0	0	0	15	13
Rice straw	0	0	0	0	142	162	0	0	59	60	9	9	60	50	0	0	0	0	0	0
Oil seed rape straw	3584	2684	1222	1254	0	0	847	940	800	1146	475	508	151	192	0	0	184	207	30	50
Sunflower straw	89	61	41	60	164	222	108	102	1281	1224	1360	1183	2020	1798	0	0	184	96	451	425
Sugarbeet leaves	1016	949	771	743	96	94	246	254	135	131	83	111	148	144	0	0	69	71	270	264
Maize stover	1724	1844	1744	1157	627	699	921	676	4851	4302	4476	4517	1220	1217	0	0	559	540	3611	3518
Cereals Straw	21624	20945	16582	14289	796	897	5088	5139	4599	4155	3525	3244	3062	2996	0	0	1143	1080	1420	1557

Graph 4. Sustainable agro-biomass potential in European countries with the highest lignite production at a regional level (year 2020 and 2030).

3.2 Forestry

In the EU-28 there are 182 million hectares of forests and other wooded land; this corresponds to about 43 % of its land area. During the past 25 years, the European wooded land has grown by 5% - approximately 0.2 % per year [23]. In 2015 the largest wooded area was in Sweden (30.5 million ha), followed by Spain (27.6 million ha), Finland (23.0 million ha), France (17.6 million ha), Germany (11.4 million ha) and Italy (11.1 million ha) [24]. According to studies, the majority of European forests is covered by coniferous trees (42%) and is followed by mixed trees (40 %) and broadleaved trees (18 %) [25]. Most of the coniferous trees can be found in Scandinavian countries and also in countries like Austria, Poland, Germany and Turkey [25]. On the other hand, mixed forests predominate only in Czech Republic and Malta.

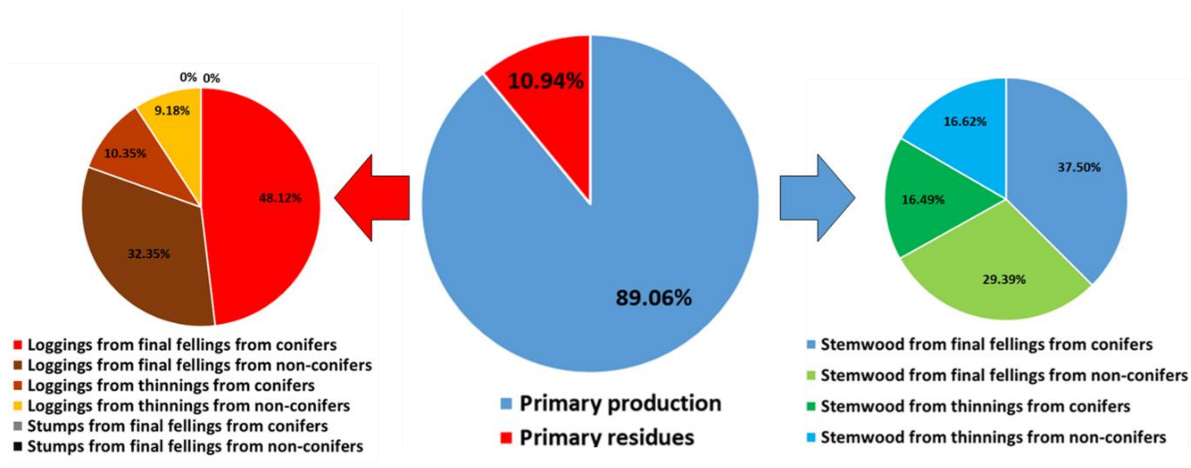
Based on data retrieved from Eurostat, the total production of **roundwood** in Europe was more than more than 425 million cubic metres, out of which 98 million cubic meters was fuel wood and the rest of it industrial roundwood (reference year 2014). The overall value of marketed roundwood is still increasing; in 2010 it reached EUR 21.1 billion in 2010 [5]. As regards **wood pellets**, the EU is the largest global producer (13.1 million ton in 2014) and an important importer (8 million ton in 2014). The major produced in wood pellets in EU-28 is Germany with a share of almost equal to 16 %. Wood pellets, are a fast growing energy source in Europe and are made from dried sawdust (their potential will be analyzed in Secondary residues section), shavings or wood powder [24].

Woody biomass sustainable potential for reference yeas 2020 and 2030 have been retrieved from S2biom platform, which in turn has been based on EFISCEN forest residue model and international forestry statistics. As abovementioned, woody biomass can be largely produced in northern Europe from forestland. Between the EU Member States the share of forest area reaches up to 75% and 76% of Sweden and Finland. Thus, the area of study entailed, apart from countries with highest lignite production, is **northern Europe**, including **Denmark, Estonia, Finland, Latvia, Lithuania, Norway and Sweden**. Two alternate sources of forest biomass are considered in this analysis: production from forests, including **stemwood** from final fellings and thinnings, and primary residues from forests. The latter include **logging residues** from final fellings and thinnings and **stumps** from final fellings. All these categories presented in this work are summarized in Table 7.

Forest residues	
Production from forests Stemwood from final fellings & thinnings	**Primary residues from forests (Logging residues and stumps)**
Final fellings from conifer trees	*Logging residues from final fellings from conifer trees* *Stumps from final fellings from conifer trees*
Final fellings from nonconifer trees	*Logging residues from final fellings from nonconifer trees* *Stumps from final fellings from nonconifer trees*
Thinnings from conifer trees	*Logging residues from thinnings from conifer trees*
Thinnings from nonconifer trees	*Logging residues from thinnings from nonconifer trees*

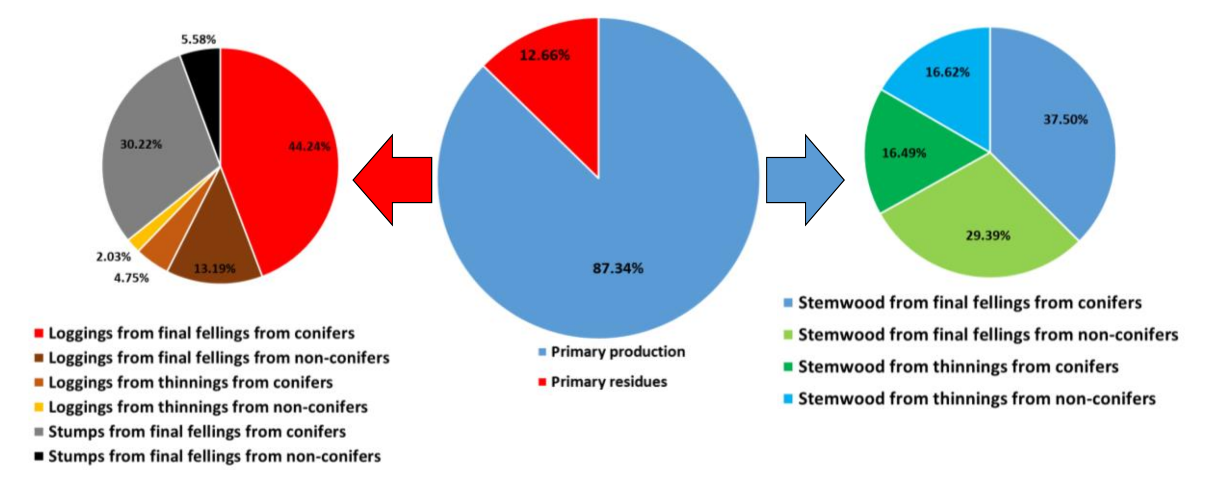
Table 7. Investigated forest biomass types.

The estimated sustainable potential of forest biomass (designated as Base potential) presented in S2biom platform refers to maximum volume of stemwood that could be harvested annually during 50-year periods. As regards residue and stump collection, several technical and environmental constraints are taken into account. These include: i. site productivity, ii. soil and water protection: ruggedness, soild depth, soil surface texture, soil compaction risk, iii. Biodiversity (protected forest areas) and iv. soil bearing capacity.



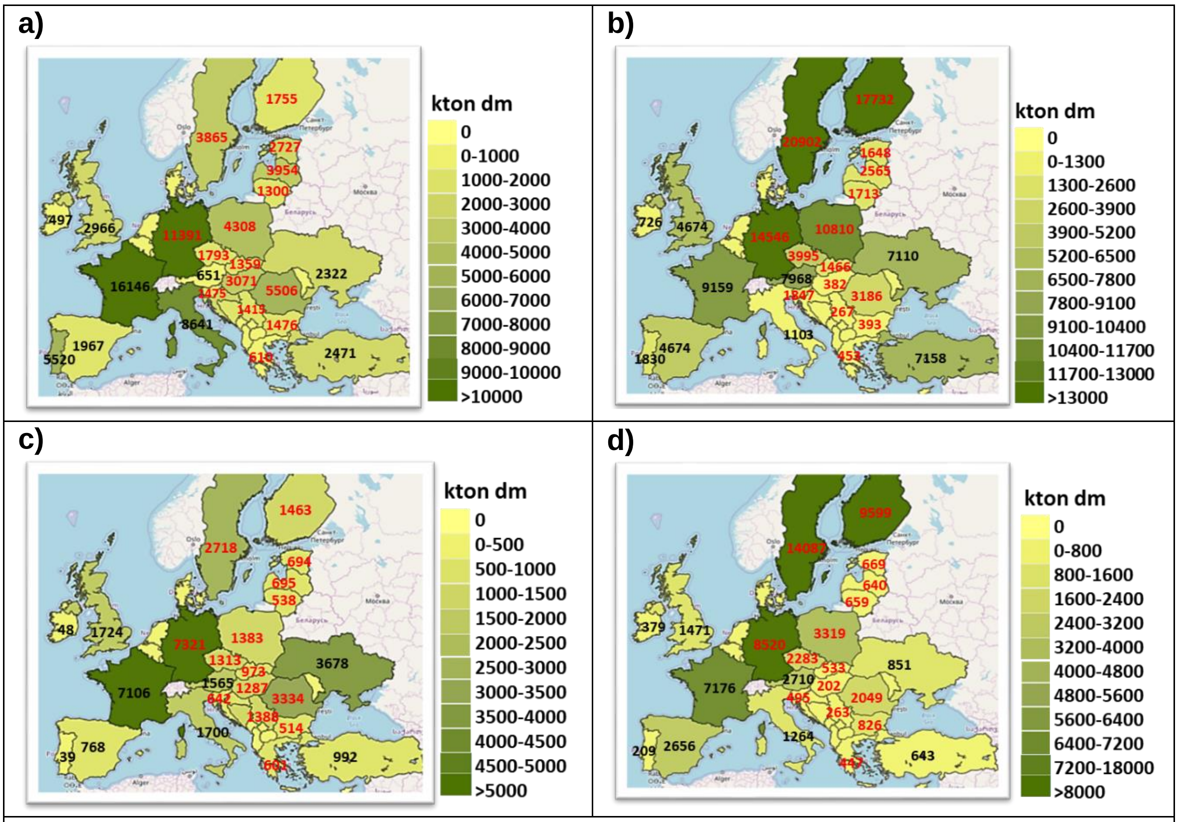
Graph 5. Sustainable forest biomass potential shares for the European countries with the highest lignite production (reference year 2020).

As can be seen from Graph 5 in the **European countries with the highest lignite production**, the majority of forest potential is in stems, about 89 %, and the rest of it is in logging residues. Some production from stumps can be found in northern European countries, Graph 6. Overall, the potential supply for the forest biomass for the Base (sustainable) potential is estimated at 39.36,13.27 and 14.59 Mton dm for the EU-28, northern European countries and European countries with the highest lignite production, respectively.



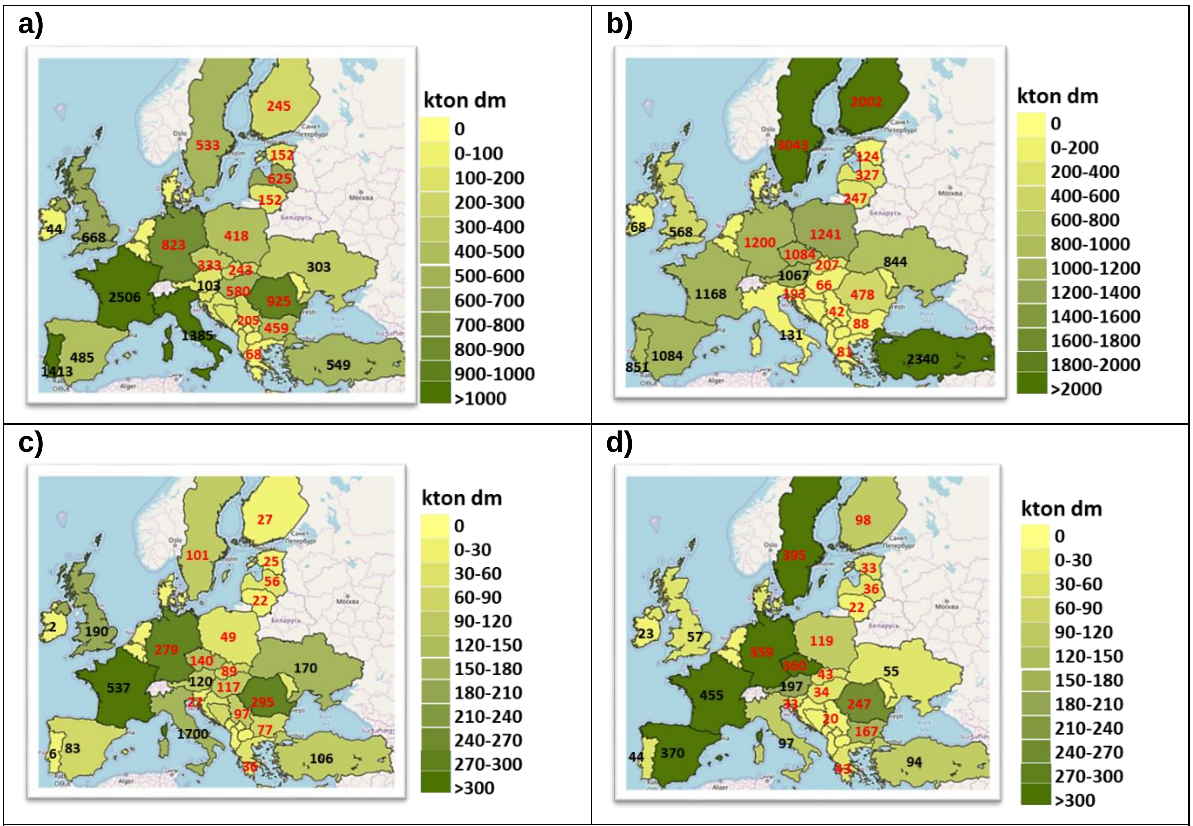
Graph 6. Sustainable forest biomass potential shares for the northern European countries (reference year 2020).

At a NUTS0 level, as can be noticed in Map 3, Map 4, the wood biomass potentials are not equally distributed between the European countries. The countries with the highest forest biomass production (primary and residues) are Finland, Sweden, Germany, Poland and France. However, in contrast to agricultural crops, woody biomass –especially stemwood- can be generally found throughout the whole area of Europe.



Map 3. Sustainable potential for primary production from forests (year 2020): a) final fellings from non-conifer trees , b) final fellings from conifer trees, c) thinnings from non-conifer trees, and d) thinnings from conifer trees.

As concerns logging residues, the availability is rather limited and mostly higher in central-northern countries, such as Finland, Sweden, Germany and Poland. In these countries, the majority of the forest land is covered by coniferous trees and to a smaller extend by non-conifer trees. Thus, the sustainable forest potential in these areas, lies on coniferous trees.

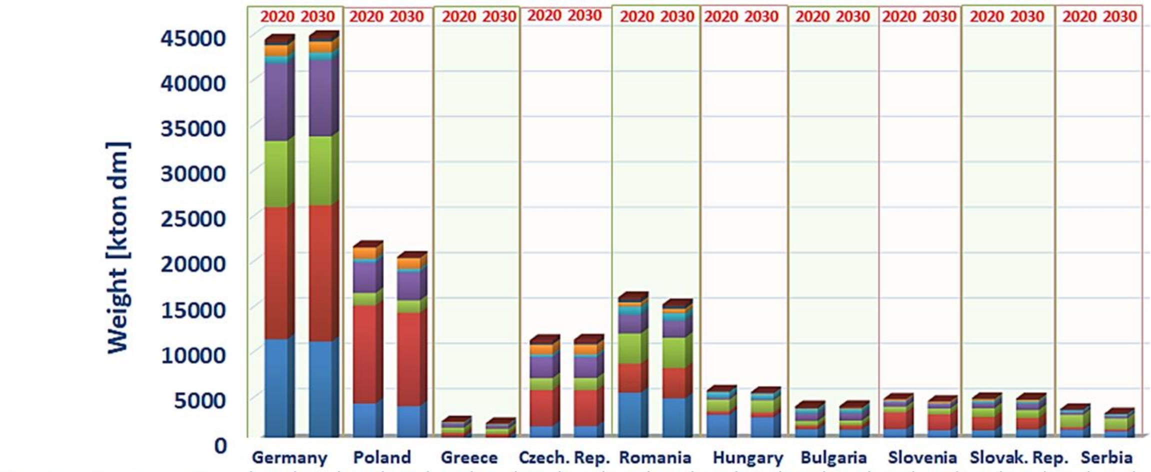


Map 4. Sustainable potential for primary logging residues from forests (year 2020): a) final fellings from non-conifer trees , b) final fellings from conifer trees, c) thinnings from non-conifer trees, and d) thinnings from conifer trees.

Finally, **Graph 7**, **Graph 8** present a comparison as regards the sustainable forest biomass potential for the European countries with the highest lignite production and Northern European countries, respectively. An important conclusion to be drawn is that the regional distribution of the 2020 and 2030 forest potential does not differ much in the areas of interest. More specifically,

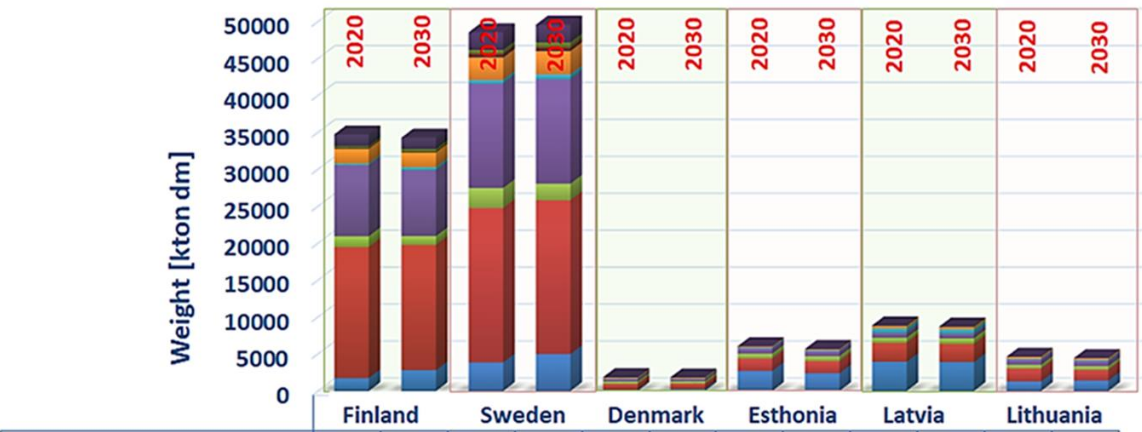
- In **Germany**, the total potential is equal to 44,439 Mton in 2020 and 44,827 Mton in 2030 (this is in compliance the steady increase in the European forest land). The majority of this amount is based on stemwood,
- In **Poland**, a lower potential than Germany is equal to 21,647 Mton in 2020 and 20,492 Mton in 2030 (in this case there a small decrease of almost 5 % is expected in the forest potential).
- **In Finland**, a total potential of equal to ~34 Mton in both reference years is identified. From this amount, only 4 Mton come from logging residues and stumps, which corresponds to a share of almost 12 %.
- **In Sweden, is estimated the highest potential in forest biomass amongst all EU-28 countries.** More specifically, a total potential of equal to 48-50 Mton for the period 2020-2030 is identified.

More analytical data can be found in Table 12 and Table 13 in the Appendix section.



	Germany 2020	Germany 2030	Poland 2020	Poland 2030	Greece 2020	Greece 2030	Czech. Rep. 2020	Czech. Rep. 2030	Romania 2020	Romania 2030	Hungary 2020	Hungary 2030	Bulgaria 2020	Bulgaria 2030	Slovenia 2020	Slovenia 2030	Slovak. Rep. 2020	Slovak. Rep. 2030	Serbia 2020	Serbia 2030
Loggings thinnings conifer	359	332	119	108	43	39	360	407	247	193	34	18	167	141	33	37	43	88	20	17
Loggings thinnings nonconifer	279	292	49	48	36	33	140	147	295	295	117	125	77	78	27	28	89	80	97	84
Loggings fellings conifer	1200	1213	1241	1185	81	74	1084	1100	478	501	66	98	88	106	193	183	207	179	42	36
Loggings fellings nonconifer	823	830	418	392	68	63	333	344	925	816	580	524	459	452	113	103	243	259	205	178
Thinnings conifer trees	8520	8412	3319	3086	447	408	2283	2252	2049	1877	202	124	826	811	495	477	533	671	263	228
Thinnings nonconifer trees	7321	7589	1383	1370	601	549	1313	1334	3334	3333	1287	1352	514	521	642	650	973	872	1388	1206
Final fellings conifer trees	14546	15028	10810	10292	453	413	3995	3981	3186	3347	382	526	393	467	1847	1751	1466	1268	267	232
Final fellings nonconifer trees	11391	11131	4308	4011	610	557	1793	1799	5506	4879	3071	2788	1476	1442	1475	1351	1359	1444	1415	1230

Graph 7. Forest sustainable biomass potential in European countries with the highest lignite production in 2020 and 2030.



	Finland 2020	Finland 2030	Sweden 2020	Sweden 2030	Denmark 2020	Denmark 2030	Esthonia 2020	Esthonia 2030	Latvia 2020	Latvia 2030	Lithuania 2020	Lithuania 2030
Stumps fellings conifer	1611	1571	2397	2407	0	0	0	0	0	0	0	0
Stumps fellings nonconifer	214	345	533	692	0	0	0	0	0	0	0	0
Loggings thinnings conifer	98	89	395	396	40	25	33	33	36	32	22	23
Loggings thinnings nonconifer	27	22	101	84	26	26	25	26	56	64	22	22
Loggings fellings conifer	2002	1996	3043	3159	133	128	124	121	327	310	247	214
Loggings fellings nonconifer	245	402	533	691	38	55	152	133	625	621	152	161
Thinnings conifer trees	9599	8924	14087	14104	382	325	669	661	640	592	659	674
Thinnings nonconifer trees	1463	1208	2718	2246	302	296	694	694	695	770	538	522
Final fellings conifer trees	17732	16949	20902	20822	771	723	1648	1621	2565	2436	1713	1427
Final fellings nonconifer trees	1755	2815	3865	5002	191	272	2727	2402	3954	3923	1300	1422

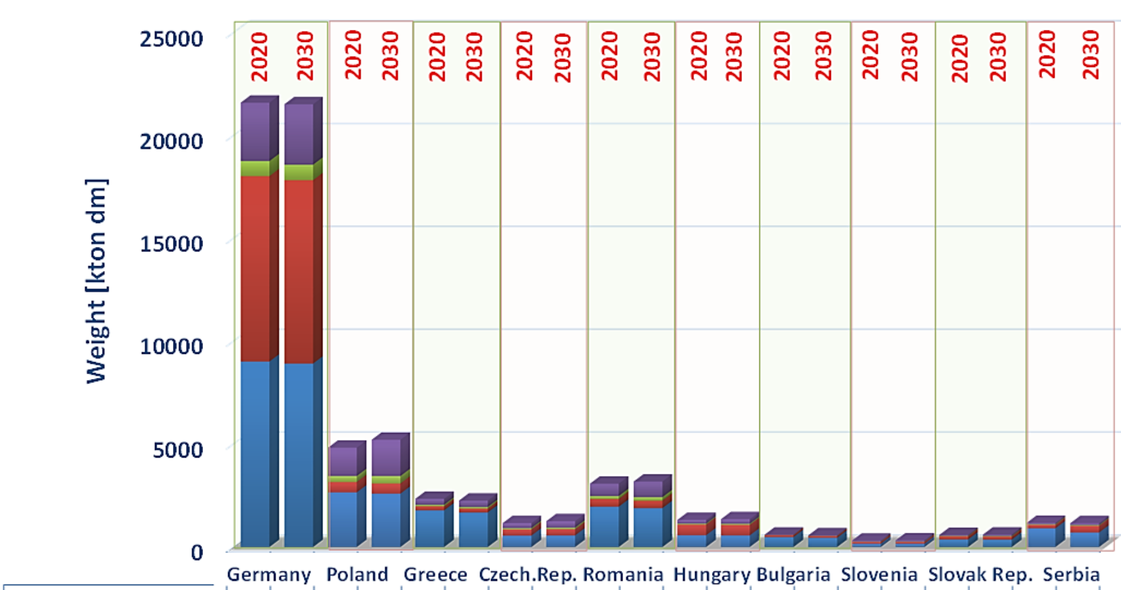
Graph 8. Forest sustainable biomass potential in northern European countries in 2020 and 2030.

3.3 Waste collection

In general, biogenic waste is considered as the part of biodegradable municipal waste, excluding textile and separately collected paper and paperboard. This type of waste can be available in different forms, such as unseparated/mixed municipal waste (MSW), separately collected organic waste, organic industrial waste (non-woody), common sludges, verge grass & nature grass and landfill gas [26].

S2Biom platform provides information on the first two categories, i.e. **biowaste separately** and **integrally (unseparately) collected**. In general separately collected biowaste can be used to generate energy by anaerobic digestion followed by composting, whilst integrally collected is the biowaste that can be incinerated with energy generation. Part of the biowaste integrally collected can be separated as part of "refuse derived fuel - RDF" and combusted in a plant. RDFs contains mainly high quantities of biodegradable material but also a small fraction of plastics. More specifically, RDFs comprise mainly paper, cardboard, non-recyclable plastics, and other uneven materials. This waste is shredded, dried and hard-pressed before its utilization [27]. This type of waste biomass, municipal waste unseparately collected is of great interest and its sustainable potential in Europe for 2020 and 2030 id presented in this section.

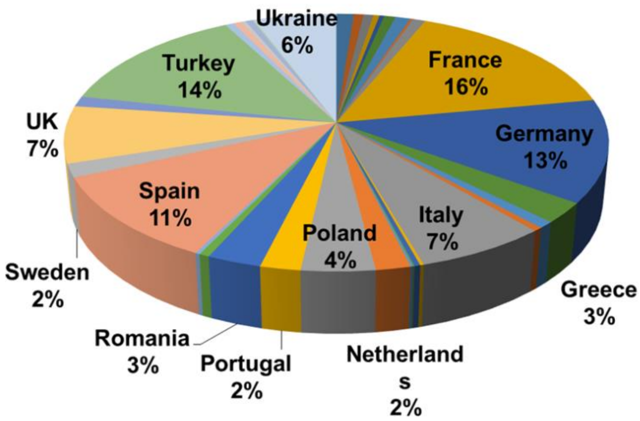
Overall, from Graph 9 it is inferred that amongst the ***European countries with the highest lignite production***, Germany is the leading country in both woody and municipal waste, with a total sustainable potential exceeding 20 Mton dm. An important share of this amount is from biowaste unseparately collected –equal to 9 Mton in 2020 and 9.8 Mton in 2030. In Poland, the sustainable potential of biowaste unseparately collected in estimated equal to ~2.6 Mton for both reference years. In Greece, there will be a rather small availability of equal to ~1.7-1.8 Mton with the period 2020-2030.



	Germany 2020	Germany 2030	Poland 2020	Poland 2030	Greece 2020	Greece 2030	Czech.Rep. 2020	Czech.Rep. 2030	Romania 2020	Romania 2030	Hungary 2020	Hungary 2030	Bulgaria 2020	Bulgaria 2030	Slovenia 2020	Slovenia 2030	Slovak Rep. 2020	Slovak Rep. 2030	Serbia 2020	Serbia 2030
Non-hazardous wood	2840	2938	1379	1766	294	316	247	318	606	762	184	228	22	29	51	64	48	71	67	96
Hazardous wood	732	752	291	362	70	74	62	75	143	172	44	52	6	7	11	13	18	23	30	35
Separately collected	9016	8918	505	494	198	187	298	302	373	360	518	511	92	85	86	86	156	153	170	325
Unseparately collected	9016	8918	2653	2593	1781	1679	554	561	1958	1890	570	563	481	447	160	160	365	358	907	703

Graph 9. Sustainable waste biomass in European countries with highest lignite production (year 2020/2030) –NUTS0 statistical level.

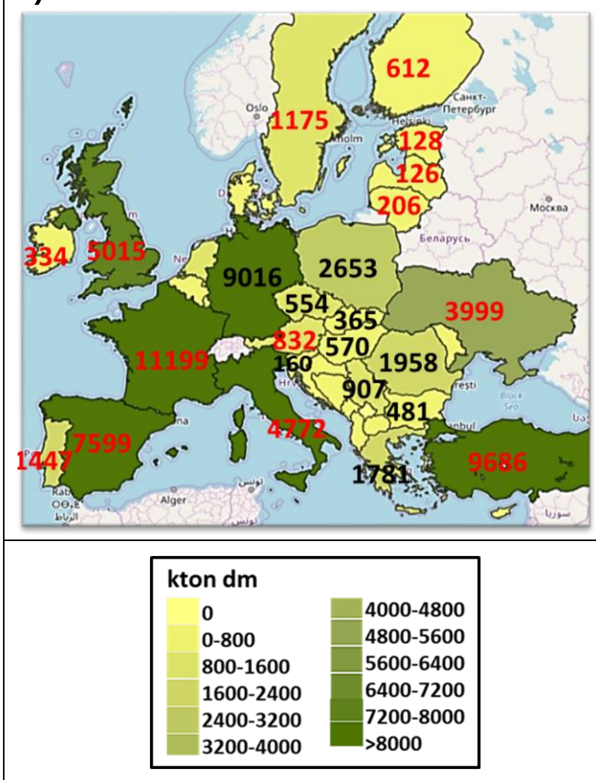
Specifically, as concerns unseparately collected waste biomass, in which RDF is incorporated, the biggest contributors at European level are Germany, France, Spain and Turkey with a total share equal to 54 %, Graph 10. Other European countries with moderate waste production include UK (7%), Italy (7%), Greece (3%), Romania (3%) and Poland (4%). Among the countries with the highest lignite production, Germany is the leader with a sustainable potential equal to 9 Mton dm, Map 5.



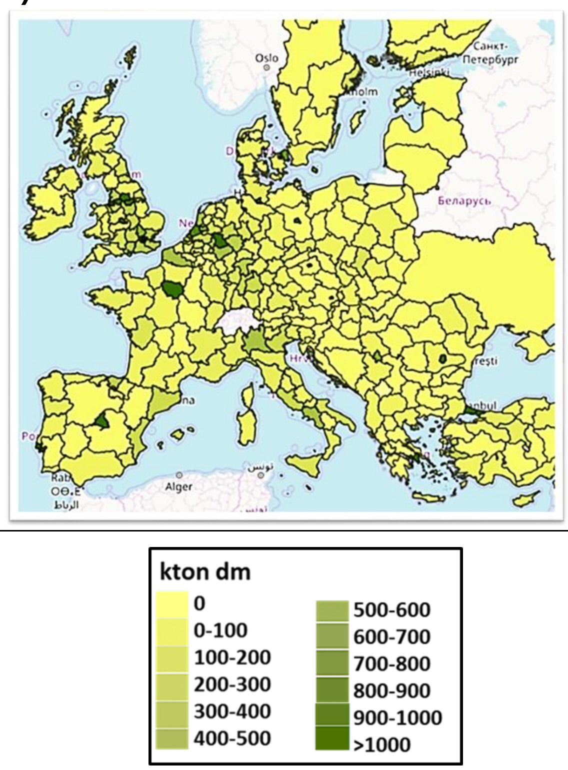
Graph 10. Sustainable waste biomass (unseparately collected) in European countries with highest lignite production (year 2020/2030).

From Map 5 it can be also observed that the municipal waste density, as expected, is higher in big European cities. This raises questions, whether there is a high RDF availability near different European lignite mining areas. Taking as a reference three mining areas in three different countries – Ptolemaida in Western Macedonia, Greece, Hambach mines, in Koln, Germany and Bełchatów, in Lodzkie, Poland- and looking at Graph 11 and Table 15, in the Appendix section, it can be deduced that near important European mining areas, areas, where is a high lignite production, the RDF availability is rather moderate [0.4-0.6 Mt dm]. **<u>Thus, this fuel can be used for co-firing in small-scale units or at low rates in the fuel blend.</u>**

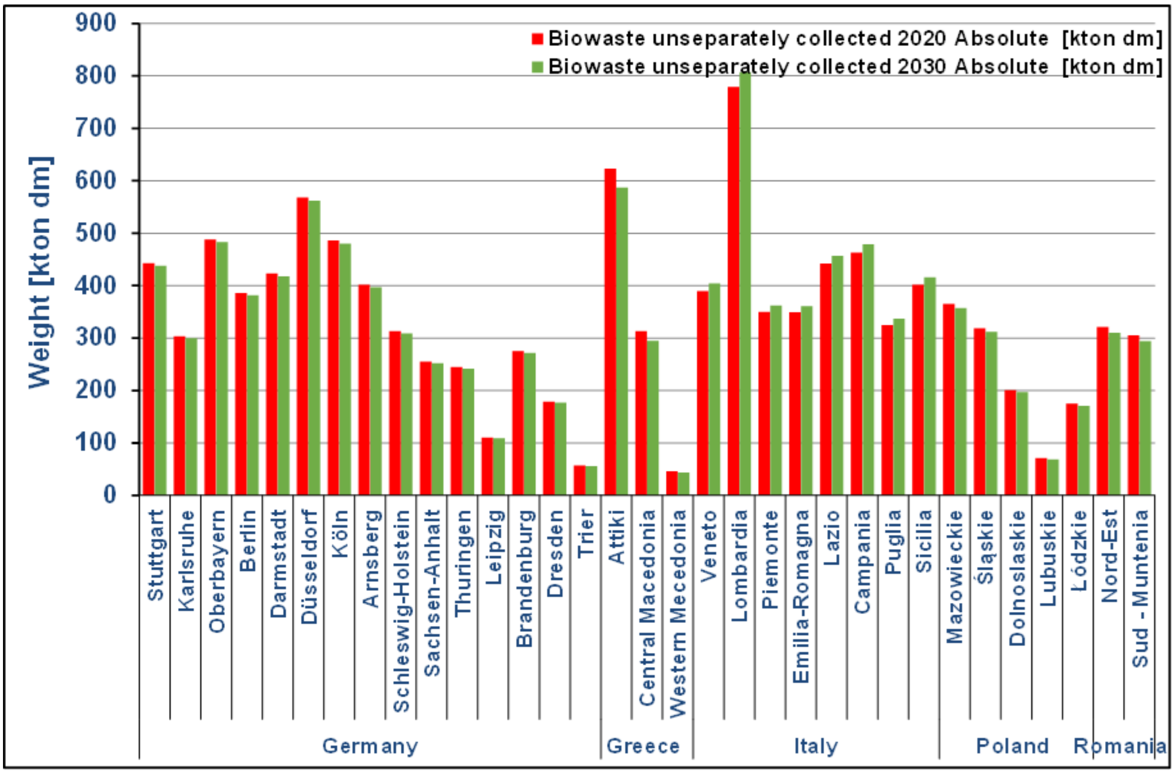
a)



b)



Map 5. Sustainable municipal waste biomass unseparately collected in Europe in a) absolute and b) area weighted levels (year 2020).



Graph 11. Sustainable waste biomass –unseparately collected in selected European areas (year 2020/2030) –NUTS2 statistical level.

3.4 Lignocellulosic biomass crops

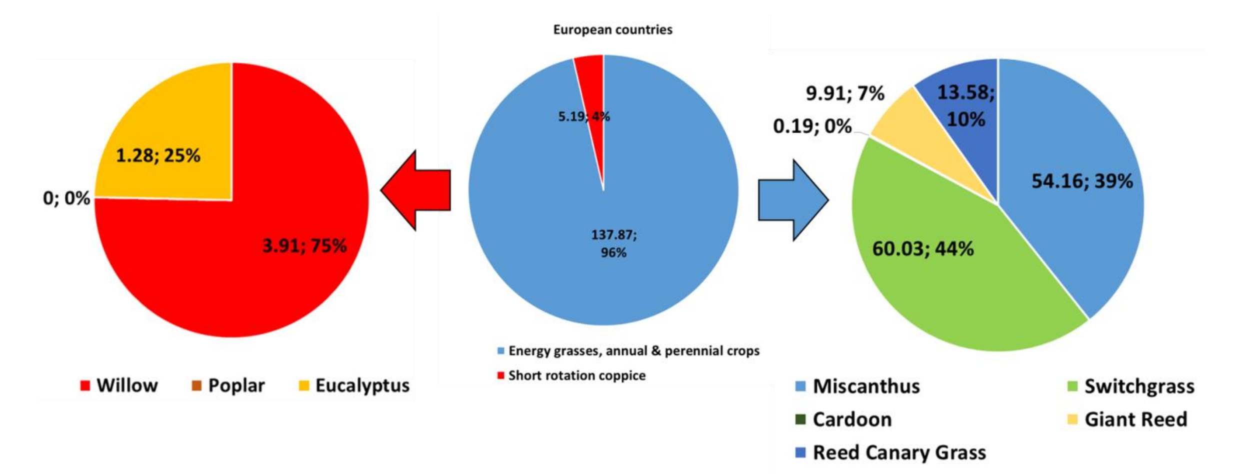
In general, lignocellulosic biomass refers to biomass that consists of cellulose, hemicellulose, and lignin. In this category are contained wood from forestry, short rotation coppice (SRC), and lignocellulosic energy crops, such as energy grasses and reeds. In this section lignocellulosic biomass crops including energy grasses and short rotation coppice are presented, Table 8.

Lignocellulosic materials have potential for use as a feedstock for advanced diesel and drop-in biofuels (via thermochemical conversion) and for production of cellulosic ethanol (via biochemical conversion). Lignocellulosic crops generally have a higher GHG efficiency then rotational arable crops since they have lower input requirements and the energy yield per hectare is much higher.

Lignocellulosic biomass crops	
Energy grasses, annual and perennial crops	**Short rotation coppice**
Miscanthus	SRC Willow
Switchgrass	SRC Poplar
Cardoon	Other SRC (including **Eucalyptus**)
Giant reed	
Reed canary grass	

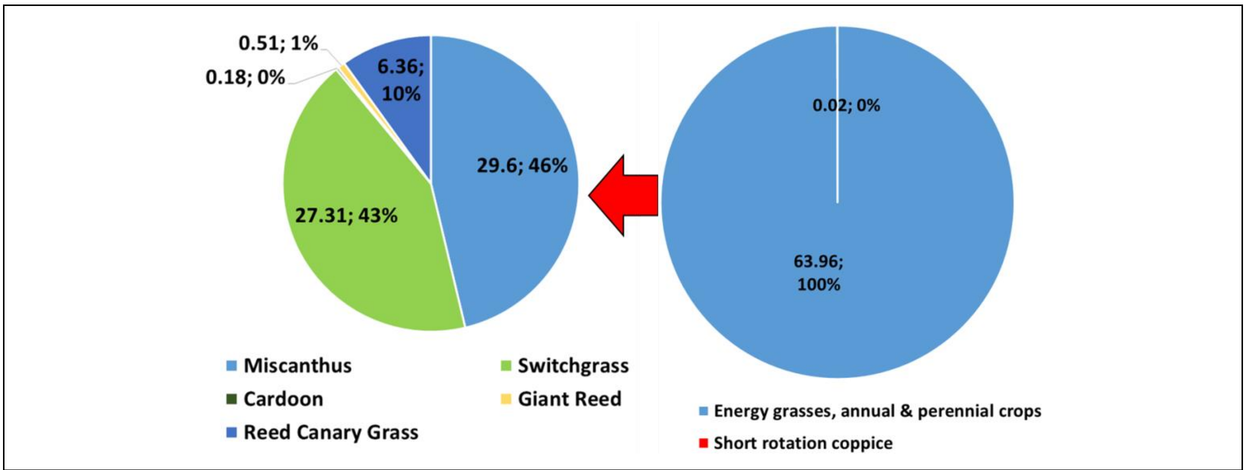
Table 8. Investigated lignocellulosic biomass types.

Amongst the lignocellulosic crops tested miscanthus and switchgrass seem quite promising for fuel feedstocks, since both crops have high availability in Europe and present quick adaptability to climate changes [28]. More specifically, based on the S2biom platform it is estimated that in 2020 (2030) there will be approximately 140 Mton (146 Mton) of lignocellulosic biomass -originating from energy crops and grasses and short rotation coppice- available across Europe (Table 16, Table 17 on Appendix). Out of it, 96% will be energy grasses and crops and only a small share of equal to 5.19 % will be from short rotation coppice. Overall, the crops with the highest sustainable potential across Europe are **switchgrass** (44% of the available energy grasses and crops), **miscanthus** (39 %) and reed canary grass (10 %), Graph 12. As regards short rotation coppice, willow has a moderate availability (3.91 Mton), but mostly in countries such as Italy, France and UK, Map 6. Eucalyptous, presents as well a small potential (1.28 Mton) in southern European countries, like Spain, Italy and southern France.

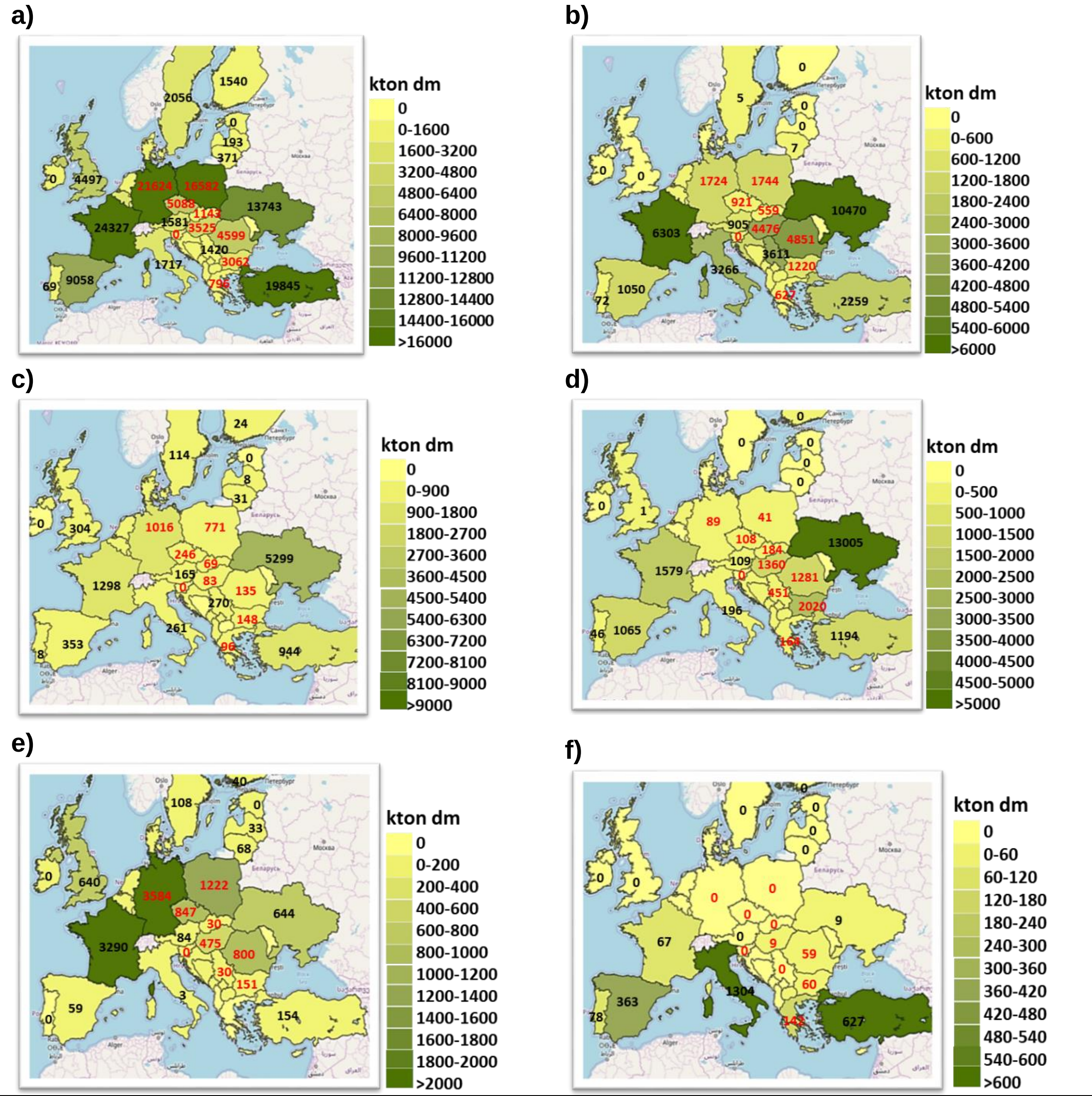


Graph 12. Sustainable lignocellulosic biomass potential shares for all the European countries-including countries outside European Union (reference year 2020).

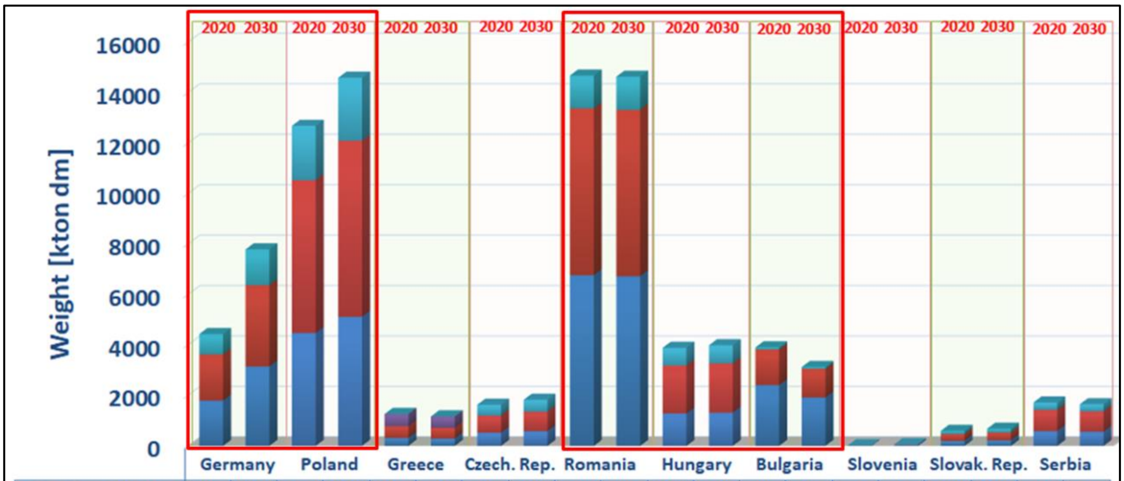
In the countries with the highest lignite production, the sustainable potential of lignocellulosic biomass crops will be mainly based on energy grasses and perennial crops, in 2020 and 2030. On the other hand, short rotation coppice will play a negligible role in these countries. As regards energy grasses, miscanthus and switchgrass will have almost the same share, as can be noticed from Graph 13, and a smaller share of equal to 10 % will be from reed canary grass.



Graph 13. Sustainable lignocellulosic biomass potential shares for the European countries with the highest lignite production (reference year 2020).



Map 6. Lignocellulosic (energy crops) sustainable potential in 2020 in absolute level for a) miscanthus, b) switchgrass, c) giant reed, d) reed canary grass, e) cardoon and f) willow, g) poplar and e) eucalyptus.



	Germany 2020	Germany 2030	Poland 2020	Poland 2030	Greece 2020	Greece 2030	Czech. Rep. 2020	Czech. Rep. 2030	Romania 2020	Romania 2030	Hungary 2020	Hungary 2030	Bulgaria 2020	Bulgaria 2030	Slovenia 2020	Slovenia 2030	Slovak. Rep. 2020	Slovak. Rep. 2030	Serbia 2020	Serbia 2030
Reed canary grass	808	1420	2157	2498	0	0	432	472	1302	1315	701	720	86	69	3	7	130	149	297	285
Giant reed	0	0	0	0	485	453	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cardoon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Switchgrass	1835	3221	6062	6982	467	428	679	773	6614	6598	1904	1956	1412	1139	6	17	274	310	840	806
Miscanthus	1790	3148	4471	5115	314	288	522	584	6765	6722	1281	1316	2409	1918	15	39	193	220	586	562

Graph 14. Sustainable lignocellulosic biomass in countries with highest lignite production (year 2020/2030).

To conclude with, miscanthus and **switchgrass** are energy crops with the highest sustainable potential in Europe. In **South-Europe** can be mostly found giant reed, cardoon, eucalyptus and willow, in Central-Europe reed canary grass and in Northern-Europe reed canary grass and willow.

3.5 Secondary residues

In this section some brief data are given, as concerns the sustainable potential of secondary residues originating from wood industries (e.g. saw mill industries) and industry utilizing agricultural products. The residues presented are summarized in the following Table 9.

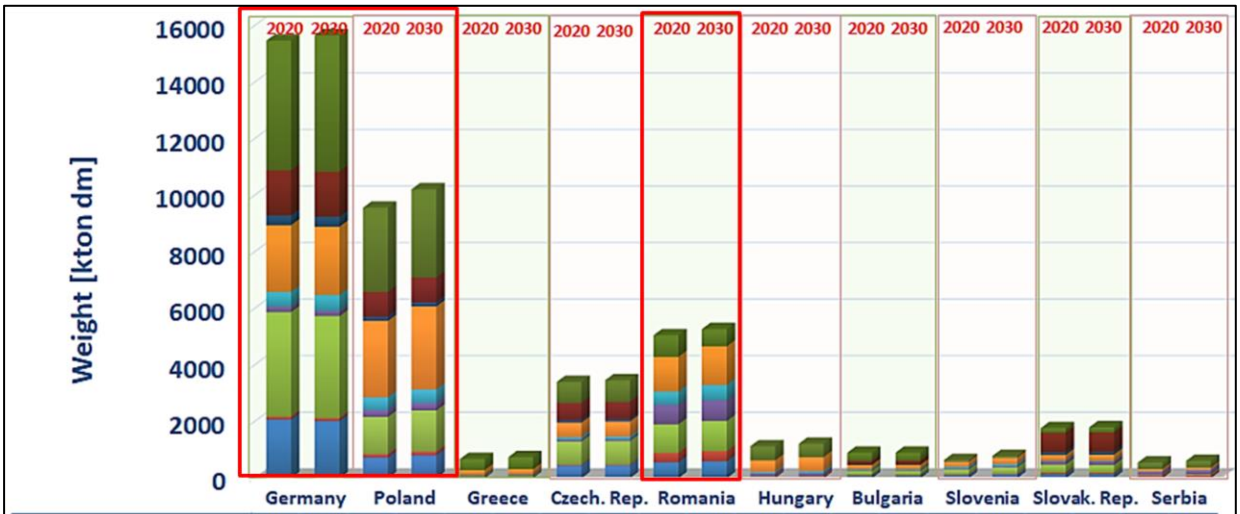
Secondary residues	
From Wood industries	**Of industry utilizing agricultural products**
Saw mill residues: i. Sawdust from conifer/nonconifer trees, ii. Other: sawmill residues excluding sawdust from conifers/nonconifers)	Olive-ston
From industries producing semi-finished wood based panels	Other food processing residues
From further woodprocessing	Rice husk
Bark	Pressed grapes dregs
Black liquor	Cereal bran

Table 9. Investigated biomass secondary residues.

As can be seen from **Graph 15** **<u>the highest potential from secondary residues is in</u> <u>Germany, Poland and Romania. Czech. Republic and Slovak. Republic have a modest potential</u>**. Moreover, it can be inferred that from 2020 to 2030 the secondary residues production is expected to increase in all countries tested. More specifically,

A. Concerning, ***secondary residues from industry utilizing agricultural products***:

- **In Germany**, the estimated potential is equal to 4.6-4.9 Mton dry matter, within the period 2020-2030 and will be mainly based on cereal bran (4.59-4.82 Mton dm).
- **In Poland**, the sustainable potential is equal to 2.98 Mton in 2020 and 3.12 Mton in 2030 –only based on cereal gran.
- **In Romania and Czech. Republic,** there will be a rather small availability of equal to 0.7-0.8 Mton –in each country- within the period 2020-2030.
- **In Greece,** the same small potential as in Romania and Czech. Republic is estimated. However, contrary to the rest of the countries mentioned, in Greece there will be a small potential for olive stone residues –equal to 0.17 Mton dm.



	Germany 2020	Germany 2030	Poland 2020	Poland 2030	Greece 2020	Greece 2030	Czech. Rep. 2020	Czech. Rep. 2030	Romania 2020	Romania 2030	Hungary 2020	Hungary 2030	Bulgaria 2020	Bulgaria 2030	Slovenia 2020	Slovenia 2030	Slovak. Rep. 2020	Slovak. Rep. 2030	Serbia 2020	Serbia 2030
Cereal bran	4586	4823	2977	3115	394	428	746	771	766	614	503	475	289	283	55	58	174	186	234	240
Black liquor	1591	1591	882	882	0	0	601	601	0	0	0	0	130	130	2	2	680	680	0	0
Bark	348	348	144	144	0	0	87	87	0	0	0	0	19	19	5	5	100	100	0	0
Further woodprocessing	2362	2421	2703	2937	167	181	514	529	1227	1365	409	494	142	147	173	215	195	216	73	83
Semi-finished wood panels	515	551	456	483	14	13	96	100	466	539	60	79	28	30	65	80	21	26	19	21
Other (nonconifers)	197	193	235	259	41	48	62	62	695	738	86	94	41	41	36	45	126	124	111	134
Other (conifers)	3697	3609	1318	1455	28	32	821	831	1006	1069	19	21	149	148	183	229	283	277	29	34
Sawdust (nonconifers)	103	101	117	130	19	23	31	31	334	355	41	44	21	21	18	22	53	51	68	81
Sawdust (conifers)	2071	2021	732	808	15	18	442	448	559	594	11	12	82	82	102	127	141	138	16	20

Graph 15. Sustainable biomass potential from secondary residues in countries with highest lignite production (year 2020/2030).

B. Concerning, ***secondary residues from industry utilizing agricultural products***:

- **Black liquor**, which is of high interest can be mostly found in Germany (1.59 Mton dm), Poland (0.88 Mton dm) and Slovak. Republic (0.68 Mton dm).

- **Sawdust** originating from coniferous trees presents higher potential compared to the one originating from non-coniferous trees. More specifically, the highest potential for sawdust from conifer trees is traced in Germany (2.07 Mton), followed by Poland (0.73-0.81 Mton) and Romania (0.56-0.59 Mton).

Further information concerning secondary residues sustainable potential in 2020 and 2030 can be found in Table 18, Table 19 and Table 20 in the Appendix section.

3.6 Commercialized biomass in Europe

Apart from the agricultural and forest sector, there are some solid biofuels, which are already utilized and commercialized in Greece, such as firewood, wood pellets, exhausted olive cake and olive ston and other agro-industrial residues [29].

According to a mass balance from the BIOMASUD project [17], olive ston amount to 8.3% of the weight of the olive, while the exhausted olive cake is 19.7% of the weight. Both quantities refer to dry basis, since water is given separately in the mass balance. EUROSTAT listed the production of olives for oil production in Greece as 1,570,930 t in 2014. Therefore, a preliminary assessment of the technical potential of the major solid by-products from olive production is as follows:

- Olive ston: 130 kton dm.
- Exhausted olive cake: 309 kton dm

Apart from Greece exhausted olive cake can be found in Italy (140 kton dm /y), Spain (800 kton dm/y) and in Portugal (100 kton dm/y).

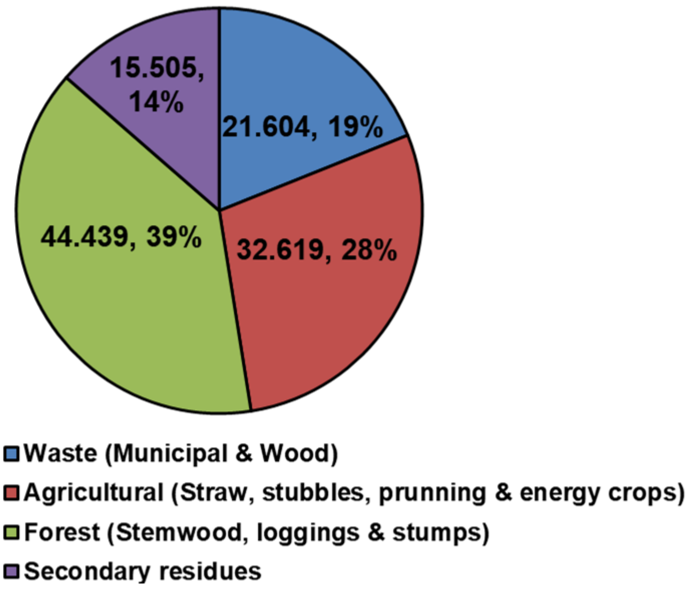
The main disadvantage of olive cake as regards its availability is that it is a seasonal residue [19]. This means that it is not easy to supply olive cake to an energy production company for its co-firing with lignite for the whole year, which reinforces the case for co-combustion in small-scale units.

4 Biomass availability per country (NUTS2 level analysis)

In the following sections, the biomass potential is presented per NUTS2 statistic regions for **i. Germany, ii. Poland, iii. Greece, iv. Czech. Republic, v. Hungary, vi. Romania, vii. Bulgaria, viii. Finland and ix. Sweden**.

4.1 Germany

Germany is one of the European countries with the highest biomass potential, from the forest, agricultural and waste sector. In 2020, the total sustainable biomass potential in Germany, including primary and secondary residues from the abovementioned sectors, is estimated equal to 113 Mton dm, Table 21 (Appendix). This potential is expected to rise slightly in 2030 (115 Mton dm). As can be seen from Graph 16 the highest share is from forest biomass, equal to 39 % -corresponding to ~44.44 Mton, whilst the agro-biomass share -including straw, stubbles, prunning and energy crops- is equal to 28 % -corresponding to ~32.62 Mton. The rest of the biomass sources, i.e. waste and secondary residues, have a lower share - 19 % and 14%, respectively. However, these sectors, regardless their relatively low share, they present a high potential of equal to 21.6 and 15.5 Mton, respectively. ***Therefore all these sectors are analyzed in the present section on a NUTS2 statistical level.***

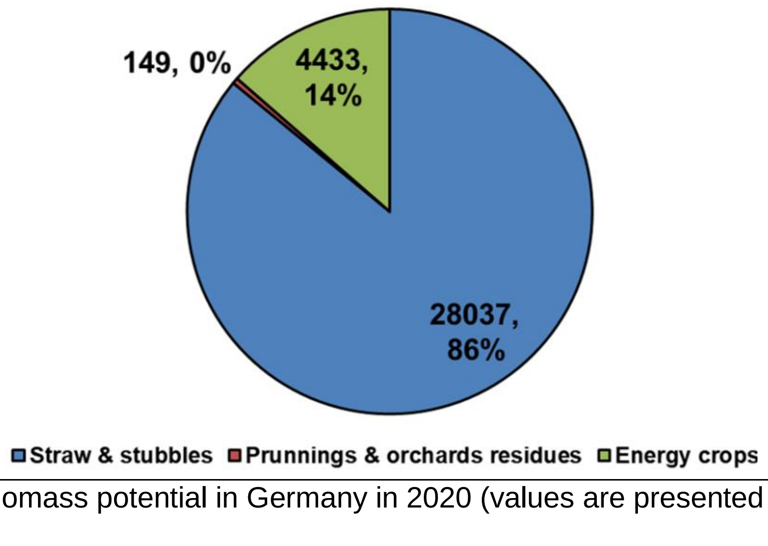


Graph 16. Biomass potential in Germany in 2020 (values are presented in Mton dm).

4.1.1 Agricultural sector

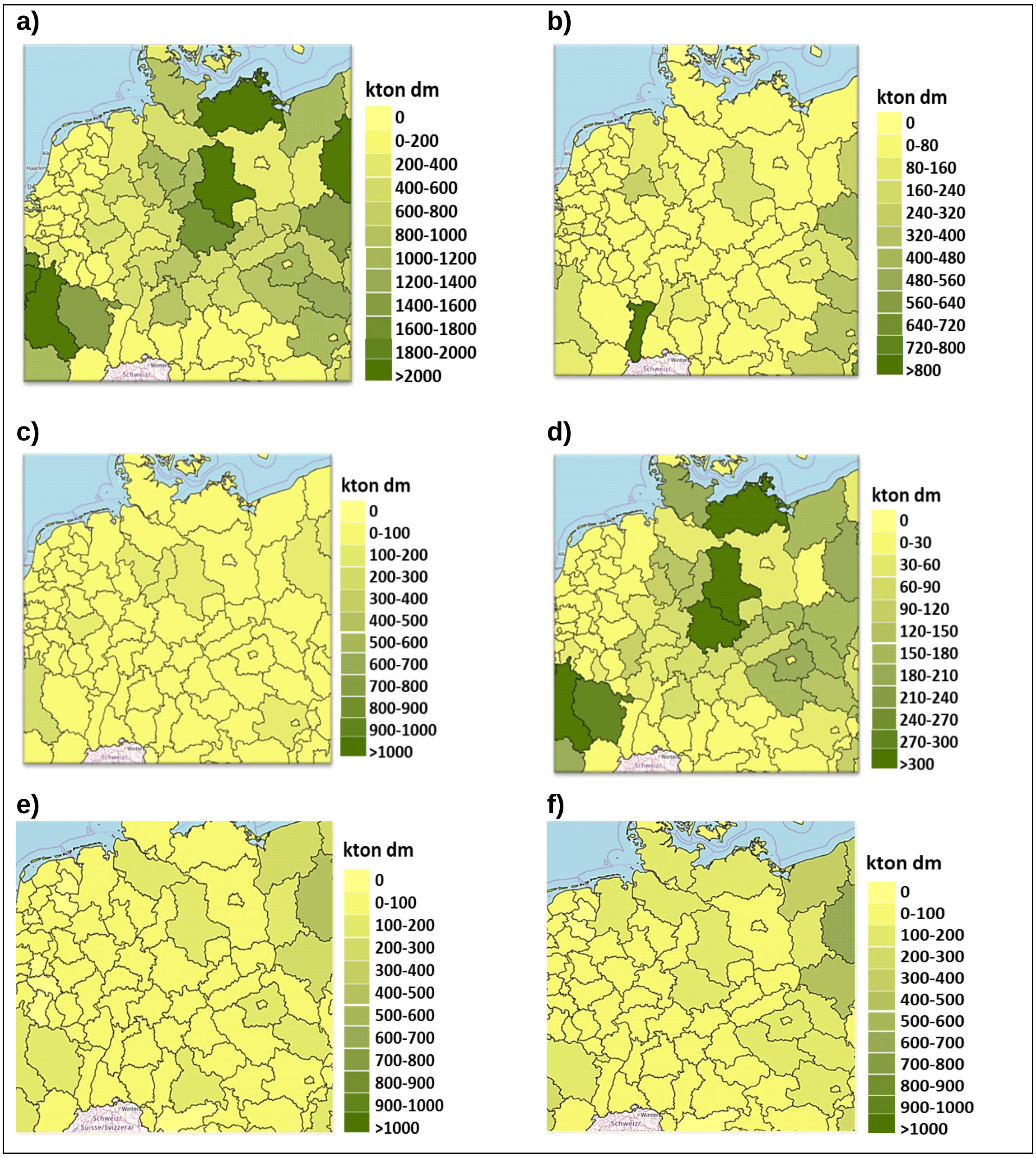
In Germany 16.8 million hectares are agricultural land and nearly 71% of it is used as arable land [30]. Overall, in 2020, the agro-biomass in Germany will be based in straw and stubbles (share equal to 86%) and energy crops (share 14 %). This corresponds to 28.04 Mton and 4.43 Mton, respectively, Table 21 (Appendix). Biomass originating from prunnings and orchards residues will not be available in high quantities in Germany the upcoming years (only 0.15 Mton). Therefore, the most important agricultural crops/residues in Germany are cereal straw, maize stover, oil seed rape straw, miscanthus and switchgrass.

Amongst them, cereal straw with a sustainable potential over 20 Mton for 2020 and 2030 can potentially play an important role in the future energy mix for Germany. **Up until now, even though this crop presented a high availability** -in 2010, cereal reported the highest share amongst agricultural crops, as they covered 6.6 million hectares of agricultural land, a value corresponding to 39.5 % of the German UAA- it remained mostly unexploited as a waste material [31].



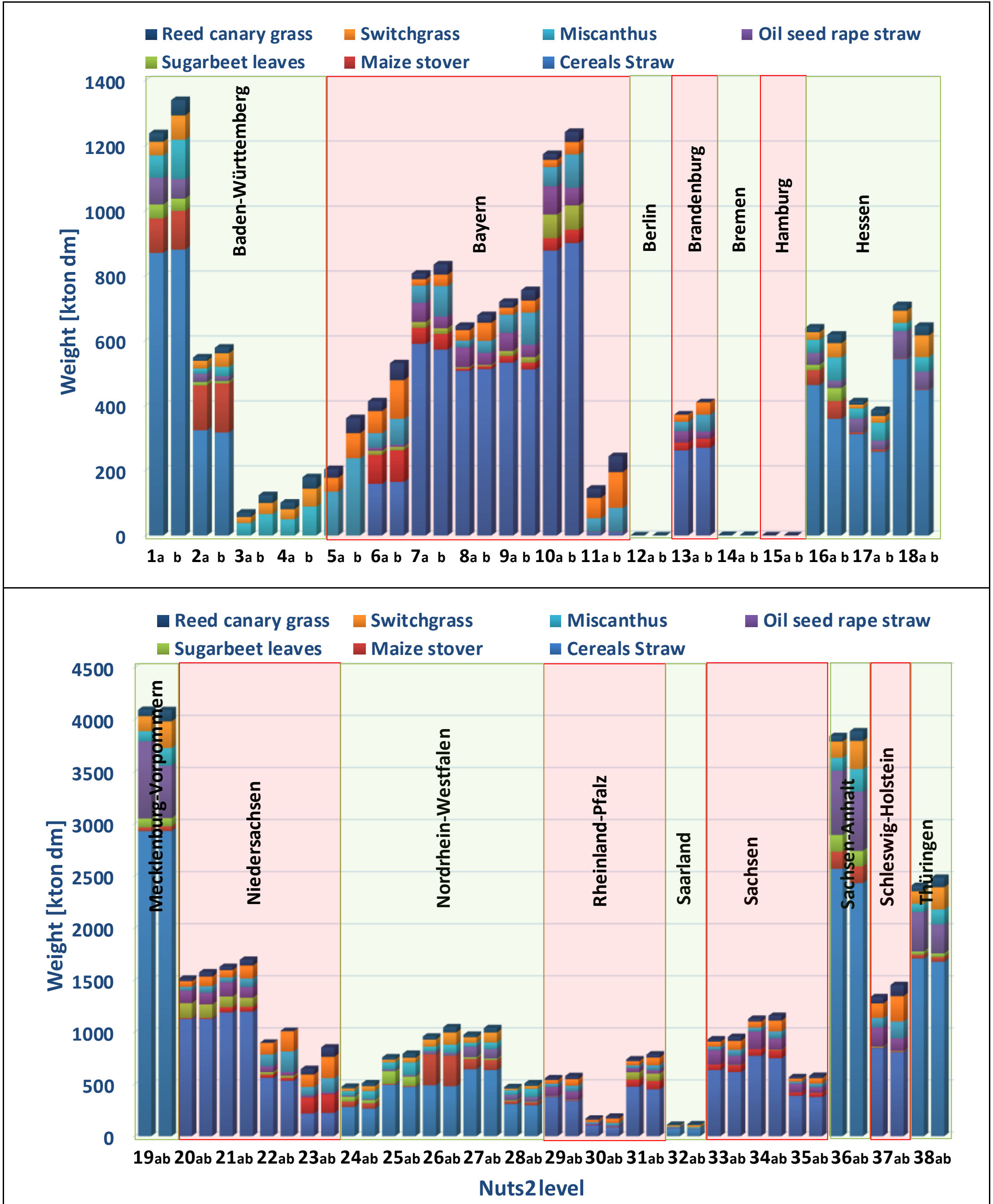
Graph 17. Agro-biomass potential in Germany in 2020 (values are presented in Mton dm).

At NUTS2 statistical level, it can be inferred from Map 7 that the cereal straw sustainable potential varies significantly across Germany. The highest sustainable potential of cereal straw is located in Mecklenburg-Vorpommern with over 2.9 Mt/year and Sachsen-Anhalt with almost 2.5 Mt/year; the latter area is near the central German and Helmstedt lignite mining areas. This implies that cereal straw can be easily utilized for co-combustion with lignite, in power plants manufactured near this area. Apart from this a potential of approximately 1.1 Mt dm in 2020 and 2030 will be theoretically available for energy purposes in nearby areas, such as Braunschweich and Hannover, and a 1.7 Mt dm in Thüringen.



Map 7. Agro-biomass potential in Germany on absolute level for a) cereal straw, b) maize stover, c) sugarbeet leaves, d) oil seed rape straw, e) miscanthus and f) switchgrass (year 2020).

In Sachsen-Anhalt there will be available, as well, in 2020 some amounts of maize stover (0.17 Mt dm), sugarbeet leaves (0.16 Mt dm), oil seed rape straw (0.6 Mt dm), miscanthus (0.12 Mt) and switchgrass (0.15 Mt dm), Graph 18.



1: Stuttgart	2: Karlsruhe	3: Freiburg	4: Tübingen	5: Oberbayern
6: Niederbayern	7: Oberpfalz	8: Oberfranken	9: Mittelfranken	10: Unterfranken
11: Schwaben	12: Berlin	13: Brandenburg	14: Bremen	15: Hamburg
16: Darmstadt	17: Gießen	18: Kassel	19: Mecklenburg-Vorpommern	20: Braunschweig
21: Hannover	22: Lüneburg	23: Weser-Ems	24: Düsseldorf	25: Köln
26: Münster	27: Detmold	28: Arnsberg	29: Koblenz	30: Trier
31: Rheinhessen-Pfalz	32: Saarland	33: Chemnitz	34: Dresden	35: Leipzig
36: Sachsen-Anhalt	37: Schleswig-Holstein	38: Thüringen		

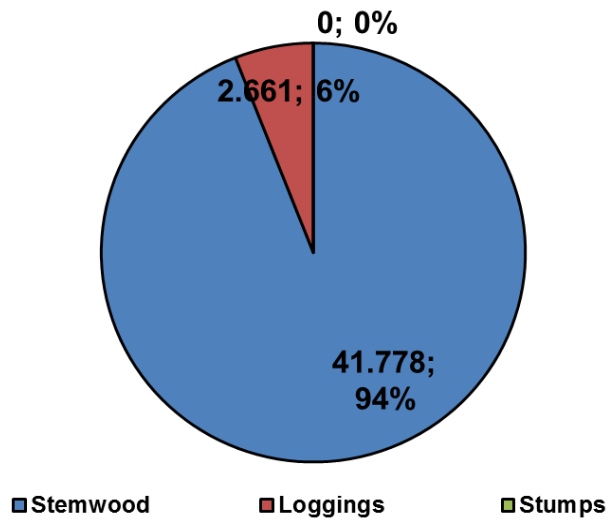
Graph 18. Agro-biomass potential in Germany at a regional level (year 2020/2030).

It should be noted that in the areas near Rhineland lignite mines, i.e. Koln, Trier, the sustainable cereal straw potential is rather moderate (equal to 0.3-0.4 Mt dm for 2020 and 2030). The rest of the agricultural crops in these areas will have a rather small availability, as well, Table 22.

4.1.2 Forest sector

Germany is one of the most densely wooded countries within Europe. One third of the total area land is covered with forests -approximately 11 million hectares. Currently, German forests consist of 60 % coniferous trees and around 40 % deciduous (non-conifer trees designated in the present deliverable) trees. Additional information obtained from the literature suggest that 73 % of the forests in the country consist of mixed stands. Spruce accounts for the largest share among the tree species (28 %), followed by pine (23 %), beech trees (15 %) and oak trees (10 %) At a regional level, the proportion of woodland cover varies widely, ranging from 10 % in Schleswig-Holstein to over 40 % in Rhineland-Palatinate and Hesse. During the last years, fuelwood has become more importance in Germany energy mix, owing to the increasing energy prices and restrictions posed by the EU that promote the use of renewable sources [32].

As concerns the sustainable potential, in 2020 the forest sector in Germany will be primarily based on stemwood from final fellings and thinnings from conifer and nonconifer trees (94 %) and on a smaller share on logging residues (6%), Graph 19. In Germany, there will not be available any stumps within the upcoming years. This situation is expected to remain steady within the period 2020-2030.



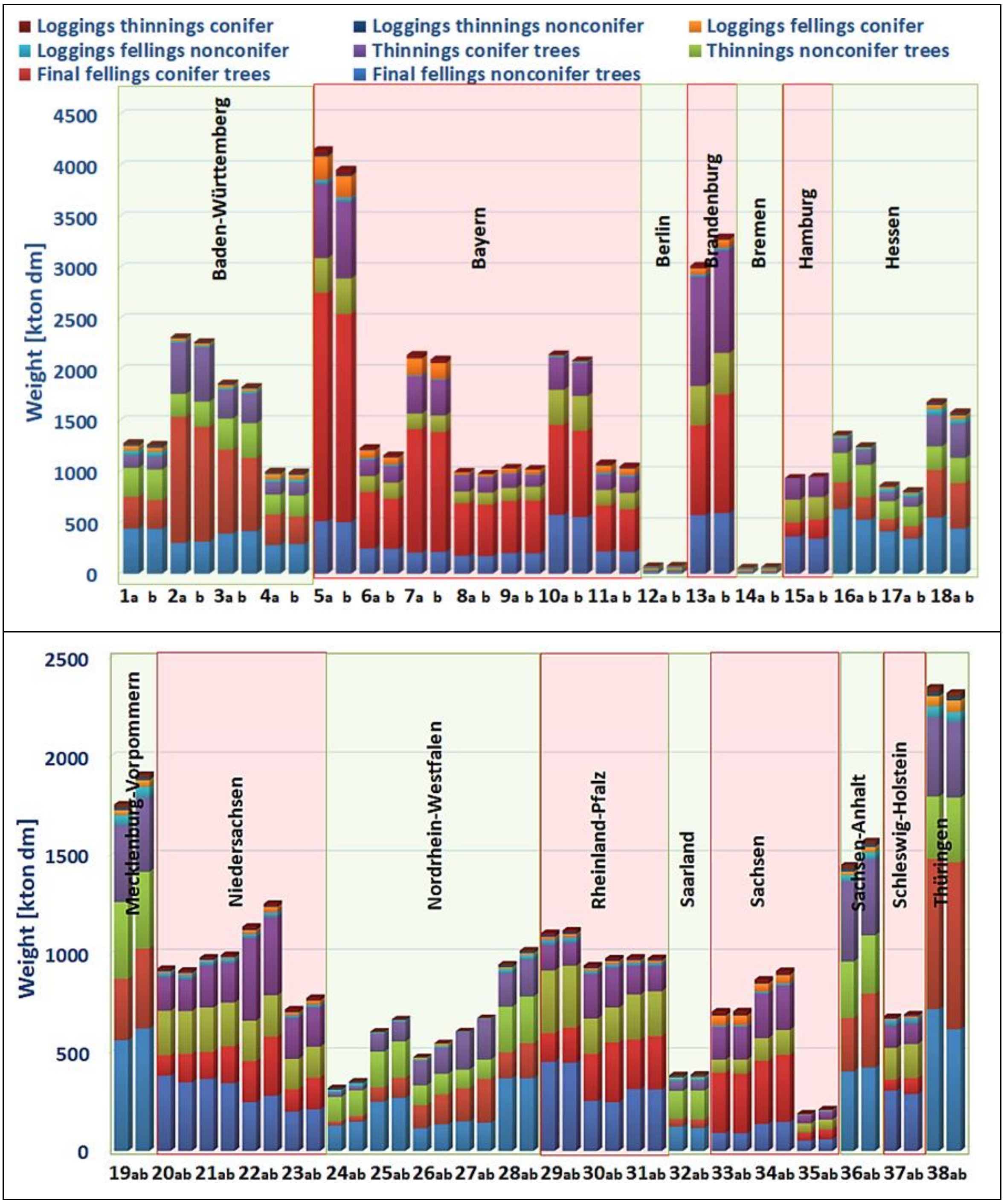
Graph 19. Forest biomass potential in Germany in 2020 (values are presented in Mton dm).

At a regional level, as can be seen from Graph 20 the highest forest biomass potential can be found in Brandenburg, Sachsen-Anhalt, Thüringen and Mecklenburg-Vorpommen, Table 23, Table 24 (Appendix). More, specifically:

- **In Brandenburg** (northeastern Germany), the forest residues –stemwood and logging residues- mostly originate from final fellings and thinnings from conifer trees. The total sustainable potential, including coniferous and non-coniferous trees is almost equal to 3 Mton in 2020 and 3.3 Mton in 2030; this corresponds to an increase of almost 9%. In this area, stemwood from conifer trees plays the primary role, with an availability theoretically calculated to 1.9 Mton in 2020.

- **In Sachsen-Anhalt** (region close to Berlin and Brandenburg) the total sustainable biomass potential, originating from forestry is estimated equal to 1.37 Mton in 2020 and 1.48 Mton in 2030; this corresponds to a substantial increase of around 8%.

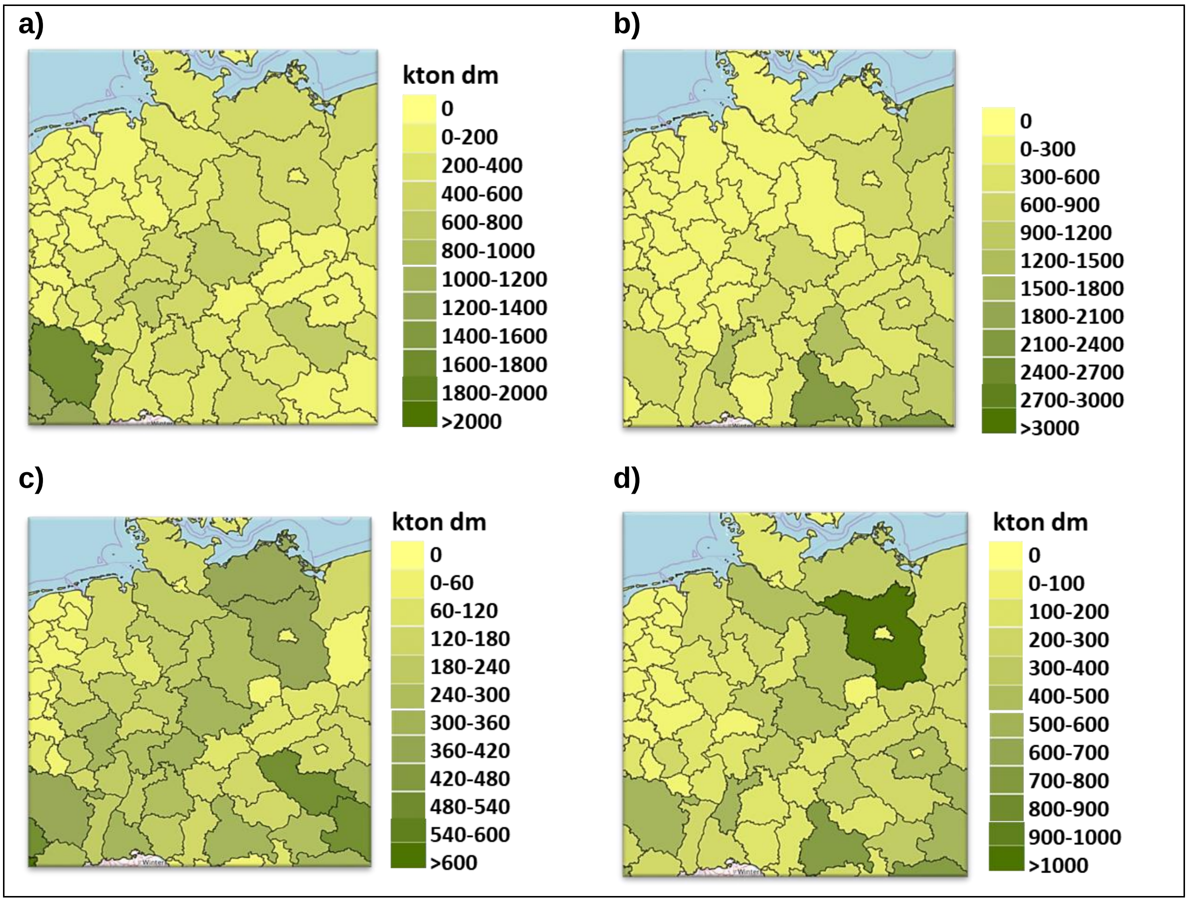
- **In Thüringen** (central Germany) the total sustainable forest biomass potential is estimated equal to 2.3 Mton for both reference years 2020 and 2030. This is the area with the highest forest sustainable potential.



Graph 20. Forest biomass potential in Germany at a regional level (year 2020/2030).

- **In Mecklenburg-Vorpommen** (northeastern Germany), the total sustainable potential from forestry is equal to almost 1.76 Mton in 2020 and 1.91 Mton in 2030.

- **In Koln** (area near Rhineland lignite mines) there will be a rather moderate availability in 2020 (~0.59 Mton), which is estimated to increase slightly (~0.66 Mton) in 2030.

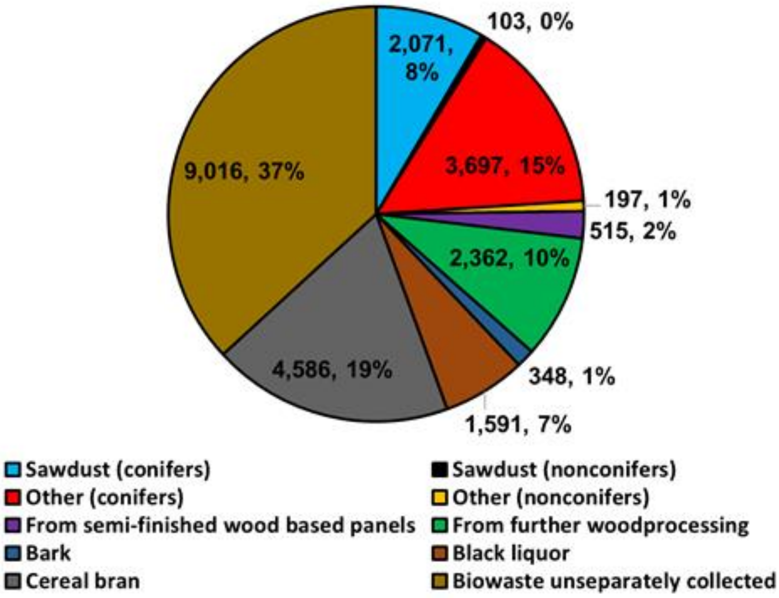


Map 8. Forest biomass –primary production- potential in Germany on absolute level from a) final fellings (non-conifer trees), b) final fellings (conifer trees), c) thinnings (non-conifer trees), d) thinnings (conifer trees) (year 2020).

4.1.3 Secondary residues/Municipal waste

In this subsection some additional data, beyond the scope of Deliverable 1.1 are provided as regards i. secondary residues, originating from pulp/ paper industry and industry utilizing agricultural crops and ii. municipal waste unseparately collected in Germany.

Generally, the biomass potential in Germany, originating from secondary residues and municipal waste, is high (~24.5 Mton), as can be observed from Graph 21 and Table 21 (Appendix). A high share from this amount almost 36.8 % (corresponding to ~9 Mton) comes from biowaste unseparately collected and is followed by cereal bran (19 %) and saw mill residues-excluding sawdust from conifer trees (15 %). Bark and black liquor have rather small shares of equal to 1% and 7 %, respectively.

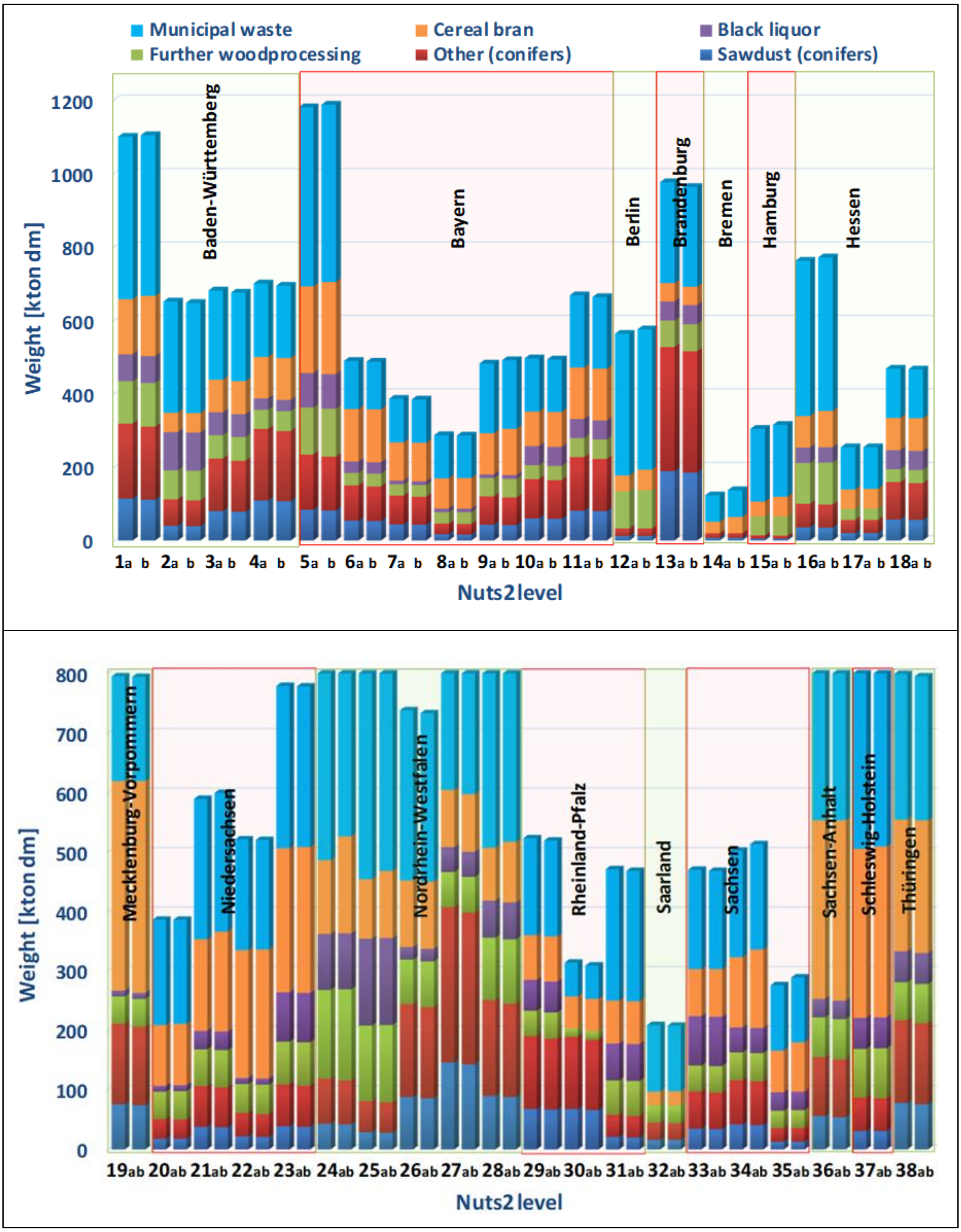


Graph 21. Biomass potential from secondary residues in Germany in 2020 (values are presented in Mton dm).

In general, Germany is characterized by a very mature waste management market with a very high average substitution rate. In Germany RDF is called EBS (Ersatzbrennstoff, alternative fuel) or SBS (Sekundärbrennstoff, secondary fuel). The status of co-combustion in German power plants is difficult to estimate since the knowledge has been scarse. Some plants, practicing co-combustion, gave up to avoid boiler corrosion. **Thus, RDF is a difficult fuel and investigation of its co-firing with lignite is recommended in the framework of Flex Flores Project.**

The areas with the highest sustainable municipal waste potential in Germany are **Stuttgart, Karlsruhe, Oberbayern, Berlin, Darmstad, Düsseldorf, Köln, Arnsberg and Schleswig-Holstein.**

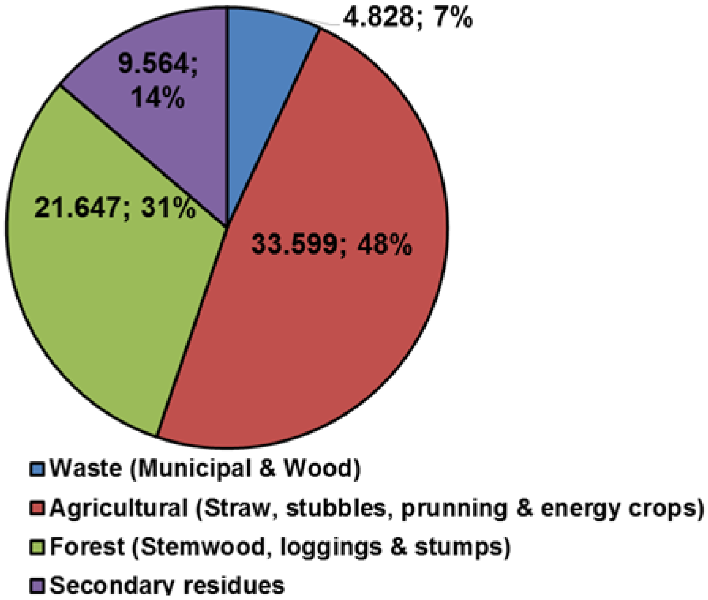
Especially in **Nordrhein-Westfalen**, where there are the areas of **Köln and Düsseldorf**, there is a total potential of almost 2 Mton for both reference years – in Köln and Düsseldorf the estimated potential is equal to ~0.48 and ~0.58 Mton, respectively.



Graph 22. Sustainable biomass potential from secondary residues in Germany at a regional level (year 2020/2030).

4.2 Poland

According to studies [33], Poland has considerable renewable energy resources -crops from 1.0 to 4.3 million ha can be used for energy production. It is estimated that the technical potential of renewables exceeds that of Denmark and Sweden that may be used to meet almost 50% of national energy demand.



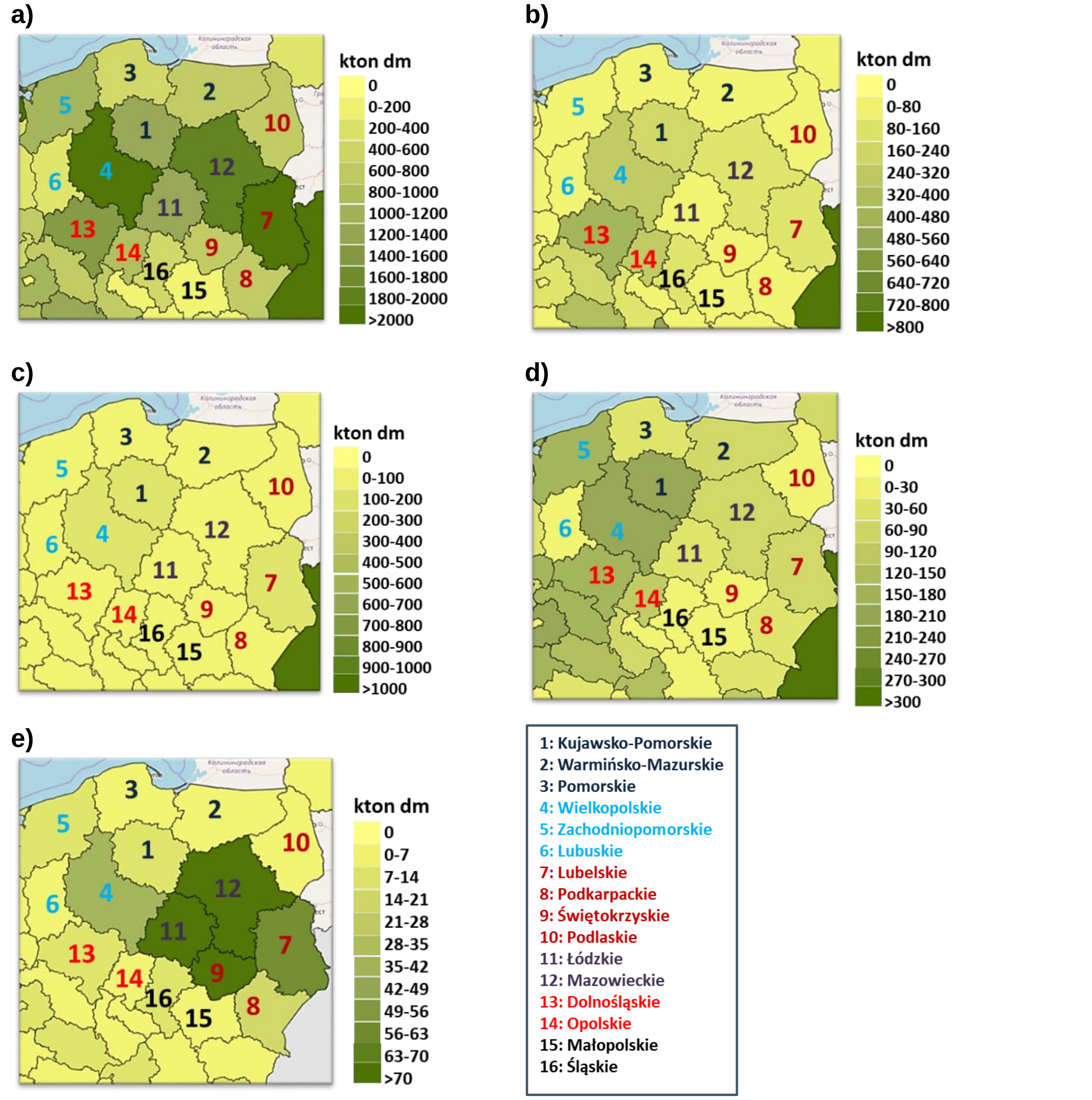
Graph 23. Biomass potential in Poland in 2020 (values are presented in Mton dm).

From Graph 23 it can be observed that the major contributor in the total sustainable biomass potential in 2020 will be the agricultural sector -with a rate equal to 48 %, which corresponds to ~33.6 Mton. In 2030, there will be a slight decrease in the agro biomass potential of almost 3%, Table 27. The forest sector will play an important role, as well, in the country's biomass sustainable potential. Its share will be approximately 31 % (this share corresponds to 21.65 Mton of forestry biomass). Finally, a rather moderate contribution will be from secondary residues (14 %) and municipal waste (7%). ***In this section, all sectors will be analyzed with a main emphasis on the agricultural and forest sectors, whilst some additional data will be delivered concerning selected secondary residues and biowaste unseparately collected.***

4.2.1 Agricultural sector

In 2015, the arable land as a share of Polish land area was 35.6 %. This share fell gradually from 50.4 % in 1966 to 35.6 % in 2015 [29]. As can be seen from Table 27 (Appendix) the largest amount of agricultural residues in Poland comes from cereal straw, maize stover and oil seed rape straw. Overall, straw production in Poland is estimated at 25 – 28 million ton annually, of which approximately 4.9 million ton of cereal and rape straw may be used for energy purposes. A moderate production is also from sugarbeet leaves and fruit tree plantations. The spatial distribution of these crops in the 12 Polish provinces for year 2020, are presented in Map 9.

More specifically, the areas with the highest cereal straw availability are Wielkopolskie (Western Poland), Lubelskie (North-East Poland) and Mazowieckie (Central Poland). Wielkopolskie along with Kujawsko-Pomorskie and the southwestern Poland are rich in maize stover and sugarbeet leaves. Fruit tree plantations are mostly available in the Northeast and central polish areas. All these data can be analytically found in Table 28 (Appendix).

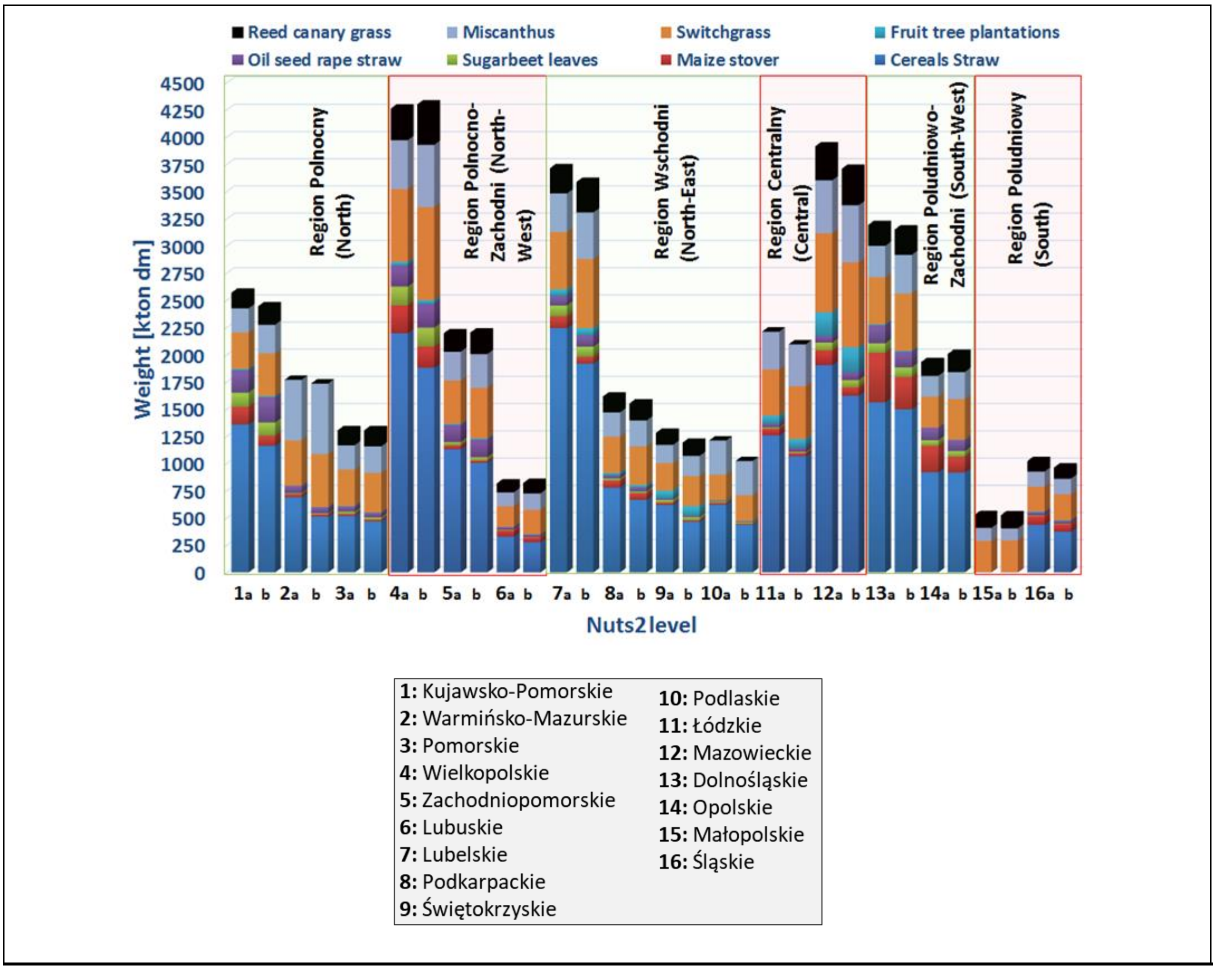


Map 9. Sustainable agro-biomass potential in individual provinces of Poland in absolute level for a) cereal straw, b) maize stover, c) sugarbeet leaves, d) oil seed rape straw and e) fruit tree plantations (year 2020).

Concerning lignocellulosic energy crops, the Polish areas with the highest sustainable potential (>1 Mton) are **Warmińsko-Mazurskie** (0.972 Mton in 2020 and 1.14 Mton in 2030), **Wielkopolskie Mazurskie** (1.4 Mton in 2020 and 1.8 Mton in 2030), **Lubelskie** (1.1 Mton in 2020 and 1.4 Mton in 2030) and **Mazowieckie** (1.52 Mton in 2020 and 1.64 Mton in 2030), Table 31. In general, the major amount of lignocellulosic energy crops in Poland comes from miscanthus, switchgrass and reed canary grass.

Another conclusion to be drawn, from Graph 24 is that, in general, the agro-biomass supply in most provinces in Poland is expected to reduce from 2020 to 2030, except for oil seed rape straw and fruit tree plantation crops, which will remain relatively stable and lignocellulosic energy crops that are expected to increase. More specifically, a substantial reduction of almost equal to 34 % is expected for maize stover and a moderate one, around 14 % for cereal straw. Finally, a small reduction of 4 % is foreseen for sugarbeet leaves. On the contrary, a notable increase, of almost 15 % is expected in all lignocellulosic energy crops, within the period 2020-2030.

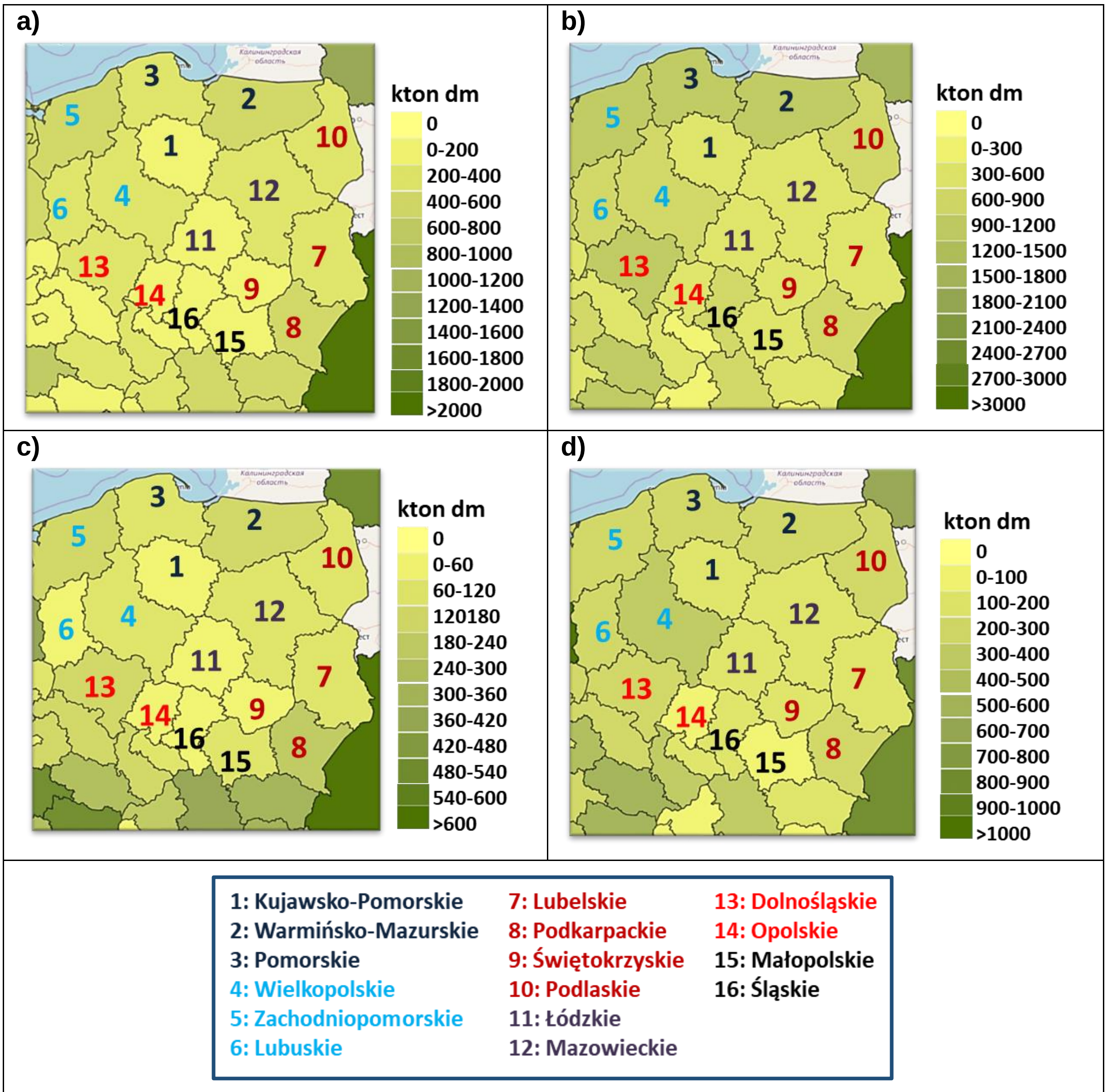
It should be noted that in ***__Lodzkie__***, ***__where there are the lignite mining areas of Bełchatów and Szczerców__***, the total agro-biomass potential is equal to 1.7 Mton and 1.9 Mton in 2020 and 2030, respectively.



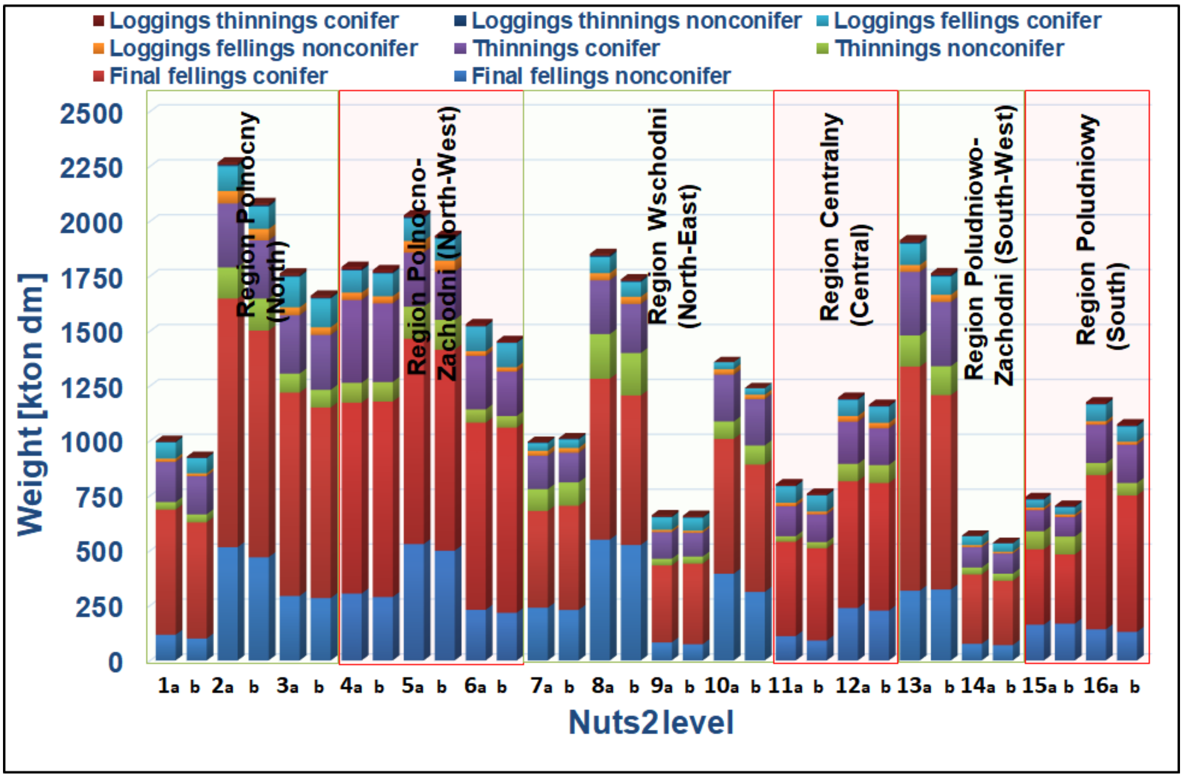
Graph 24. Sustainable agro-biomass potential in Poland at a regional level (years 2020, 2030).

4.2.2 Forest sector

Forests in Poland cover approximately 30% (corresponding to 9197.9 thousand hectares) of the total country land (reference year 2012). Coniferous forest habitats accounting for 51% of the total forest area, while broadleaved habitats account for 49%. The Lubuskie province has the highest level of forest cover (49.2%) and the Łódzkie province, where there are important lignite mining areas, has the lowest (21.3%) [34]. Based on S2biom platform, the estimated sustainable potential from forest is equal to 1.5 Mton/year and 0.8 Mton/year in these two provinces respectively, Map 10. Overall, the annual sustainable potential in the countrycan reach up to 27.6m dry ton (reference years 2020 and 2030).



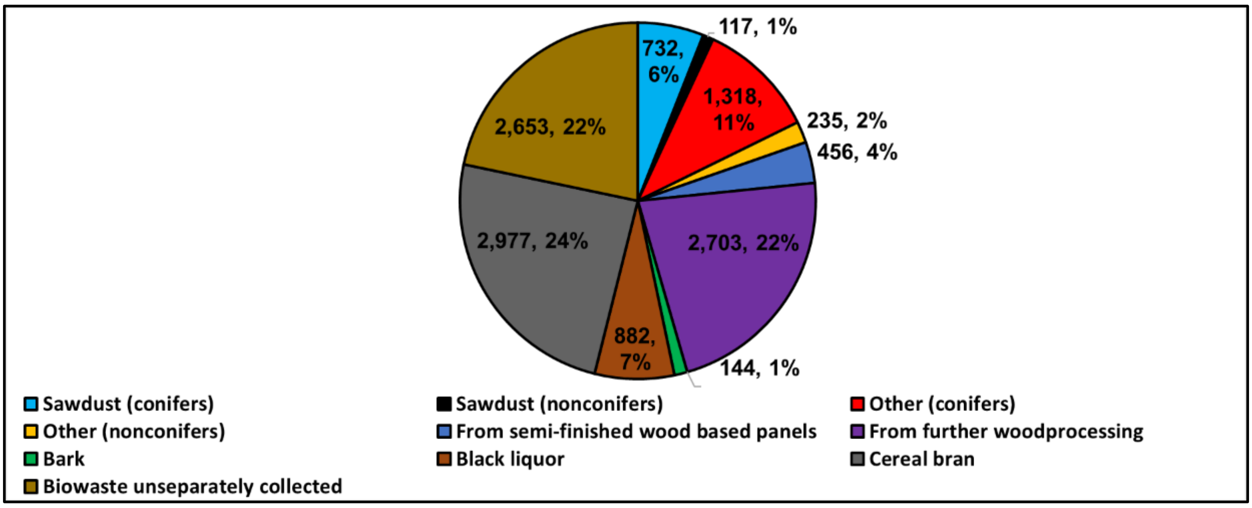
Map 10. Absolute sustainable forest biomass in Poland (year 2020): Stemwood from a) final fellings from non-conifer trees, b) final fellings conifer trees, c) thinnings non-conifer trees, and d) thinnings conifer trees.



Graph 25. Sustainable forest biomass share in Poland (a: year 2020, b: year: 2030).

4.2.3 Secondary residues/municipal waste

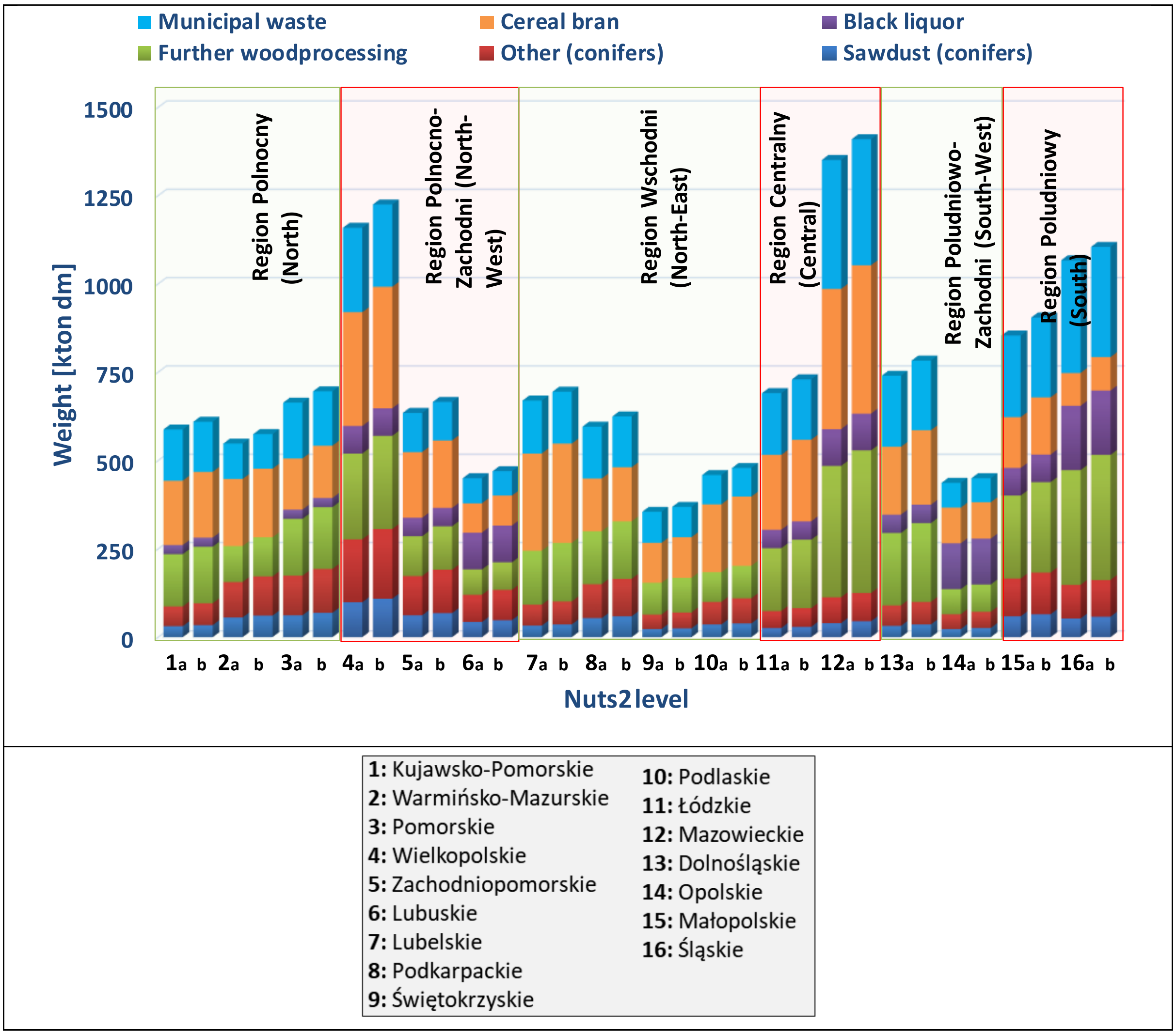
In this section, some additional data are presented as regards the regional distribution of selected secondary residues and biowaste unseparately collected in Poland. Overall, the biomass potential in Germany, originating from secondary residues and municipal waste, is high (~12 Mton/year), as can be noticed in Graph 26 and Table 27 (Appendix). A high share from this amount almost 24 % (corresponding to ~3 Mton) comes from cereal bran and is followed by biowaste unseparately collected (22 %, corresponding to almost 2.6 Mton) and residues from further wood processing (22 %), sawdust from conifer trees (6 %) and black liquor (7%).



Graph 26. Biomass potential from secondary residues in Poland in 2020 (values are presented in Mton dm).

At regional level, the areas with the highest sustainable municipal waste potential in Poland are **Wielkopolskie (~0.23-0.24 Mton/year), Łódzkie (~0.175 Mton/year), Mazowieckie (~0.36 Mton/year), Dolnośląskie (~0.2 Mton/year), Małopolskie (~0.23 Mton/year) and Śląskie (~0.32 Mton/year) for both 2020 and 2030.**

Sawmill residues from conifer trees (including sawdust) can be mostly found in Warmińsko-Mazurskie (~0.16-0.17 Mton/year), Pomorskie (~0.17-0.19 Mton/year), Wielkopolskie (~0.28-0.31 Mton/year), Zachodniopomorskie (~0.17-0.19 Mton/year), Podkarpackie (~0.15-0.17 Mton/year), Małopolskie (~0.17-0.18 Mton/year) and Śląskie (~0.15-0.16 Mton/year). In Łódzkie, there will be a rather limited availability of almost equal to 0.08 Mton/year. More information can be found in Table 32 in the Appendix section.

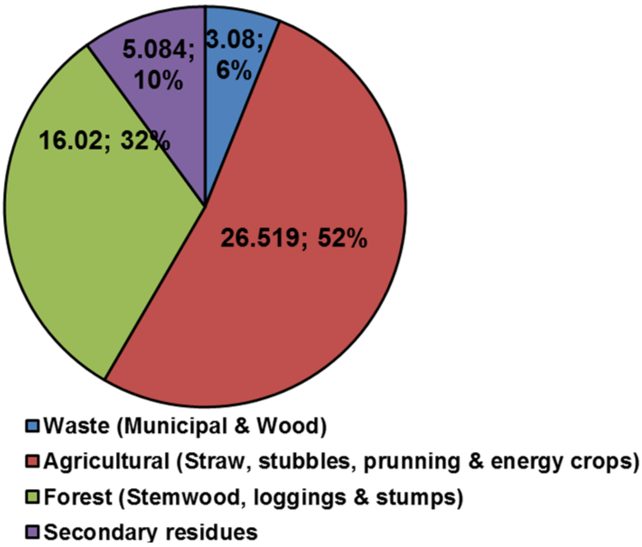


Graph 27. Sustainable biomass potential from secondary residues in Poland (year 2020/2030).

4.3 Romania

Romania is the fifth largest producer of lignite in the EU-28, following Bulgaria –total lignite mined equal to 23 Mt in 2016. Lignite resources are estimated at 9,920 Mt, while reserves are around 280 Mt, mostly located in the Oltenia basin, geographically located in Sud-Vest Oltenia [2].

The total area of Romania is approximately equal to 24 Mha. Some part of it is utilized as agricultural area (on average 10.3 Mha, 43.4% of the total area) out of which arable land is 6.6 Mha [35]. From the point of view of existing potential, biomass represents a promising renewable energy source for Romania. As regards, the sustainable potential of biomass in this country, there will be a high availability (over 40 Mton) within the period 2020-2030; this can be noticed from Graph 28 and Table 33 (in the Appendix section). More specifically, the major contributor of biomass in Romania, will be the agricultural sector -share of almost 52 % and total amount, approximately 26.52 Mton- followed by the forest sector –share 32 % and total amount ~16 Mton-, secondary residues (share 10 %, and total amount ~5 Mton- and waste –small share of 6 % and limited availability of ~3 Mton. ***In this section, all these sectors are analyzed at a NUTS2 statistical level, with main focus on agricultural and forest biomass.***



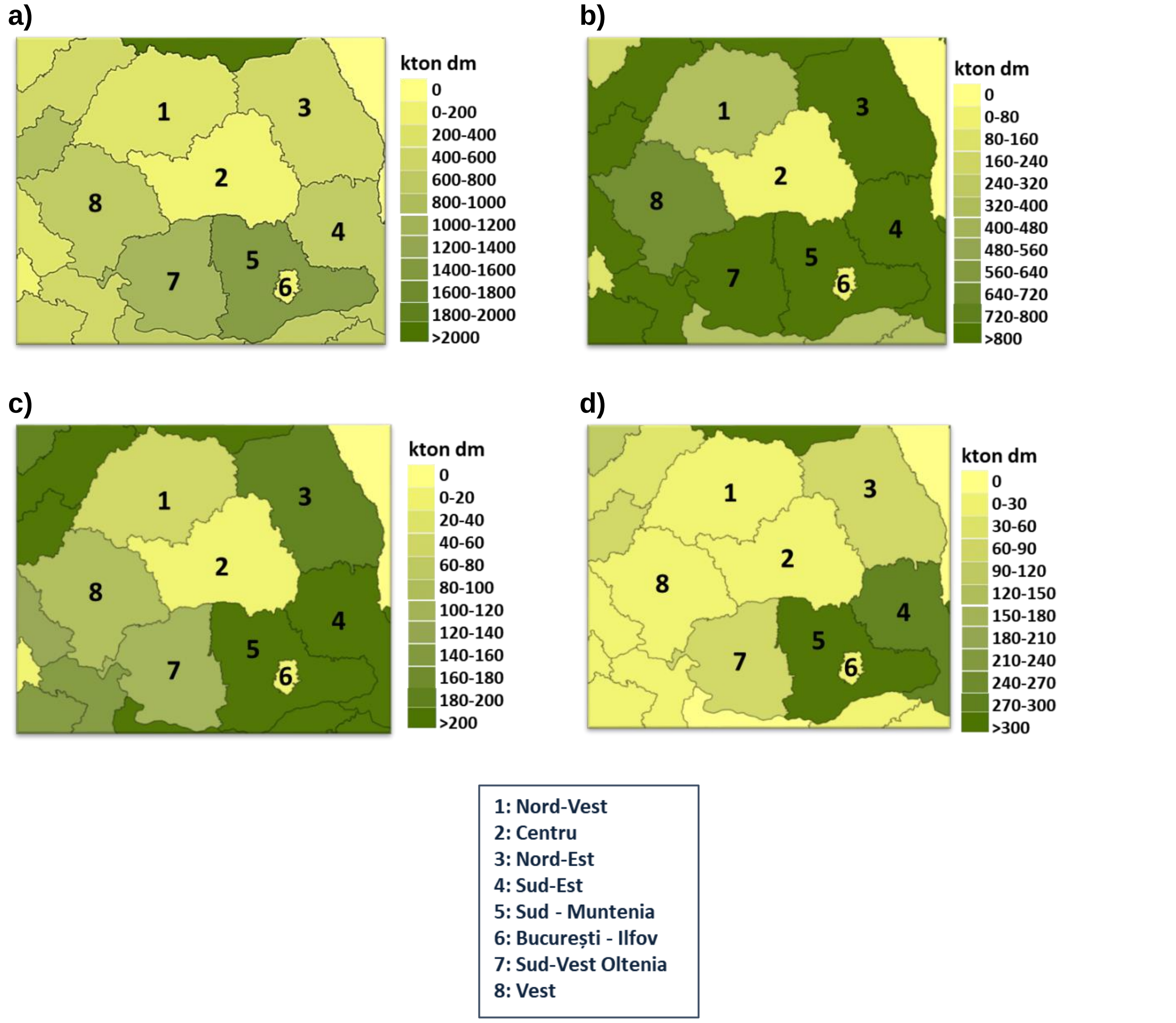
Graph 28. Biomass potential in Romania in 2020 (values are presented in Mton dm).

4.3.1 Agricultural sector

Overall, in 2020, the agro-biomass in Romania will be primarily based on energy crops (share ~55 %) and on straw and stubbles (share ~44%). This corresponds to 14.68 Mton and 11.7 Mton, respectively, Table 33 (Appendix). Biomass originating from prunnings and orchards residues will not be available in high quantities in Romania, within the next years (only 0.11 Mton). The most important agricultural crops/residues in Romania are cereal straw, maize stover, oil seed rape straw, sunflower straw, miscanthus and switchgrass.

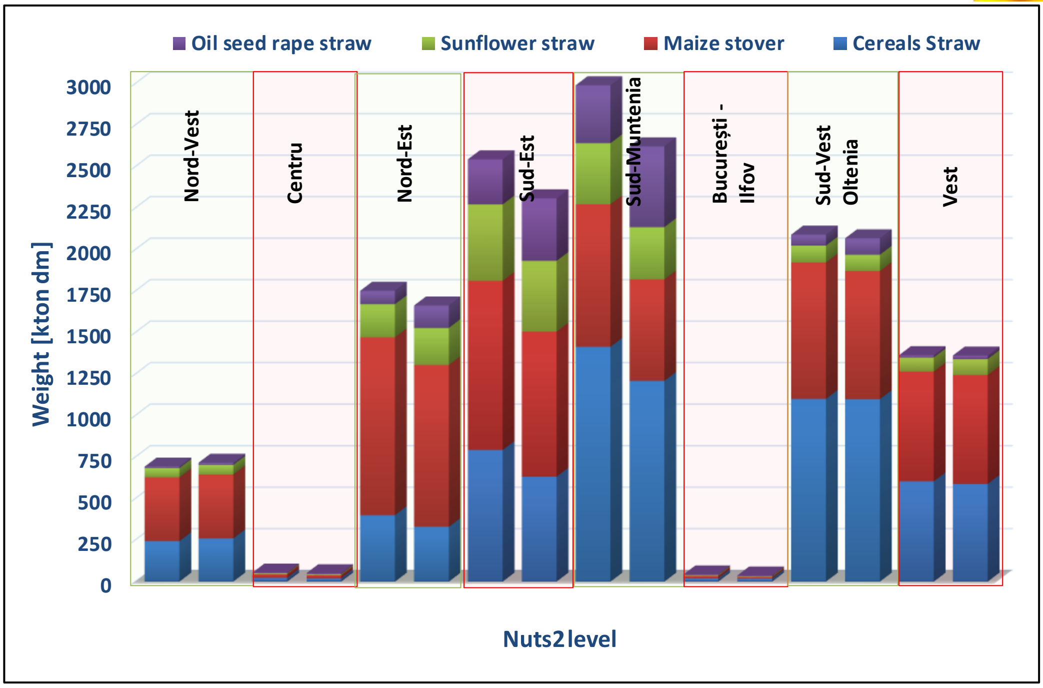
During the last years cereal used to have the highest share of agricultural production, with a production of around 7.7 Mt in 2012 (technical potential). In years 2020 and 2030 the expected sustainable cereal potential will be equal to almost 4.6 and 4.1, respectively. This is a little bit lower than the expected potential for maize stover (4.5 Mton and 4.3 Mton for 2020 and 2030, respectively). Romania is also an important producer of sunflower, with an expected production ranging from 1.3 Mt in 2020 to 1.2 Mt in 2030. Finally, oil seed rape straw will reach almost 0.8 to 1.1 Mt, between 2020 and 2030. As regards, energy grasses and perennial & annual crops, there will be a high availability in miscanthus (~6.7 Mton/year), switchgrass (~6.6 Mton/year) and reed canary grass (~0.7 Mton/year). The rest of the crops are expected to have a limited availability and, thus, are excluded from this section.

Map 11 presents the sustainable agro-biomass potential in individual provinces of Romania in absolute levels (kton dm) for cereal straw, maize stover, sunflower straw, and oil seed rape straw (year 2020). Generally, as can be seen biomass potential is regionally distributed over Romania. In the south and southeastern Romania areas, there is the highest availability all crops presented. In southwestern and western areas, only cereal straw and maize stover can be found.



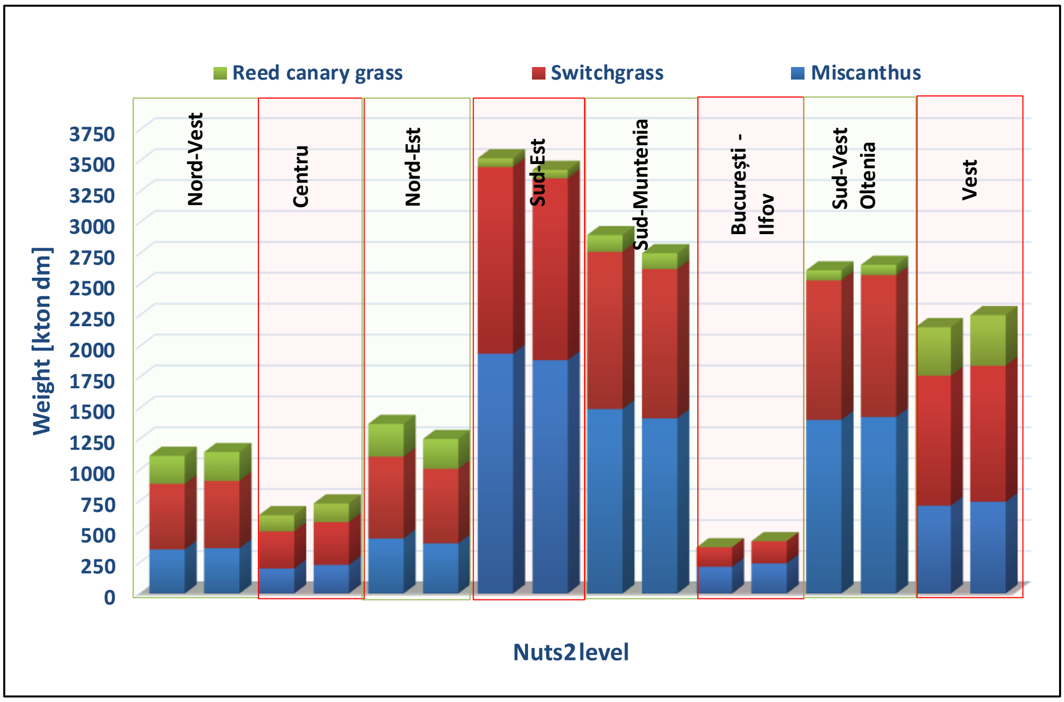
Map 11. Sustainable agro-biomass potential in individual provinces of Romania in absolute level for a) cereal straw, b) maize stover, c) sunflower straw, and d) oil seed rape straw (year 2020).

Finally, from Graph 29 it is deduced that, in general, the agro-biomass supply in most provinces in Romania is expected to reduce from 2020 to 2030, except for oil seed rape straw and sunflower rape straw; the first one, is expected to increase over 30 %, whilst the second one will remain relatively stable. On the contrary, a rather moderate reduction of almost equal to 10 % is expected for cereal straw and maize stover.



Graph 29. Agro-biomass potential –from agricultural residues- in Romania at a regional level (years 2020: first column and 2030: second column).

From Graph 30 it can be inferred that the energy crops potential will increase slightly in most Romanian provinces and reduce considerably in Nord-Est (around 9 %), Sud-Est (~2-3 %) and Sub-Muntenia (~5 %) areas.



Graph 30. Agro-biomass potential –from energy grasses and annual and perennial crops- in Romania at a regional level (years 2020: first column and 2030: second column).

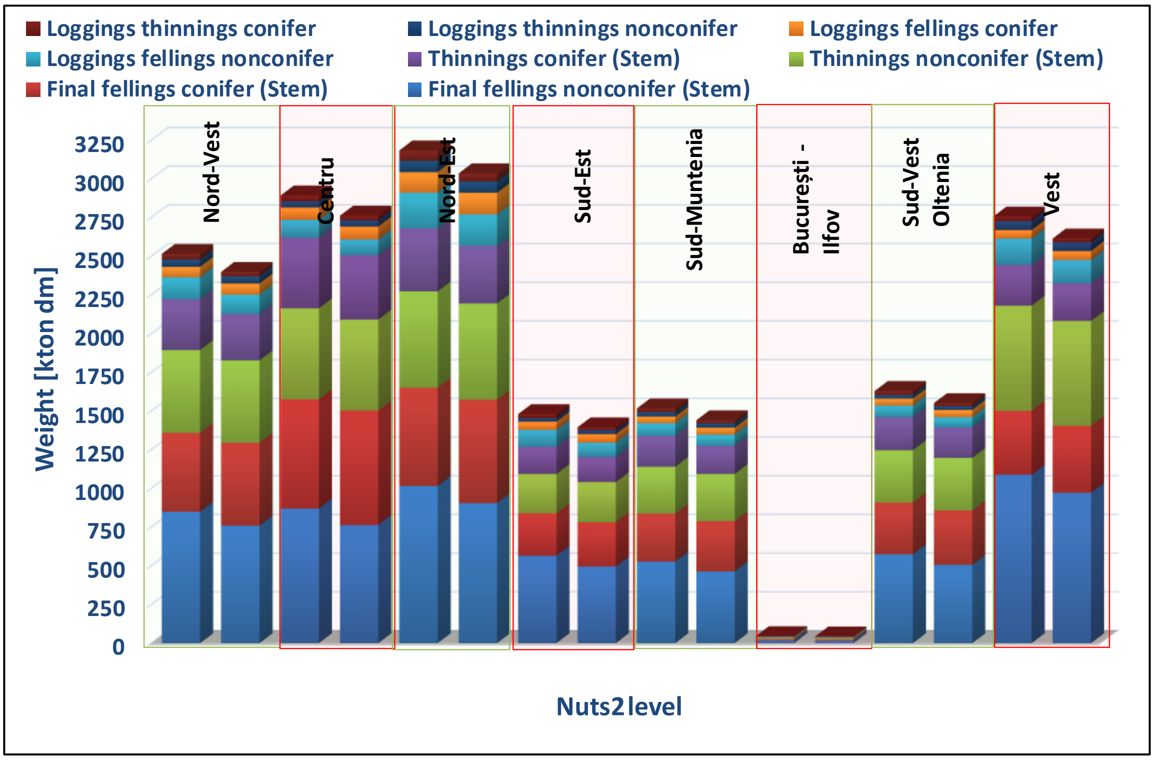
As regards, **Sud-Vest Oltenia**, where the lignite basin is located, there is a high sustainable potential for the next years originating from cereal straw (~1.1 Mton/year), maize stover (~0.77-0.82 Mton/year) and a limited one from sunflower straw (~0.1 Mton/year) and oil seed rape straw (~0.07-0.1 Mton/year).

4.3.2 Forest sector

The total forestry area in Romania covers 6.55 million hectares (HA) (according to 2015 data). This corresponds to approximately 27.5 % of the country's total area land. This rate is lower than the European average of 32 percent. In terms of species, out of this total area, coniferous trees (spruce, fir, pine) represent about 26 %, beech trees about 31 percent, oak about 16 %, other hardwoods 20 %, and other softwoods 7 % [36].

As can be noticed, in Graph 31 and Map 12, there is a high sustainable potential for woody biomass in Romania. More specifically, the total forest biomass potential in Romania is estimated equal to 16 Mton and 15 Mton in reference years 2020 and 2030, respectively. From this high amount the highest share, of almost 88 %, comes from stemwood –primary forest production- which corresponds to 14 Mton and a small share from logging residues –around 2 Mton (according to 2020 data projections).

At regional level, the highest forest availability is located in Northern, Central and Western parts of Romania, with the highest being in the Northwestern area.

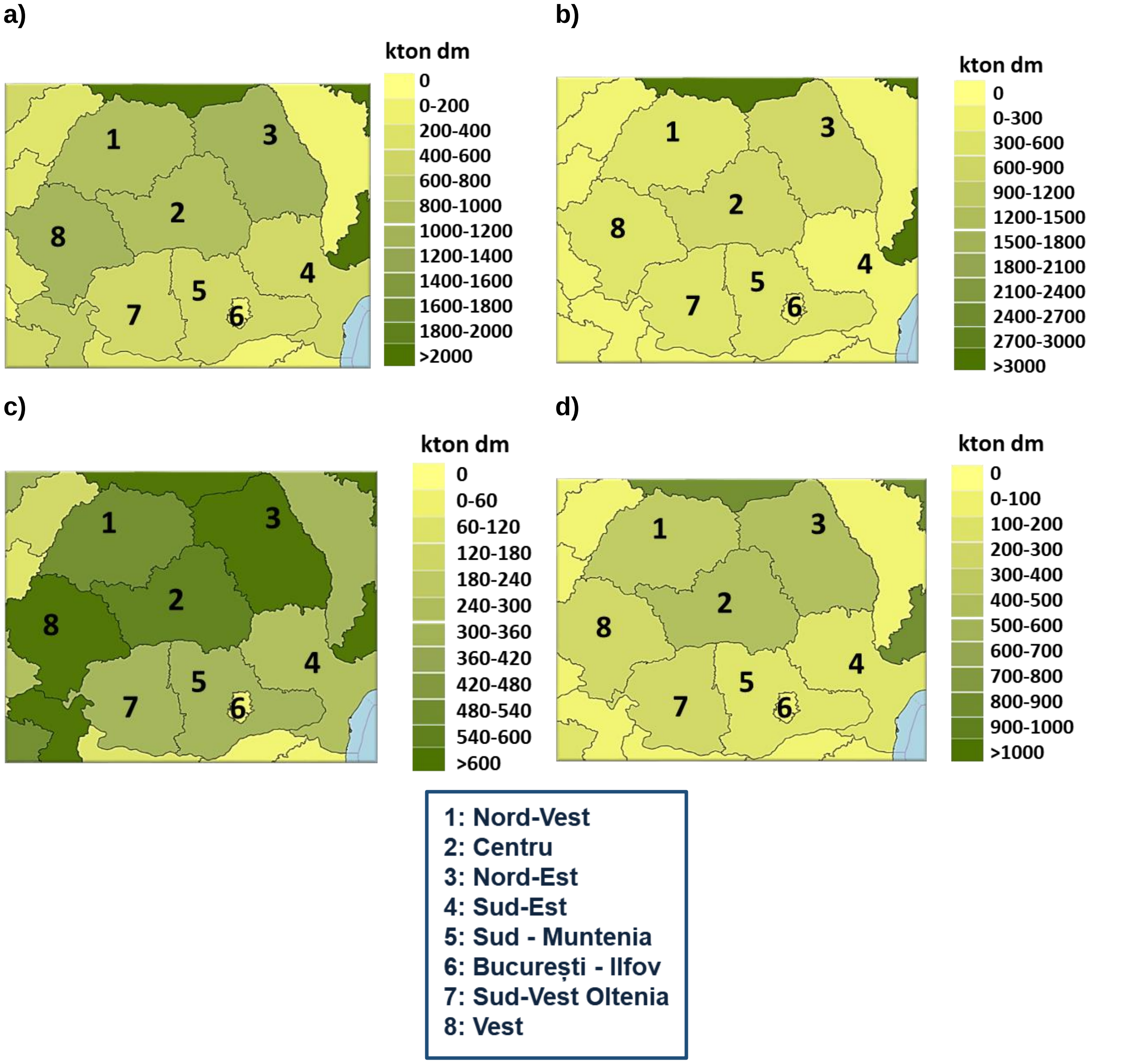


Graph 31. Sustainable forest biomass potential in Romania (year 2020/2030).

More specifically:

- **In Nord-Est**, there is a total forest potential of equal to 3.18 Mton in 2020 that will decrease slightly in 2030 –almost 4.6 %. In this area, the biomass type with the highest potential is stemwood originating from final fellings and thinning from non-conifer trees (total amount equal to 1.6 Mton is 2020.

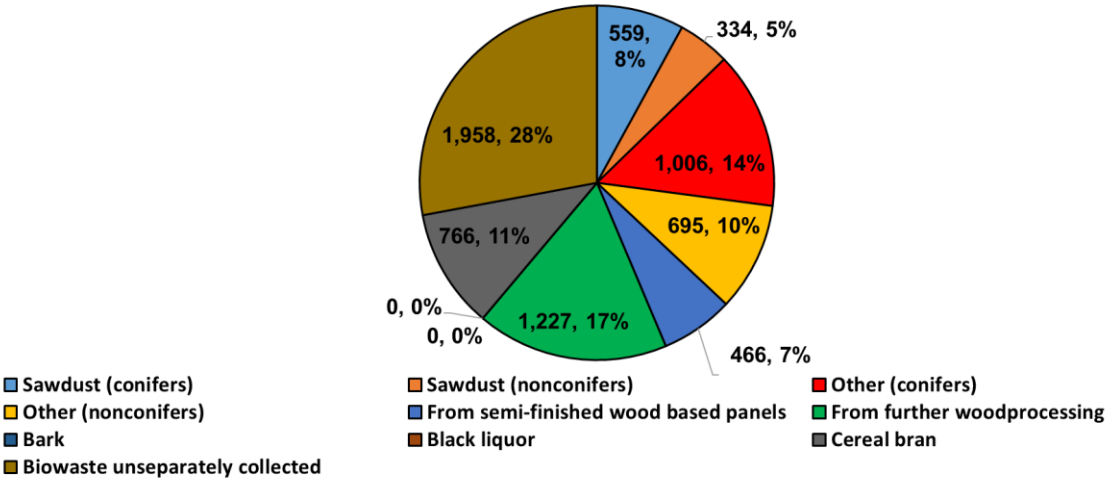
-In Sud-Vest Oltenia, which is an area of high interest, since the lignite basin is located the, there is a high sustainable potential –however, almost half of the one available in Nord-Est- for the next years originating mostly from stemwood from non-conifer trees (~0.9 Mton/year) and stemwood from conifer trees (~0.55 Mton/year).



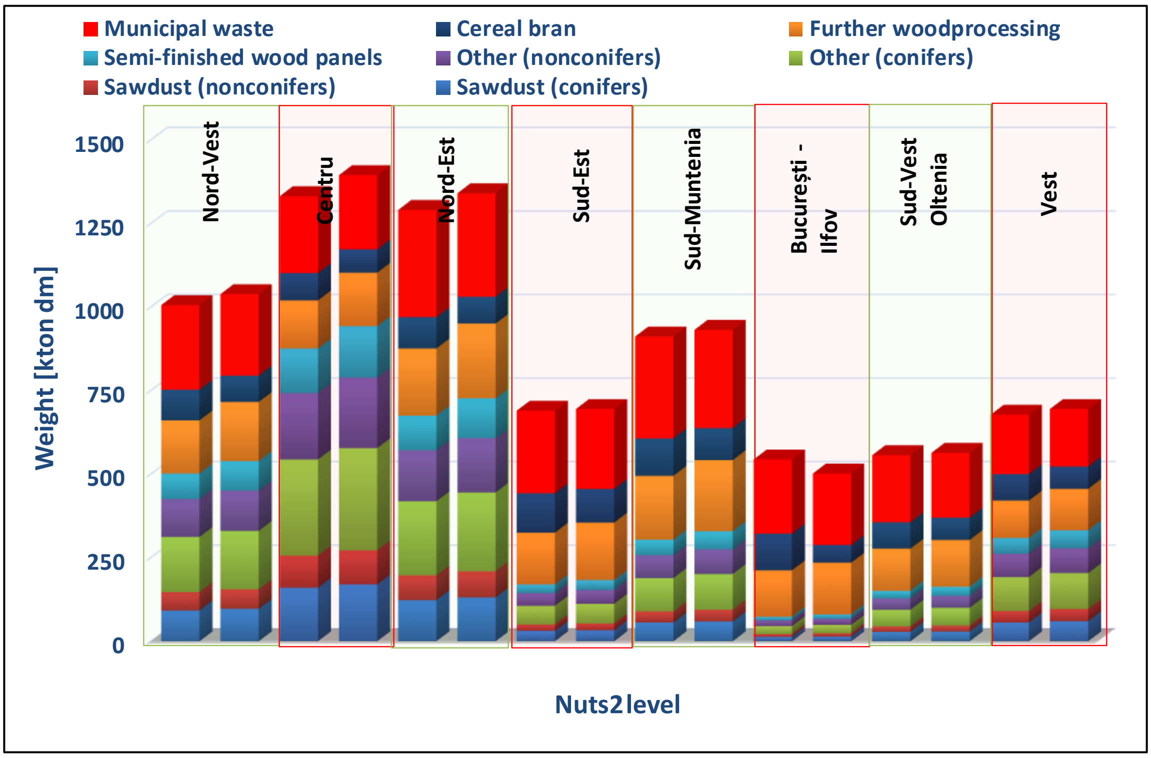
Map 12. Sustainable forest biomass potential in individual provinces of Romania in absolute level for stemwood from a) final fellings from non-conifer trees, b) final fellings conifer trees, c) thinnings non-conifer trees, and d) thinnings conifer trees (year 2020).

4.3.3 Secondary residues/municipal waste

In this section, some additional data are presented as regards the regional distribution of selected secondary residues and biowaste unseparately collected in Romania. Overall, the biomass potential in Germany, originating from secondary residues and municipal waste, is high (~12 Mton/year), as can be noticed in Graph 26 and Table 27 (Appendix). A high share from this amount almost 28 % (corresponding to ~2 Mton) comes from biowaste unseparately collected and is followed by residues from further wood-processing (share 17 %, corresponding to ~1.2 Mton), cereal bran (share 11 %, corresponding to 0.766 Mton) and sawmill residues, excluding sawdust, from conifer and non-conifer trees (total share 24 %, corresponding to ~1.7 Mton).



Graph 32. Biomass potential from secondary residues in Romania in 2020 (values are presented in Mton dm).



Graph 33. Sustainable biomass potential from secondary residues in Romania (year 2020/2030).

At regional level, Sud-Vest Oltenia has a total potential of almost 9.3 Mton (reference year 2020 that will increase up to 10.3 Mton in 2030. Biomass originating from biowaste is estimated equal to 0.2 Mton/year for this region. In Nord-Est area, the amount of biowaste calculated theoretically is equal to 0.32 Mton/year -37 % higher than the one calculated in Sud-Vest Oltenia.

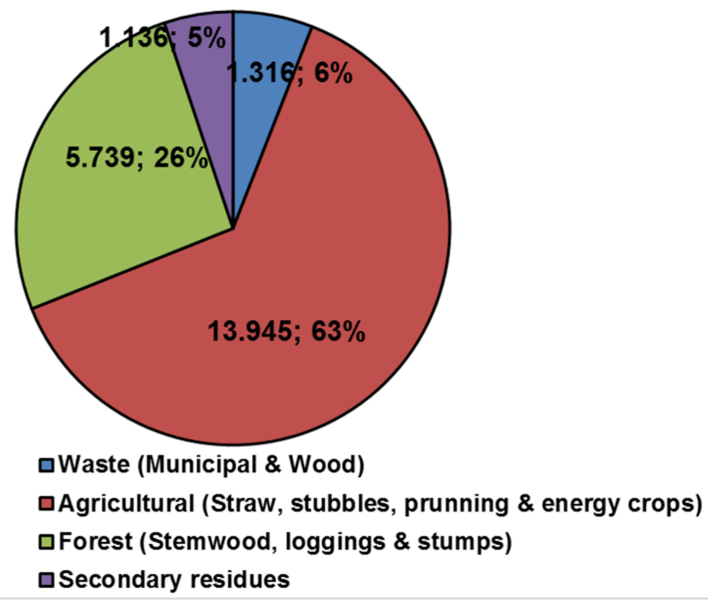
Additionally, the areas with the highest amounts of sawmill residues are located in the northern and central parts of Romania. More specifically, in **Centru** area there is the highest potential for sawmill residues – including sawdust- equal to ~0.7 Mton/year, followed by **Nord-Est** area with a potential equal to ~0.6 Mton/year.

It should be noticed, all the data presented above, concerning the sustainable biomass potential in Romania, can be found in Table 33, Table 34, Table 35, Table 36, Table 37 and Table 38 in the Appendix section.

4.4 Hungary

Biomass is considered as a promising renewable energy resource in Hungary, almost 90 % of the total renewable energy resources. More specifically, this country has a significant potential in the field of agricultural and forest waste and side-streams production. 1-1.2 million m^3 forest felling waste and 13.7-18.9 million ton of agricultural waste are produced annually [37]. Hungary is a rural country (66.3% of its area is rural). The Hungarian agricultural sector is not as typical is with an average EU country, with very high share of arable farming (81% of agricultural land) and low grassland (14.2%) [38].

The estimated sustainable agro-biomass potential in Hungary for 2020 is equal to approximately 14 Mton, Table 39. This corresponds to a 63 % share of the total biomass potential in the country. The second most important contributor with a share equal to 26 % is the forest sector. Finally, some small availability (a little bit higher than 2 Mton totally) is expected from secondary residues and waste, Graph 34.

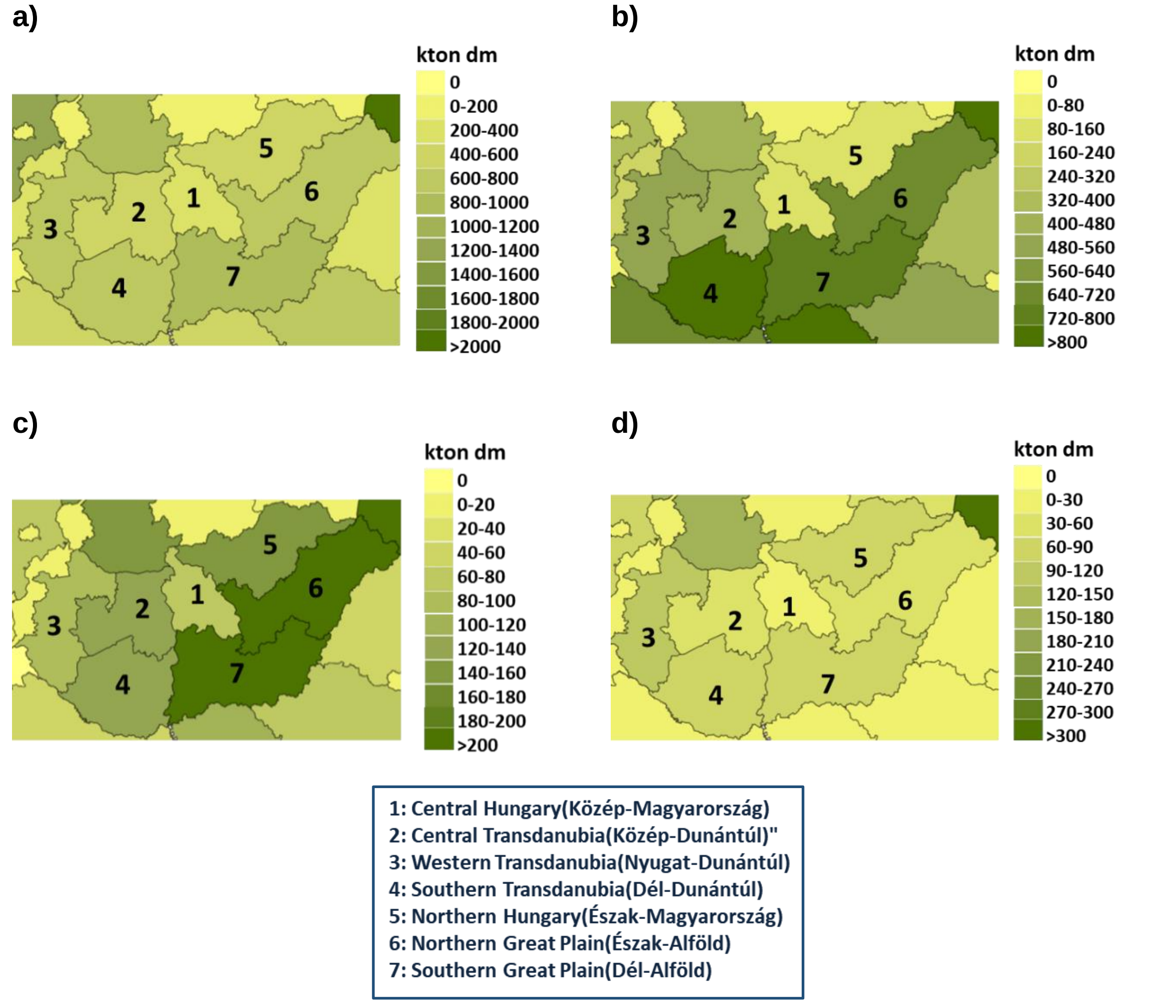


Graph 34. Biomass potential in Hungary in 2020 (values are presented in Mton dm).

4.4.1 *Agricultural sector*

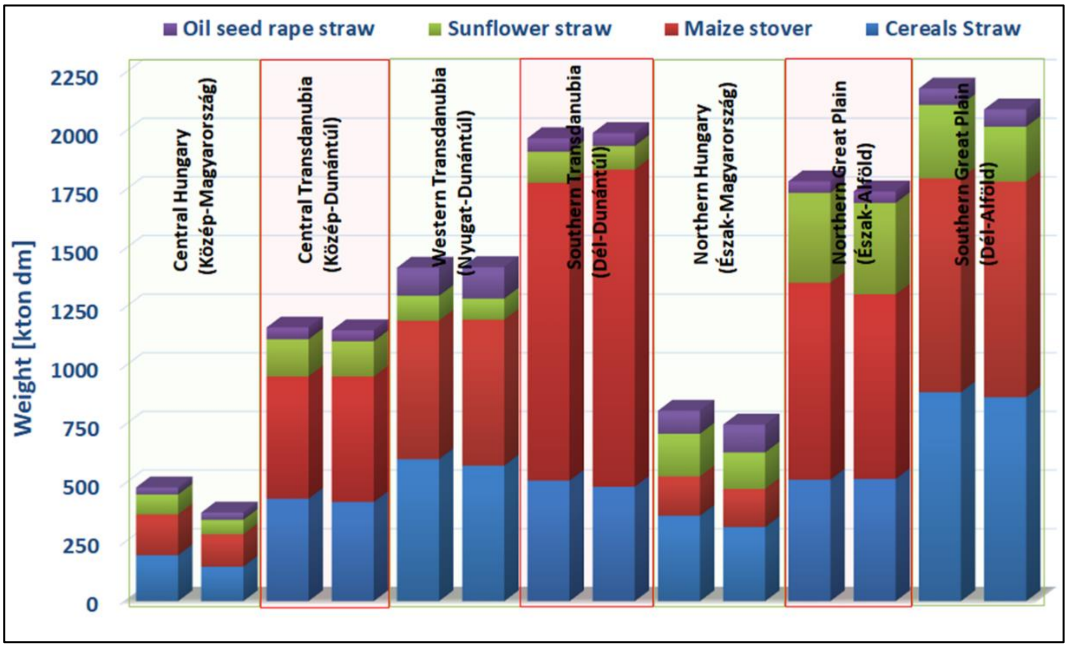
As concerns agricultural crops, 4.3 million ton of straw coming from grain cereal could be used for energy production in a sustainable way in 2020; this amount is expected to reduce almost 8 % to 4 Mton in 2030. In addition, about ~ 4.5 million ton of maize stover could be utilised as biomass for energy production (both reference years).

A significant amount of sunflower stems and oilseed rape straw can be produced annually; almost 1.36 Mton of stemwood in 2020 and ~0.5 Mton of oil seed rape straw. Finally, about 131 of fruit tree plantations are available and can be used for co-firing in small scale units.



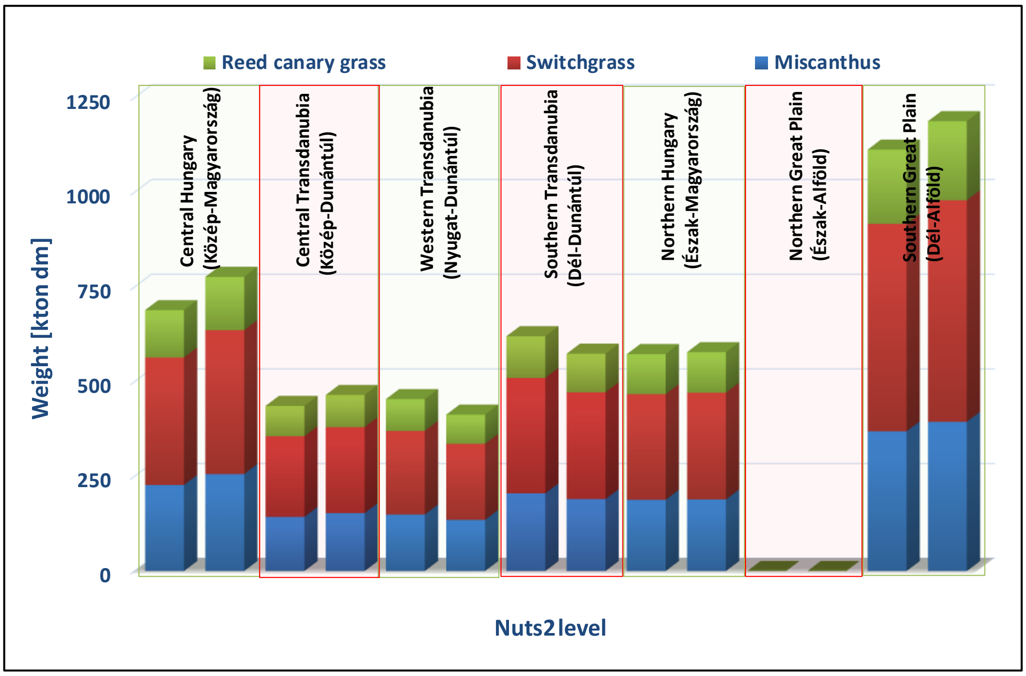
Map 13. Sustainable agro-biomass potential in individual provinces of Hungary in absolute level for a) cereal straw, b) maize stover, c) sunflower straw, and d) oil seed rape straw (year 2020).

As can be seen from Map 13, the area of **South Great plain** presents the highest potential for all agricultural crops tested –total sustainable potential almost equal to 2 ton. In this area, the grain production and the grazing management are typical. As concerns maize stover a high sustainable potential can be also traced in the area of Southern Transdanubia (of almost equal to 1.27 Mton for 2020), an area neighboring to South Great Plain.



Graph 35. Agro-biomass potential –from agricultural residues- in Hungary at a regional level year 2020).

According to projections for 2020 and 2030, Hungary presents a high sustainable potential for lignocellulosic energy crops. The total amount estimated is equal to ~3.89 Mton in 2020 and ~4 Mton in 2030. Similar to the agricultural residues, Southern Great Plain will have the highest availability in the forthcoming years, Graph 36. This corresponds to 13.2 Mton in 2020 and 14.2 Mton in 2030.

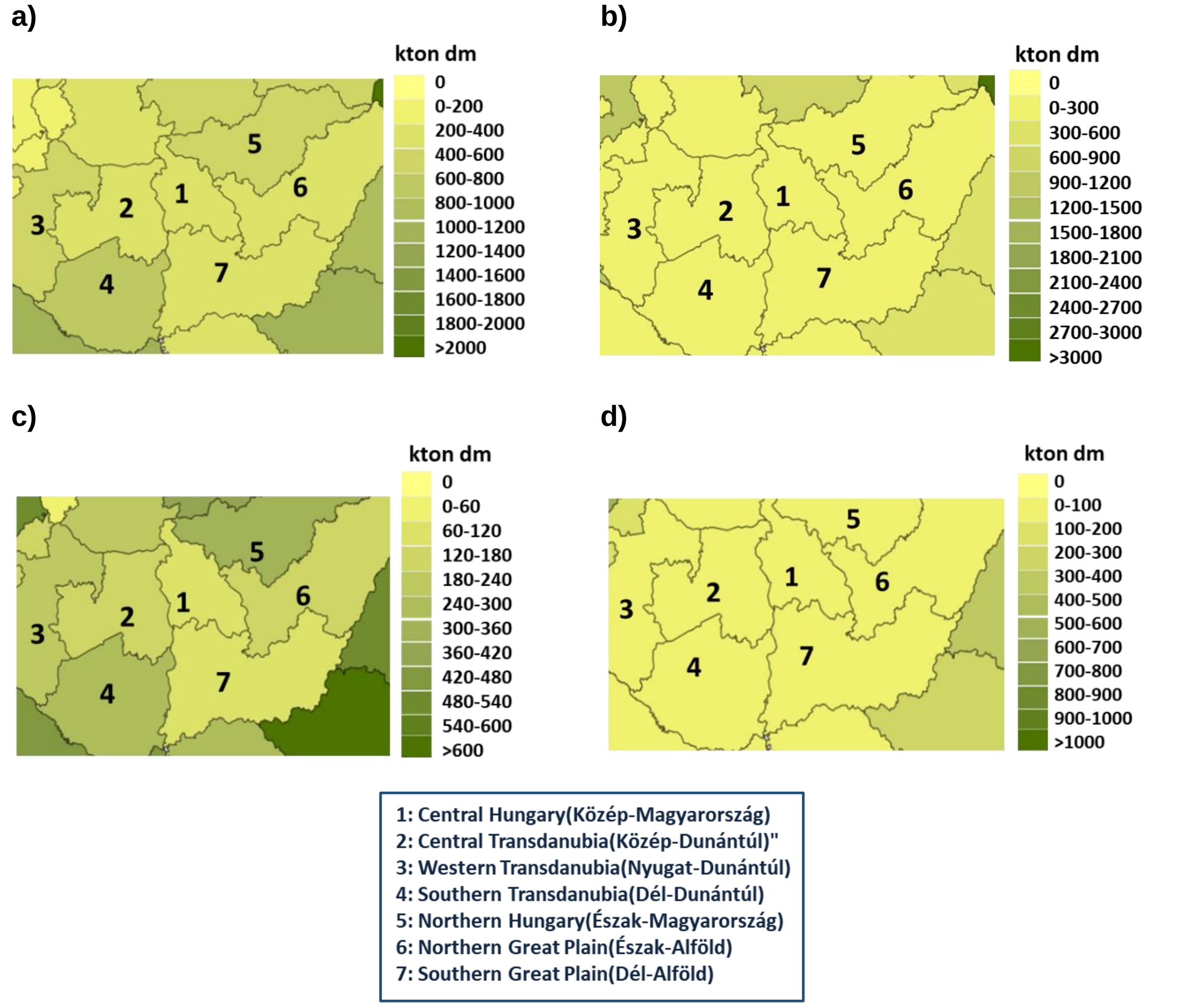


Graph 36. Agro-biomass potential –from lignocellulosic energy crops- in Hungary at a regional level year 2020).

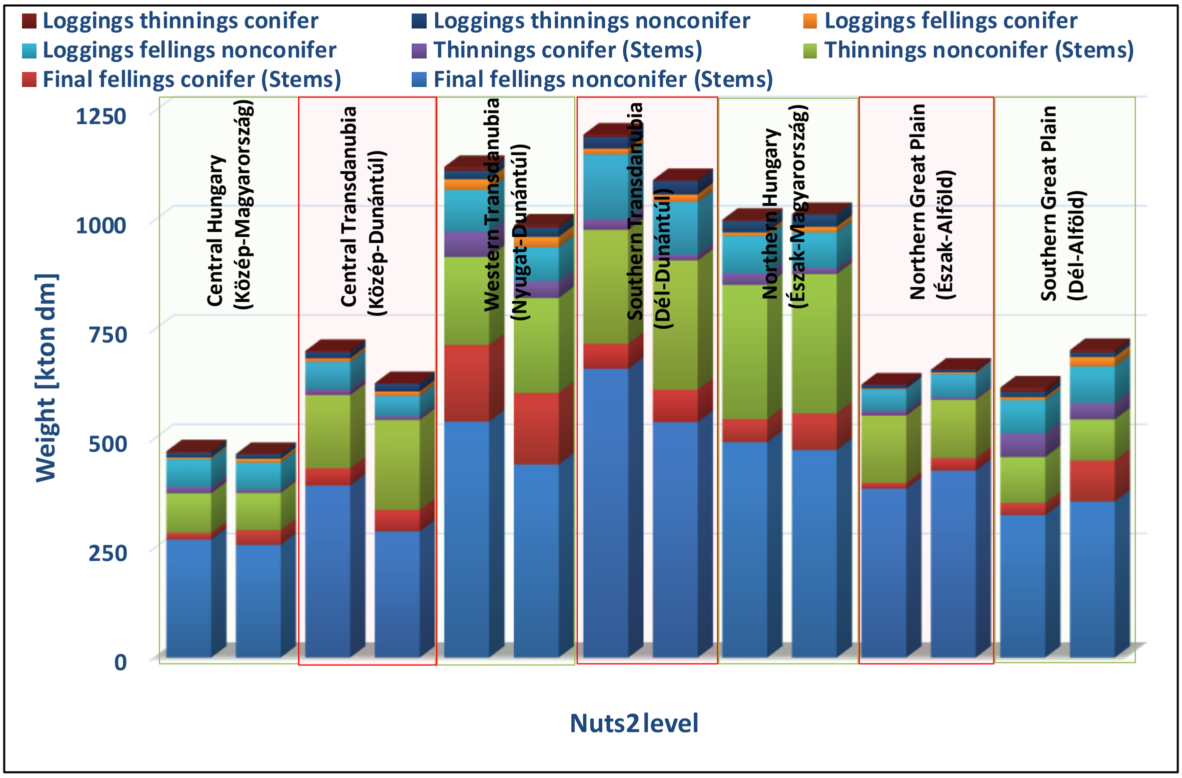
4.4.2 Forest sector

The total forest land in Hungary is approximately equal to 2 million hectares, which corresponds to a share of almost 22 % of the total area of the country. According to projections, the total sustainable forest biomass potential –originating from primary forest production and primary residues- is estimated equal to 5.56 Mton/year. From this amount the highest share comes from woody biomass from non-coniferous trees, Graph 37.

Map 14 presents the local distribution of forest biomass, originating from stemwood from final fellings and thinnings from coniferous and non-coniferous trees, at different areas of Hungary. As can be seen the highest potential is traced in Southern, Eastern and Northern Hungary.



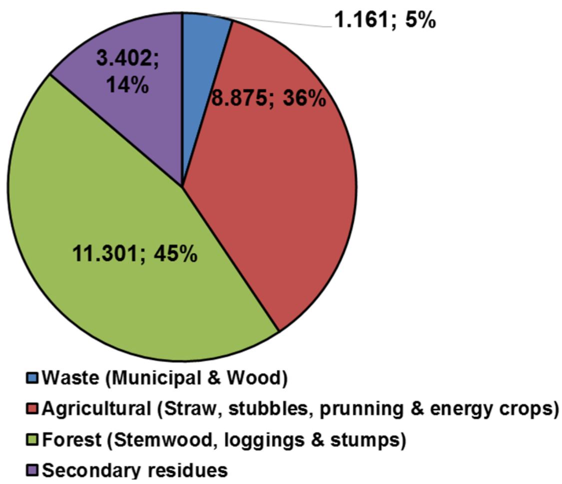
Map 14. Sustainable forest biomass potential in individual areas of Hungary in absolute level for stemwood from a) final fellings from non-conifer trees, b) final fellings conifer trees, c) thinnings non-conifer trees, and d) thinnings conifer trees (year 2020).



Graph 37. Forest biomass potential in Hungary at a regional level year (2020).

4.5 Czech. Rep.

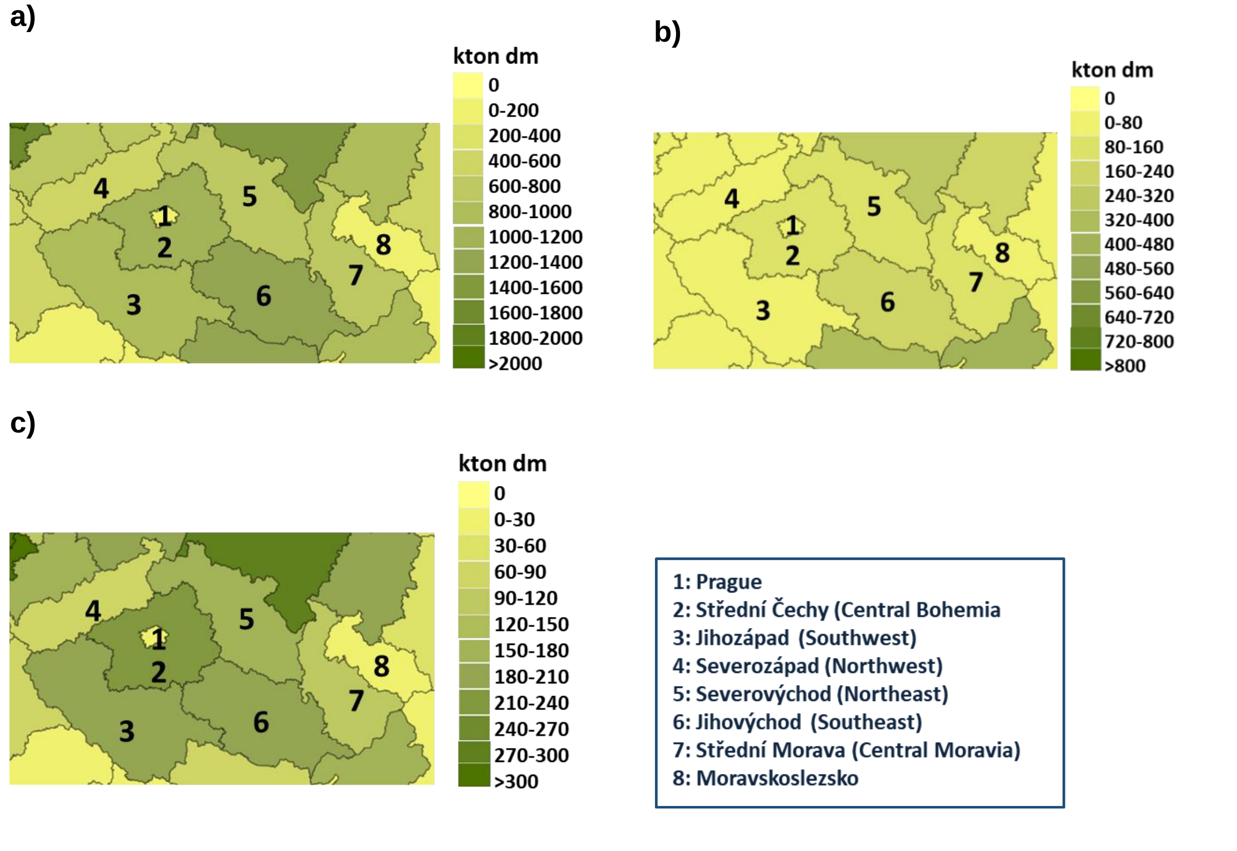
In Czech Republic, as in the entire European Union, biomass presents a high potential for development as an energy source. The national lignocellulosic biomass potential is around 15m dry ton / year (excluding primary forest harvest), based on forest and agriculture resources, waste and dedicated crops. ***This section focuses on the agro biomass and forest potential in this country, whilst some additional data are given as regards secondary residues potential.***



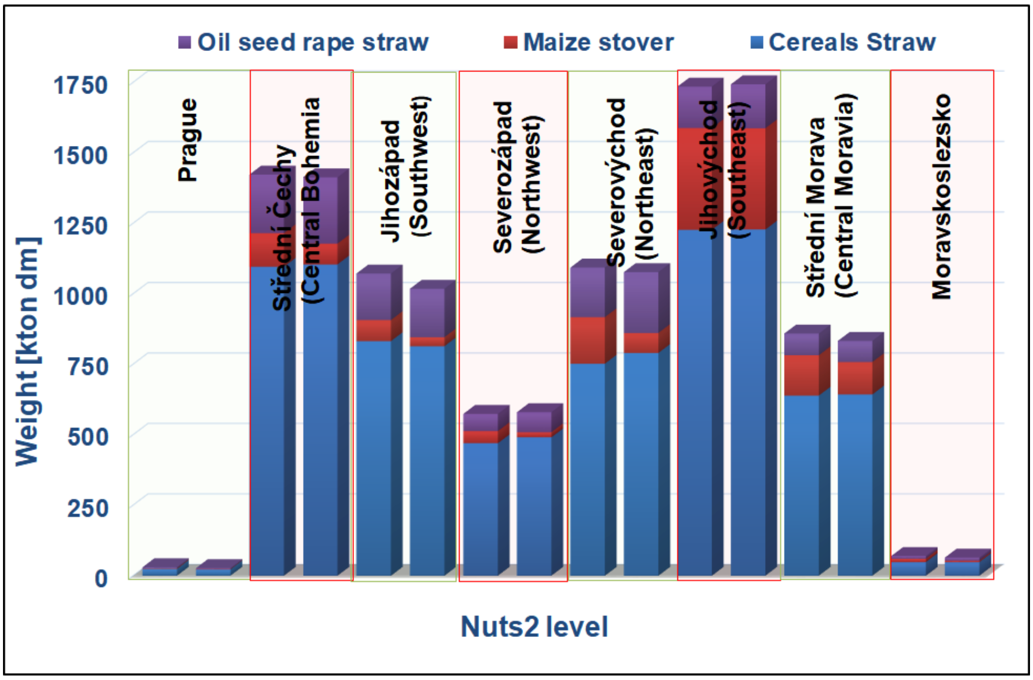
Graph 38. Biomass potential in Czech. Republic in 2020 (values are presented in Mton dm).

More specifically, according to literature surveys, Czech Republic has a biomass potential of equal to 120 PJ, suitable for direct burning and biogas production. Residual straw from cereal and rape are identified as the main source for direct burning (90 PJ). Corn silage and grass from permanent grasslands can be used as main sources for biogas (31 PJ).

According to S2biom, the estimated sustainable agro-biomass potential can reach up to 8,89 million dry ton per year both in 2020 and 2030. Regions with biomass concentration ≥ 1 million dry ton per year are: Vysočina Region, South Bohemian Region and South Moravian Region. Such observation is proven by Graph 39, where it is obvious that there is high potential in these areas, especially for cereal straw and oil seed rape straw. This is actually promising, after a significant decrease observed in various crops from year 2012 to year 2020.



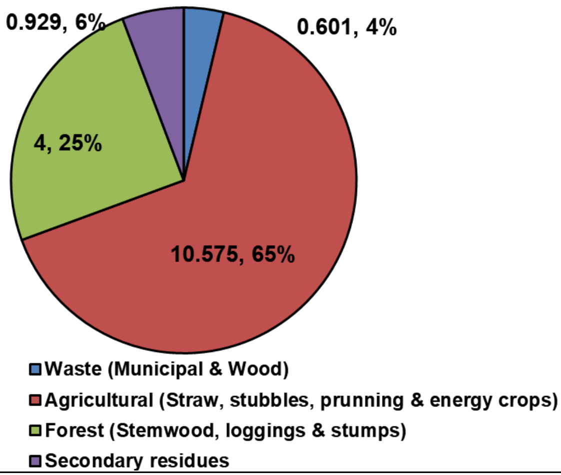
Map 15. Sustainable agro-biomass potential in individual provinces of Czech. Rep. on absolute level for a) cereal straw, b) maize stover, and c) oil seed rape straw (year 2020).



Graph 39. Sustainable agro-biomass potential in Czech. Republic at a regional level (In each area: first column: year 2020, second column: year 2030).

4.6 Bulgaria

With a production of 31.2 Mt in 2016, Bulgaria is the fifth major producer of lignite in the EU-28, following Germany, Poland, Greece and Czech. Republic [1]. The Bulgarian lignite is characterized by a high sulphur content (2.2 – 2.8% wt. as received) [39]. Lignite co-firing with Biomass is considered as a feasible scenario in Bulgaria for the upcoming years. Most of the sustainable biomass in the country is from the agricultural sector –with a total share equal to 65%, which corresponds to ~10.6 Mton- and then from the forest sector –with a share equal to 25%, which correspond to ~4 Mton. Some small availability is theoretically calculated from secondary residues -~1Mton- and waste -~0.6Mton. ***This section will mainly focus on biomass originating on agricultural sector and some brief data will be given as well for forest sector.***



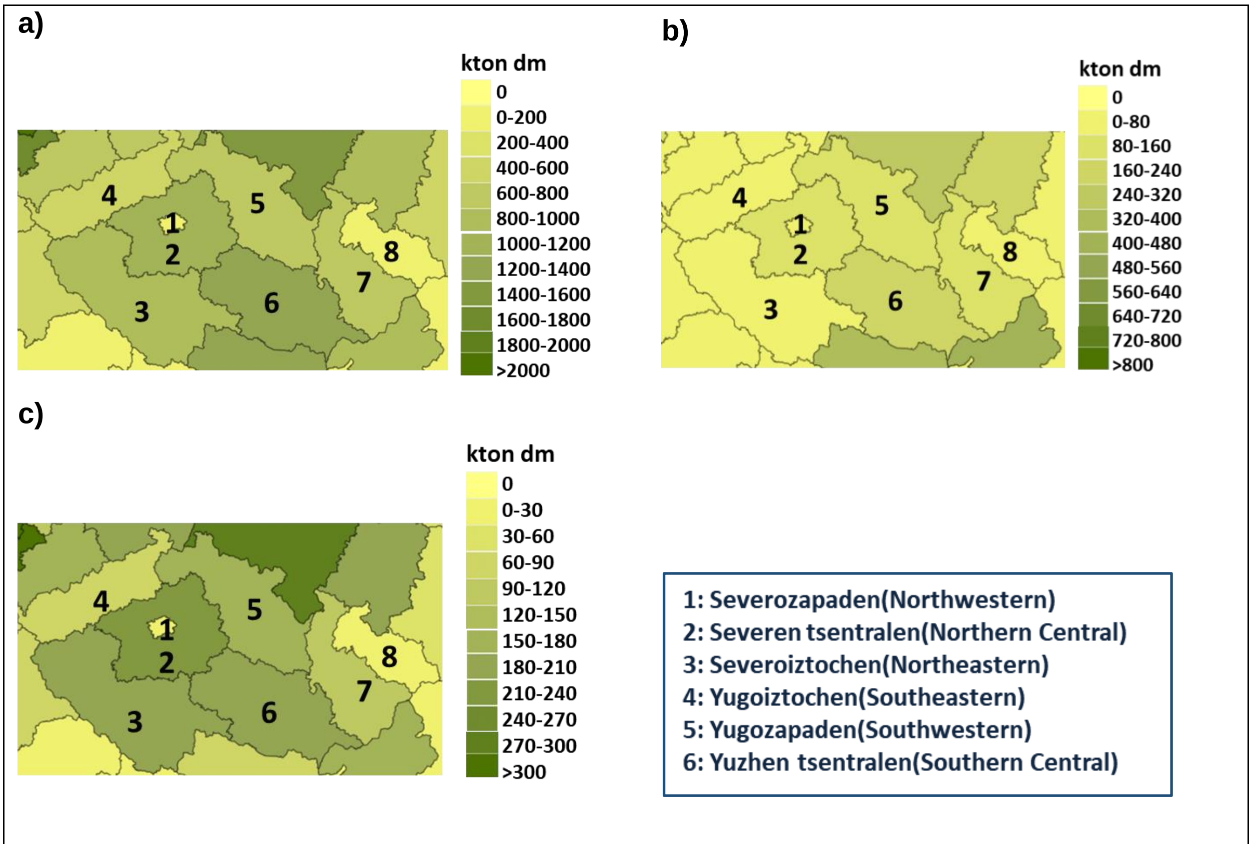
Graph 40. Biomass potential in Bulgaria in 2020 (values are presented in Mton dm).

4.6.1 Agricultural sector

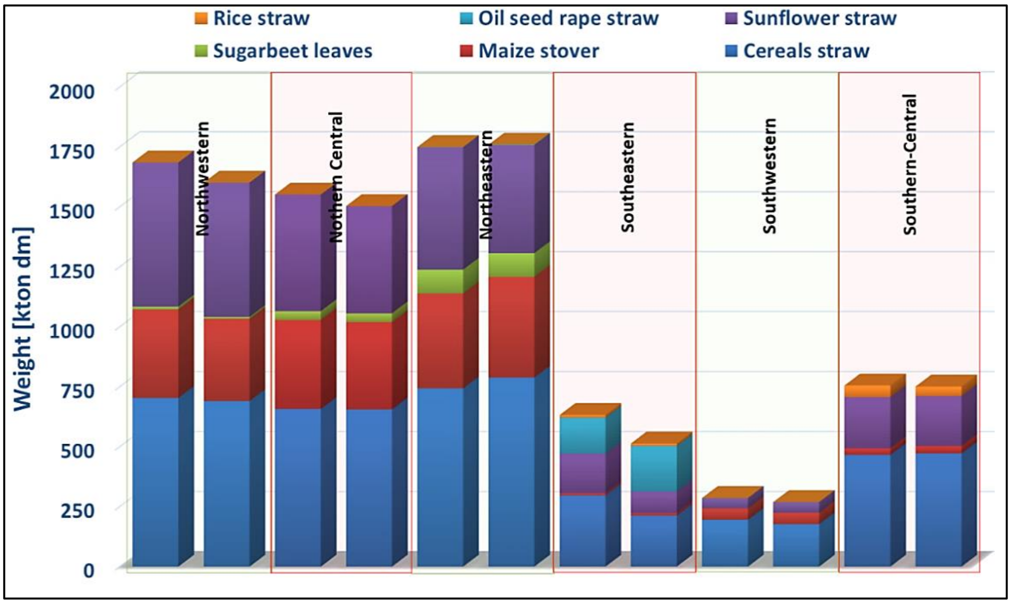
The agrobiomass potential for the Stara Zagora area in Bulgaria, where the AES Galabovo and other lignite-fired power plants are located is of particular interest in the specific country. Stara Zagora is a province of ***Southern Central Bulgaria***, Map 16. As can be seen, this area has a high potential for cereal straw (almost 0.47 Mton) and sunflower straw (0.2 Mton). According to S2biom Project, the cereal straw potential of the area alone is theoretically enough to support co-firing at 5% thermal shares.

However, the areas with the highest agro-biomass potential are located in the northern parts of Bulgaria. More specifically, as can be noticed from Graph 41 and Table 50 (Appendix):

- In **North Eastern, North Central and North Western Bulgaria** the total agrobiomass potential is theoretically equal to almost 4.99 Mton in 2020 and 4.87 Mton in 2030 – this corresponds to a 75 % of the total agro-biomass potential of the country; a small reduction of equal to 2.5 % can be noticed within the 2020-2030 period. The agro-biomass in these areas is mainly based on cereal straw (~2.1 Mton, almost 42 % of the total agro-biomass potential), sunflower straw (~1.6 Mton in 2020 and ~1.46 Mton in 2030) and to a smaller rate on maize stover (~1.1 Mton for both reference years). Generally, the highest agro-biomass concentration can be found in Dobrich (North-Eastern Bulgaria) with >500 dry kton per year) [40].
- In **South Eastern, South Central and South Western Bulgaria** the total agrobiomass potential is theoretically equal to almost 1.68 Mton in 2020 and 1.54 Mton in 2030 – a reduction of equal to 8 % can be noticed within the 2020-2030 period. The agro-biomass in these areas is mostly based on cereal straw (~0.96 Mton in 2020 and 0.86 Mton in 2030). Sunflower straw (~0.42 Mton in 2020 and ~0.34 Mton in 2030) can be also found in these regions and in smaller quantities oil seed rape straw (0.15-0.19 Mton).



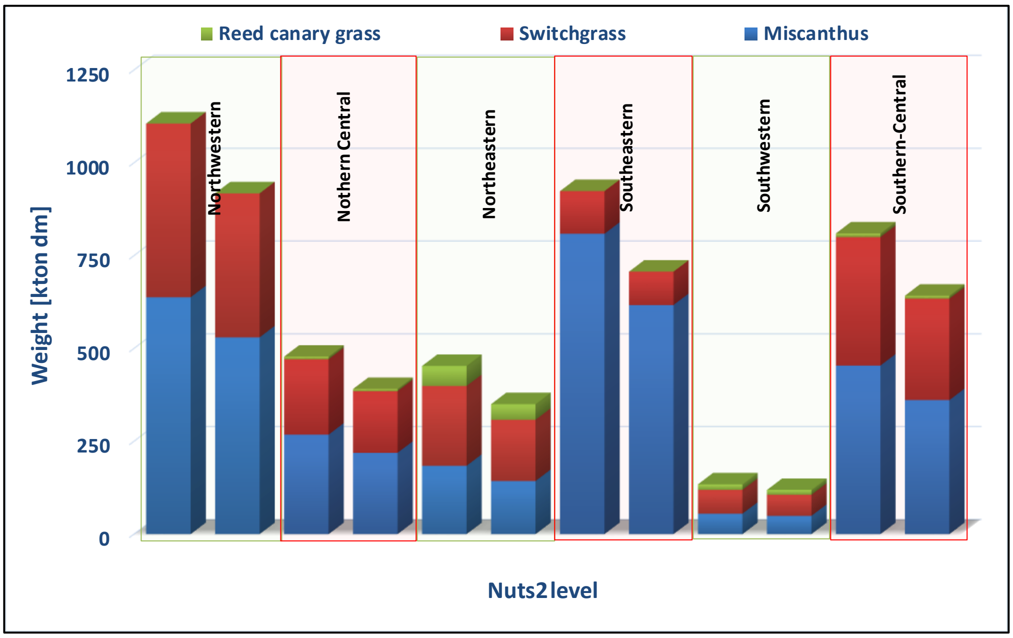
Map 16. Sustainable agro-biomass potential in individual provinces of Bulgaria in absolute level for a) cereal straw, b) maize stover, and c) sunflower straw (year 2020).



Graph 41. Agro-biomass potential in Bulgaria at a regional level (first column: 2020, second column: 2030).

As concerns lignocellulosic biomass crops, it can be noticed from Graph 42 and Table 53 that the highest share comes from miscanthus (almost 61 % for both reference years) and then switchgrass (~36%). More specifically:

- The highest sustainable biomass from lignocellulosic energy crops can be found in **Northwestern, Southeastern and South Central Bulgaria**. In reference years 2020 and 2030 the total potential originating from these crops is estimated equal to 2.84 Mton and 2.27 Mton respectively – a considerable decrease of around 20% is estimated within the period 2020-2030.



Graph 42. Biomass potential– from lignocellulosic energy crops- in Bulgaria at a regional level (first column: 2020, second column: 2030).

- **South Central Bulgaria**, in specific, has a sustainable potential of 0.81 Mton and 0.64 Mton for 2020 and 2030, respectively.

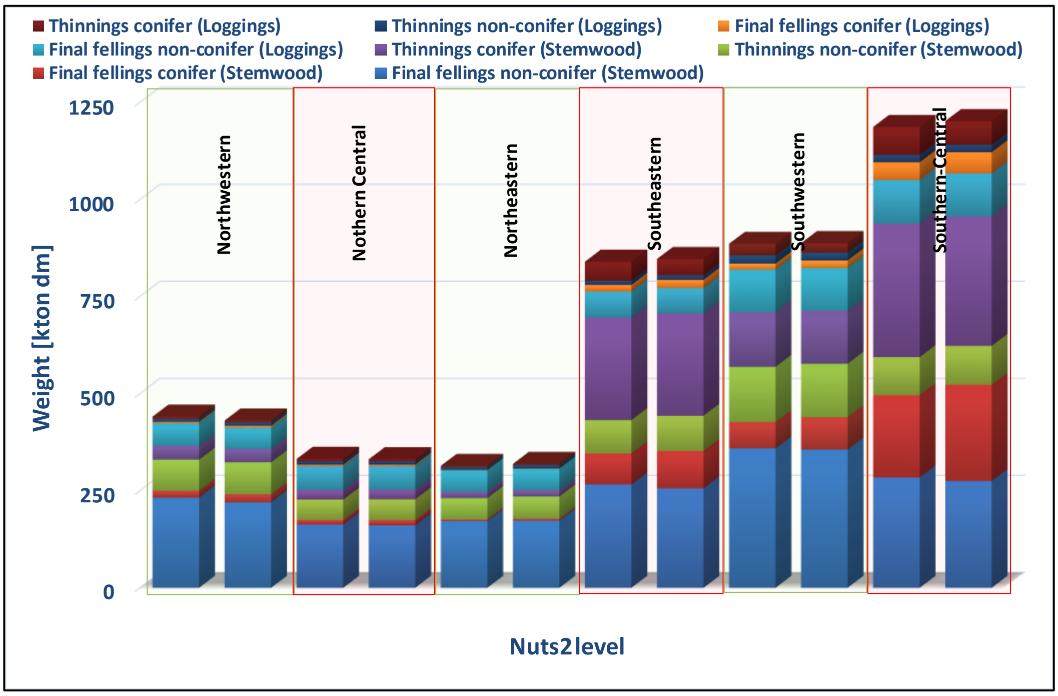
Owing to the fact that the lignocellulosic energy crops availability is expected to decrease considerably in the upcoming years, these crops are not recommended as suitable for co-firing with lignite, especially in large-scale power plants.

4.6.2 Forest sector

According to the U.N. FAO, 36.1% or about 3,927,000 ha of Bulgaria is forested [41]. This country is the third richest in biodiversity amongst the European countries; its forests have increasingly important environmental and recreational role. The growing stock in Bulgarian forests is equal to 656 million m^3, out of which 287 million m^3 are coniferous trees and 369 million m^3 broadleaved (non-conifer trees, designated in this deliverable). According to surveys, the Bulgarian forestland has grown almost 8% within the period 2000-2015[42].

Based on S2biom platform, the estimated sustainable potential from forest sector can reach up to 4 dry Mton/ year (reference years 2020 and 2030). Regions with biomass concentration ≥ 100 dry kton per year are Sofia, Blagoevgrad, Plovdiv, Haskovo, Pazardzhik, Smolyan, Kardzhali, Lovech, Veliko Tarnovo, Burgas, Sliven, Stara Zagora and Varna [40]; these areas are mostly located in the southern part of Bulgaria.

More specifically, in South Central Bulgaria, which is the area of highest interest, the biomass potential originating from forest sector approaches 1.25 Mton, Graph 43. The total forest potential in this area is expected to remain almost steady within the period 2020-2030.



Graph 43. Biomass potential– from forest sector- in Bulgaria at a regional level (first column: 2020, second column: 2030).

4.7 Greece

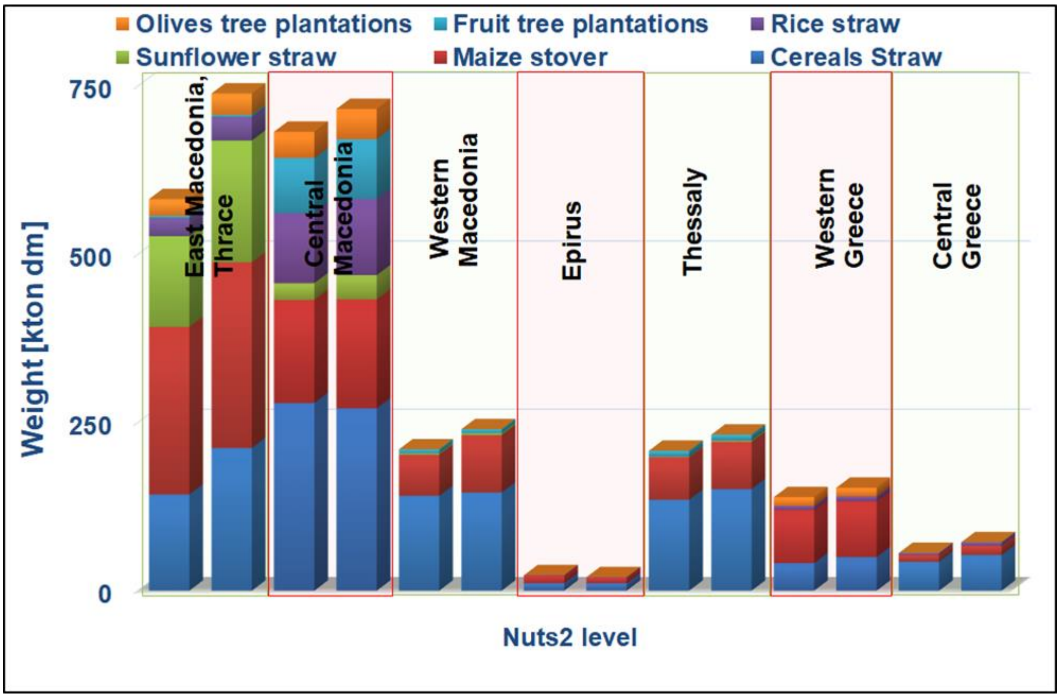
Greece is a country with a relatively high biomass potential. The national biomass potential –from agriculture, forests and waste, excluding primary forest harvest- is around 6.24 dry ton/ year.

4.7.1 Agricultural sector

In Greece almost 36.8% of the total land area is Utilized Agricultural Land (UAA), corresponding to 4,856.8 thousand ha. A 37.4% of this area corresponds to arable land, mostly used for cereal production and 19.1% to permanent crops. In this section, an estimation of the biomass potential from the rather unexploited agricultural sector is presented for three main types of biomass: a) herbaceous biomass residues, b) prunings from permanent plantations and c) energy crops.

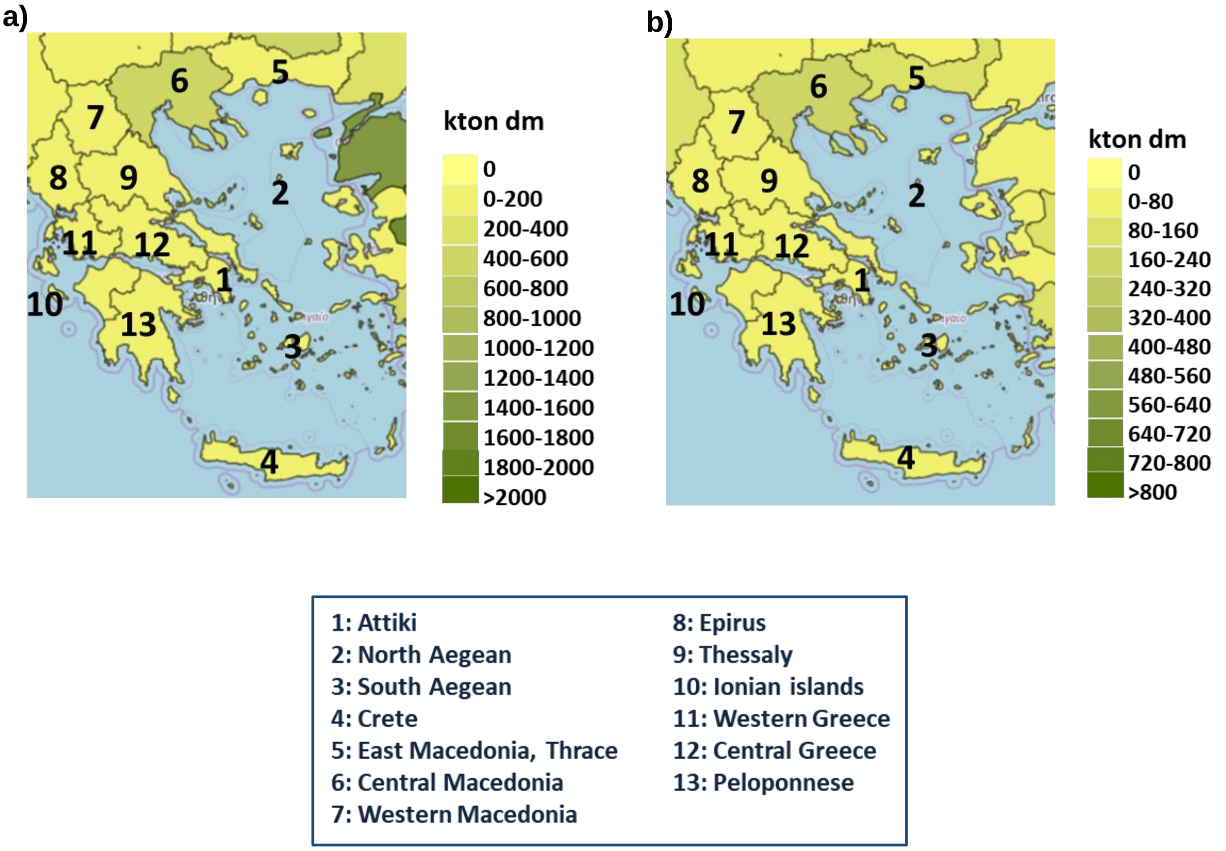
4.7.1.1 Straw and stubbles & prunnings from permanent plantations

Graph 44 presents the sustainable agro-biomass potential in Greece at a NUTS2 statistical level. As can be seen cereal straw and maize stover present the highest availability, especially in Eastern and Central Macedonia, Map 17. This availability is expected to rise from 2020 to 2030. In total, the biomass potential in Greece from straw and stubbles and prunnings from permanent plantations is in the range of 2.5 million ton dm (year 2020).



Graph 44. Agro-biomass potential in Greece at a regional level (first column: 2020, second column: 2030).

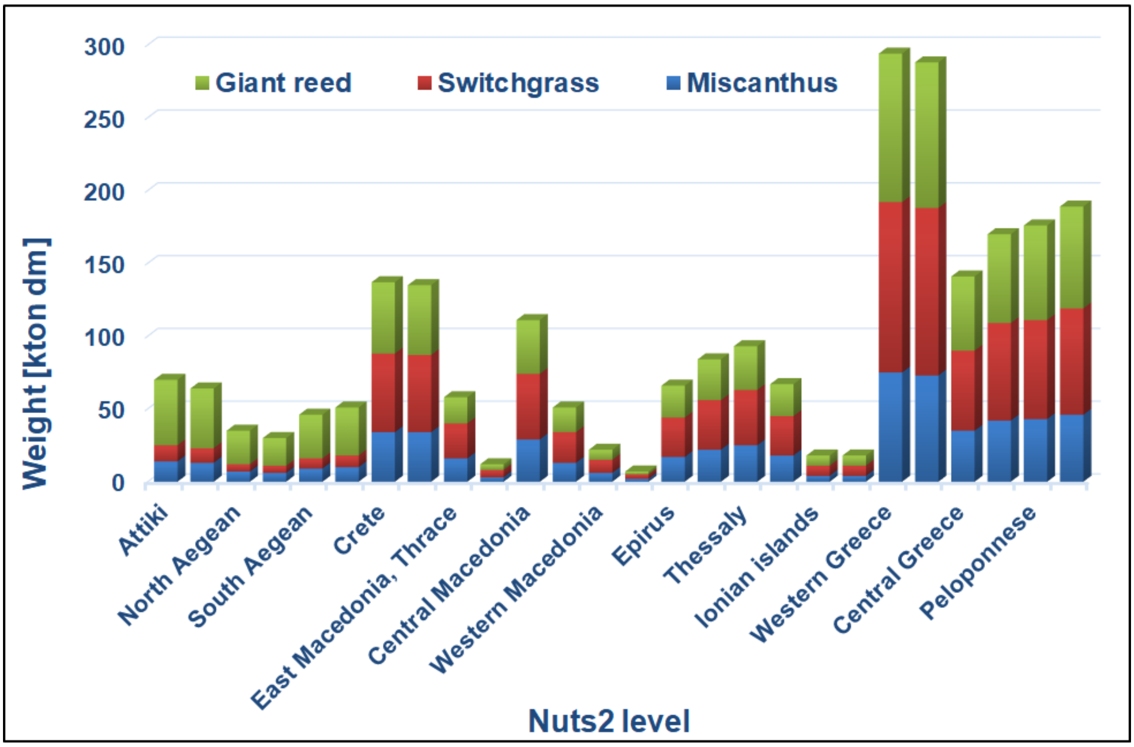
More specifically, the cereal straw and maize stover potential is almost equal to 0.8 and 0.6 Mton dm, respectively, and an increase of almost equal to 12 % is expected for these two crops. ***However, even so the biomass co-firing scenario in Greece is still impossible for large-scale units. Some amounts can be used for co-firing with lignite in Greece or delivered to neighboring countries, but only for pilot scale units.***



Map 17. Sustainable agro-biomass potential in individual areas of Greece in absolute level for a) cereal straw and b) maize stover (year 2020).

4.7.1.2 Energy crops

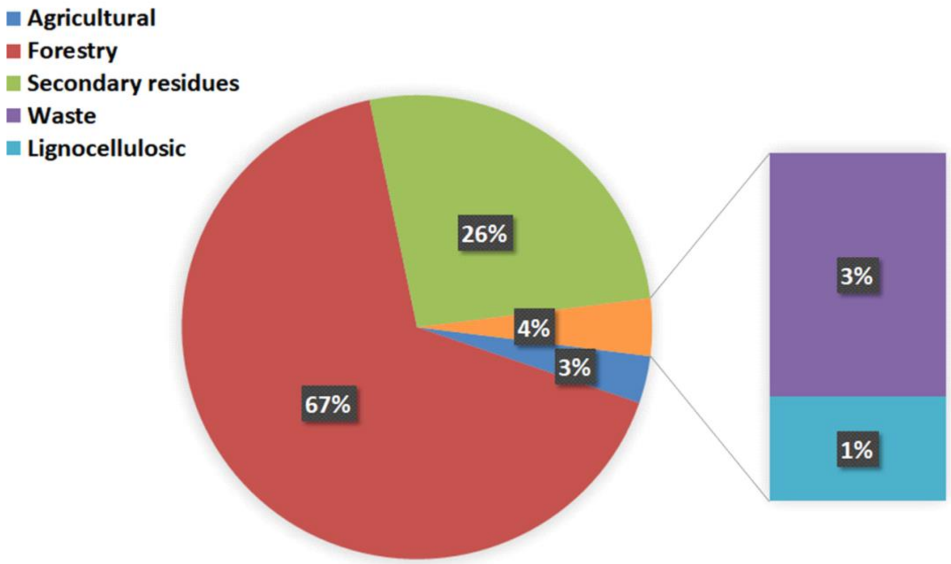
Overall, the energy crop potential in Greece is in the range of 1.3 million ton dm. Amongst the herbaceous energy crops presented in S2Biom platform the ones that are appropriate for the Greek conditions and have, thus, the highest potential are: **miscanthus, switchgrass and giant reed**. Contrary to straw and stubbles & prunnings from permanent plantations, which are more available in northern Greece, the energy crops can be mostly found in central and southern Greece and in the Greek islands – especially in Crete, Graph 45.



Graph 45. Biomass potential from energy crops in Greece at a regional level (first column: 2020, second column: 2030).

4.8 Finland

Finland is one of the world's leading countries in the utilization of **wood fuels and peat**. Three fourths of the Finnish land area, corresponding to 23.1 million hectares, is covered by forests (forest land and poorly productive forest) [43]. The country's energy mix has been up to now and will continue to be based on forest biomass co-firing with peat, whilst coal plays a rather small role. This is because there is not inland coal production in this country and coal is mainly imported by Russia, US, Canada and Australia. On the other hand, peat is a significant energy resource in Finland, mainly used in co-firing with woody biomass in CHP plants, accounting for 17.6% of all fuels used (in TWh) in such plants (reference year 2011). According to projections, there will be a further development of co-generation based on peat and wood chips/forest industry by-products and in power plants and CHP plants until 2020 [44].



Graph 46. Biomass potential in Finland in 2020.

Forest land area per capita is 4.56 in Finland, whereas in Europe is 0.65. A high share of almost 90% of the country's forest area is predominantly coniferous and 10% is broad-leaved (non-conifer trees designated in the present deliverable) [43]. Therefore, the forest sector will play an important role in the energy mix in the the upcoming years.

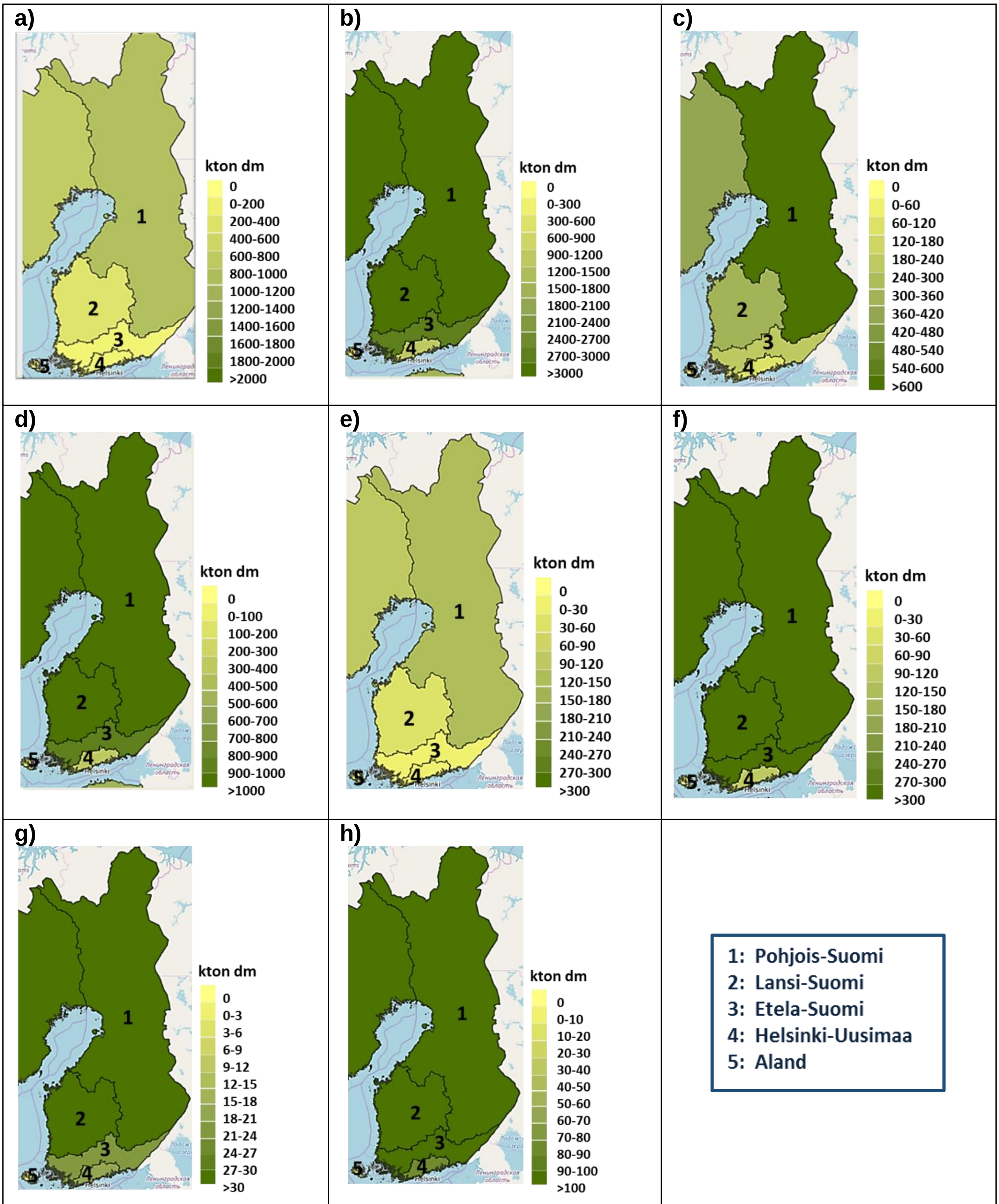
Forest biomass is sold after a minimum of one drying season. Stumps from final fellings from conifer trees are a large potential source of biomass but they are only harvested to a limited extent. Stump wood is used for heat and power production, both in Sweden and Finland, contrary to the rest of the European countries presented above. The available biomass from stumps is similar to that for branches and tops [45].

After harvesting process, trees and stumps are dried either in the forest or at the roadside. For a biomass moisture content of 40%, one tonne of forest biomass can potentially yield around 3 Mwh of energy. For a lower moisture content (of 25%) one tonne gives almost 4 Mwh. However, in the latter casebut if the load contains snow and ice, the yield may remain below 1.5 Mwh/t [46]

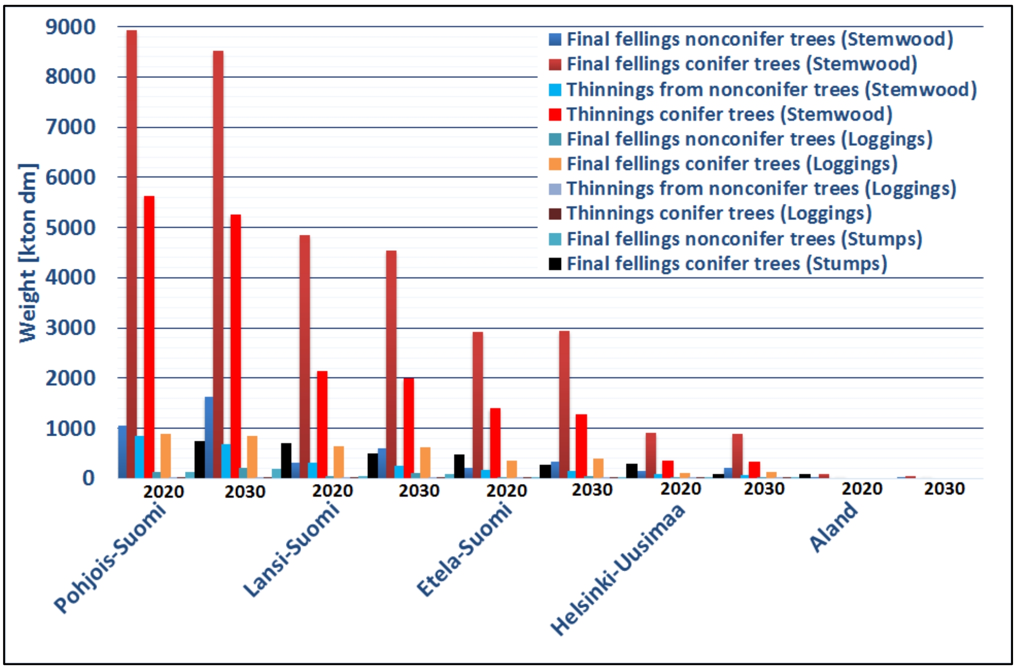
In 2020 the sustainable biomass potential in Finland, as can be seen from Graph 46, will be mainly based on forestry (67 %) –logging residues, stumps and stemwood- and on a smaller extent on secondary residues from wood industries (26 %), such as sawdust, bark and black liquor. The situation will be more or less the same in 2030, Table 54. ***Thus, this section will present data regarding these two biomass categories, i.e. forest sector and secondary residues.***

4.8.1 Forest sector

As can be seen from Map and Graph the highest forest biomass production is mainly located in the district of Pohjois-Suomi (> 18 Mton/ year). Out of it ~16.45 Mton, corresponding to a share 90%, is stemwood and ~0.85 Mton is stumps. When moving to the south the total forest potential reduced and becomes almost neglible in the areas of of Aaland and Helsinki-Uusimaa.

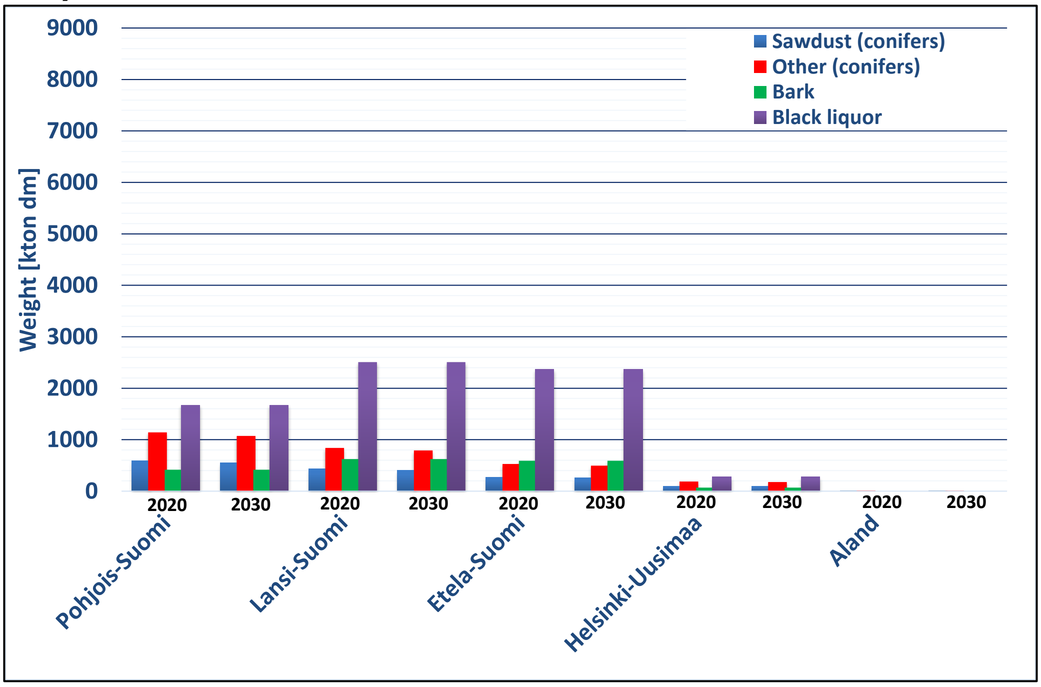


Map 18. Sustainable forest biomass potential in individual areas of Finland in absolute level for i. stemwood from a) final fellings from nonconifer trees, b) final fellings conifer trees, c) thinnings nonconifer trees and d) thinnings conifer trees, ii. logging residues from e) final fellings from nonconifer trees and f) final fellings from conifer trees and iii. stumps from g) final fellings from nonconifer trees and h) final fellings from conifer trees (year 2020).



Graph 47. Absolute sustainable forest biomass (Stemwood, logging residues and stumps from final fellings & thinnings –conifer and non-conifer trees) in Finland (years 2020 and 2030).

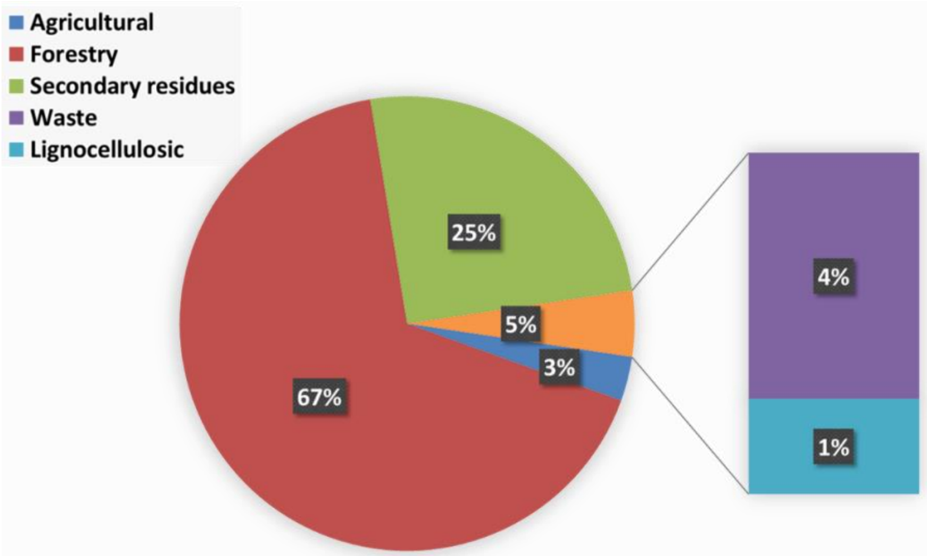
4.8.2 Secondary residues



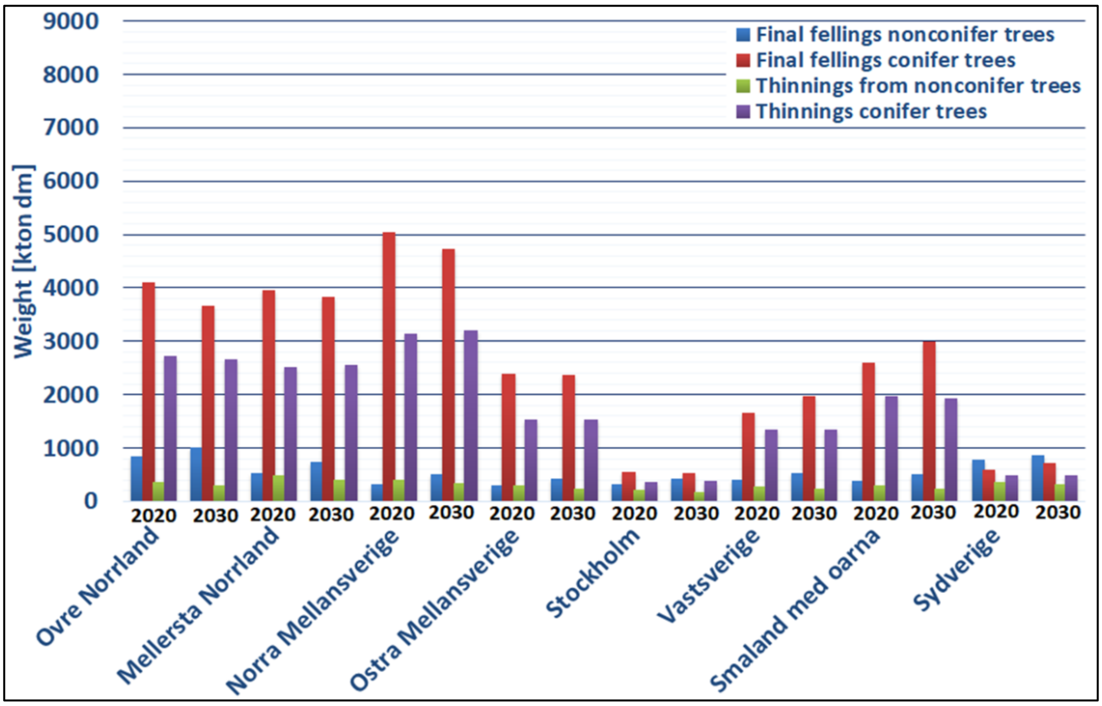
Graph 48. Absolute sustainable from secondary residues from wood industry –saw mill and pulp and paper industry- in Finland (years 2020 and 2030).

4.9 Sweden

In Sweden, the situation for the country's sustainable biomass potential is more or less the same, as in Finland. As can be seen from Graph 49, the biomass potential in Sweden in 2020 will be mainly based on forestry (67 %) –logging residues, stumps and stemwood- and on a smaller extent on secondary residues from wood industries (25 %), such as sawdust, bark and black liquor. The situation will be more or less the same in 2030, Table 58, Graph 50.

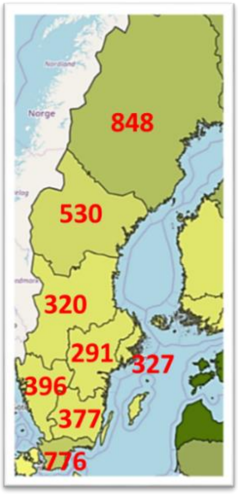


Graph 49. Biomass potential in Sweden in 2020.



Graph 50. Absolute sustainable forest biomass (Stemwood from final fellings & thinnings –conifer and non-conifer trees) in Sweden (years 2020 and 2030).

Another conclusion to be drawn is that in Sweden the forest biomass mostly comes from conifer trees, as in Finland. High biomass resources can be found thought the whole country, except for the areas of Stockholm and Sydverige, Map 19.

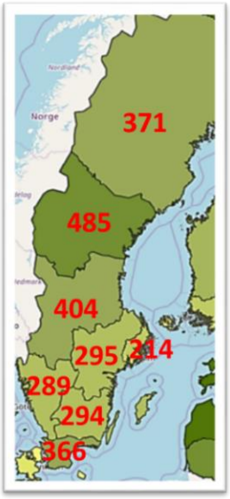


Final fellings from nonconifer trees

kton dm	
0	1000-1200
0-200	1200-1400
200-400	1400-1600
400-600	1600-1800
600-800	1800-2000
800-1000	>2000

Final fellings from conifer trees

kton dm	
0	1500-1800
0-300	1800-2100
300-600	2100-2400
600-900	2400-2700
900-1200	2700-3000
1200-1500	>3000



Thinnings from nonconifer trees

kton dm	
0	300-360
0-60	360-420
60-120	420-480
120-180	480-540
180-240	540-600
240-300	>600

Thinnings from conifer trees

kton dm	
0	500-600
0-100	600-700
100-200	700-800
200-300	800-900
300-400	900-1000
400-500	>1000

Map 19. Absolute sustainable forest biomass (Stemwood from final fellings & thinnings) in Sweden (year 2020).

5 Biomass cost

Through S2biom platform, it is possible to estimate the roadside cost of the crops presented in the previous sections in different locations across Europe, for reference years 2020 and 2030. The road side cost are a fraction of the total 'at-gate-cost. **Unfortunately in this platform are not available data as concerns at-gate-cost projections, however, the values presented can be helpful for any economic analysis.** In this platform, all information is provided at NUTS3 statistical level. Thus, in this analysis the cost at a NUTS0 statistical level is presented, by taking average values.

As aboventioned, the costs provided include only the costs made to produce biomass for the **non-feed or food market**. This cost varies amongst the different crops studied

- In the case of straw and stubbles –like cereal straw and maize stover- only the cost of harvesting, fertilization, due to nutrient removal with the straw, baling and collecting to the **roadside farm/gate** are taken into account [47].

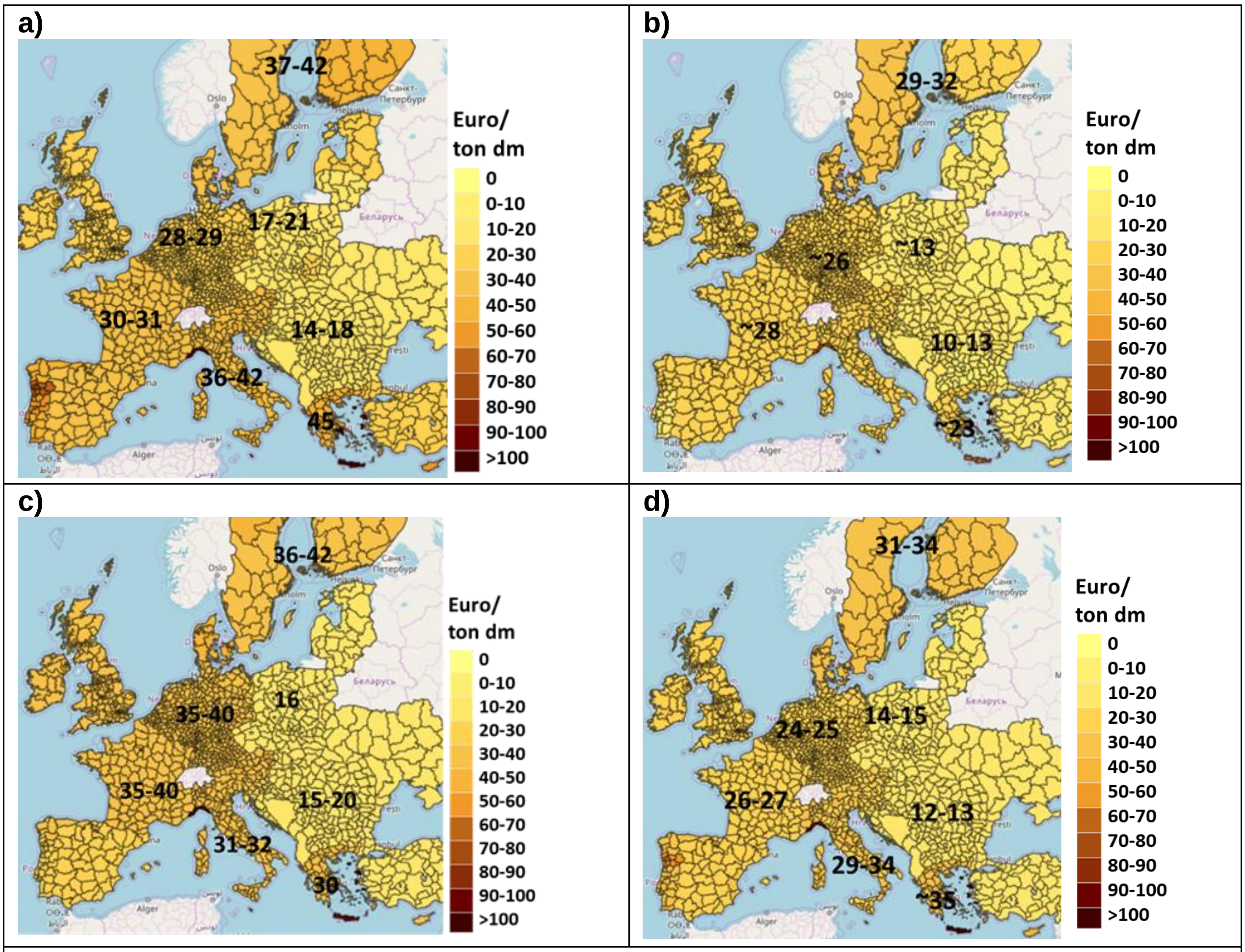
- In the case of prunnings from permanent crops, the cost of collecting branches left on the soil, as shredded material at roadside is included.

5.1 Roadside cost

As regards the roadside cost (Euro/ton dry matter) of selected agricultural crops, the highest values can be observed, Map 20 in Scandinavian and Southwestern European countries. More specifically:

- **Cereal straw** is estimated to have high values in Greece (~45 Euro/kton dry), in Italy (36-42 Euro/kton dry), Germany (28-29 Euro/kton dry), France (30-31 Euro/kton dry) and Sweden-Finland (37-42 Euro/kton dry). The lowest prices are traced in Poland (17-21 Euro/kton dry) and Southeastern countries like Bulgaria, Hungary and Romania.

- For the rest of the crops maize stover, sunflower straw and oil seed rape straw the situation is more or less the same, with the highest prices observed in Central (except for Poland), Southwestern and Northern Europe and the lowest prices traced in Southeastern Europe.

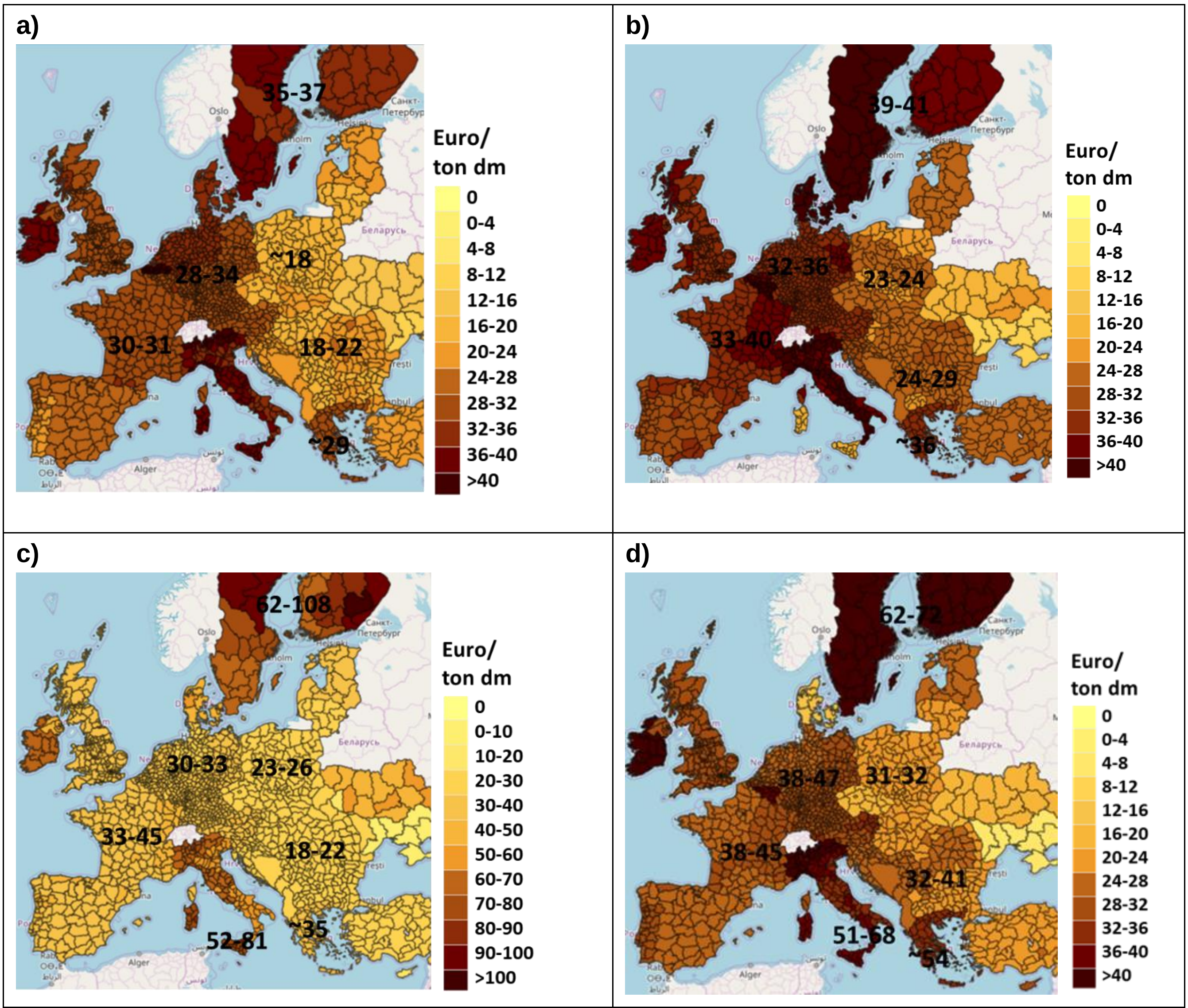


Map 20. Cost of selected agricultural residues a) cereal straw, b) maize stover, c) sunflower straw, and d) oil seed rape straw for reference year 2020.

Concerning Stemwood from final fellings and thinnings from coniferous and non-conifer trees the following conclusions can be drawn:

- In general, stemwood originating from coniferous trees has higher roadside cost, compared to the one originating from non-conifer trees. The same applies for the logging residues, as can be seen in Table 62 in the Appendix section.

- **Stemwood from non-conifer trees** is estimated to have –as in the case of agricultural crops- lowest prices in Poland (18-26 Euro/kton dry) and Southeastern countries like Bulgaria, Hungary and Romania. In the same areas, the price of **stemwood from coniferous trees** will be approximately (23-32 Euro/kton dry).



Map 21. Cost of selected forest residues: ***Stemwood*** from a-b) final fellings from non-conifer and conifer trees and c-d) thinnings from non-conifer and conifer trees for reference year 2020.

5.2 Plant-gate cost and market price

In this section, some additional data are delivered regarding plant-gate and market cost in various European countries. For the current values of straw and wood pellets cost in the market, data can be retrieved from the literature and previous European projects. For biomass sources, for which markets are (practically) not developed yet (e.g. dedicated perennial crops for ligno-cellulosic) their roadside cost is considered adequate for the economic analysis. The roadside cost of different crops has been presented in the previous section.

It should be noted that for most regions, there are no official statistics available for cereal straw prices, because straw is not generally considered as a marketable commodity. Some data concerning different countries for the gate-cost and market prices are presented based on FP7 Biocore [48] and Biomasud [49] project:

- **In UK** 40 €/t to 50 €/t can be expected to be typical price levels for **wheat straw** market price and 80 €/t to 85 €/t at the factory gate (data available for 2011).
- **In France** the average dry **wheat straw** price market prices go up to 60 €/t (data available for 2011); this is almost double the roadside cost estimated for this crop in this country.
- **In Hungary** a price for **small baled straw** (approximately 15 kg to 20 kg) is approximately 59 €/t to 79 €/t. (data available for 2012).
- **In Germany** **miscanthus** can be up to 100 €/t of dry matter in the Muensterland, Germany, because of specific regional demand. In the same country **dry sawdust** prices were approximately 20 €/t to 40 €/t (market prices) and 80 €/t to 100 €/t (plant gate cost) (period 2006-2010). In 2011 **grade dry pellets** in Germany ranged between 200 €/t and 250 €/t. The average price for **bark-free dry wood chips** from sawmills, originating from soft wood and hardwood was approximately 58 €/t in the same period while the maximum price reached 68 €/t.
- **In Netherlands,** the Rotterdam price (including cost, insurance and freight) for industrial **grade dry pellets** was approximately 130 €/t in 2011 [50].
- **In Greece,** **firewood** is sold in a price of around 60 – 80 €/m^3 (bulk). **Wood pellets** (A1 quality) have a market price equal to 290 – 320 €/t and A2 quality a price equal to 230 €/t. In 2016, the market price for the **exhausted olive cake** was in the range of 70-80 €/t (VAT included) and for **olive ston** equal to 150 €/t.

6 General overview (biomass/lignite co-firing)

- In this section, a general overview is given of the co-firing potential of lignite with biomass originating from selected crops; these crops are chosen based on the previous analysis concerning their sustainable potential in Europe for the forthcoming years. Three countries with high lignite production are selected for demonstration, i.e. Germany, Poland and Greece, Figure 2; in each country, the co-firing potential is identified near lignite mining areas.

More specifically,

- In **Germany** there is a high potential for biomass co-firing, especially at power plants installed near ***Sachsen Anhalt*** –The biomass availability in this area along with the nearby areas, i.e. Thuringen and Leipzig, can reach up to 4.5 Mton/year for cereal straw (CS), 0.2/year Mton for maize storer (MS) and sugar beet leaves (SBL), 1 Mton/year for oil seed rape straw (OSRS) and 0.6 Mton/year for miscanthus (MS) and switchgrass (SG). In this area, there is also a high potential originating from primary production from forests, such as stemwood (>3.6 Mton/year) and a moderate potential from logging residues (0.1-0.2 Mton/year) and biowaste (0.6 Mton/year).
  In Koln, there is a lower potential as regards cereal straw, compared to Sachsen-Anhalt. Even so, this amount –almost equal to 1 Mton/year- is adequate to cover the needs for co-firing.
- ***In Greece, there is a limited potential for biomass co-firing, due to low biomass availability.*** Thus, biomass co-firing can be utilized at either small-scale units or at large scale units with fuel blends of low biomass rate.
- ***In Poland,*** the biomass availability is high in all lignite mining areas***.*** Especially, near Bełchatów lignite basin, located in Lodzkie, the cereal straw potential is adequate enough –over 1 Mton- to cover the needs for co-firing. Supplementary maize stover or sugarbeet leaves can be used for co-combustion. Co-firing in this area is favored and from an economic point of view, since

agricultural residues in Poland, have a rather low roadside cost. Biowaste in this area present a rather limited availability -0.2 Mton/year- and can be used only as a supplementary fuel in the lignite-cereal straw blend.

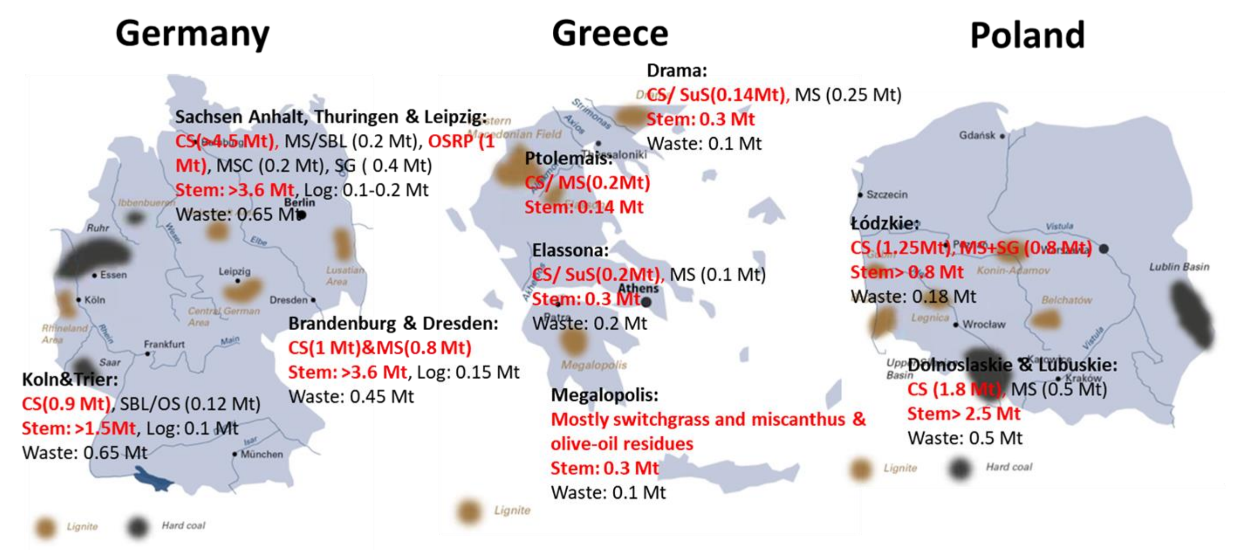


Figure 2. Sustainable biomass potential near lignite mining areas in three European countries with high lignite production –Germany, Greece and Poland (reference year 2020).

7 Conclusions

In the framework of Task 1.1, an extensive analysis has been conducted as concerns the sustainable biomass potential in Europe for reference years 2020 and 2030. For the purpose of this analysis, the S2Biom platform has been utilized. Primarily, the EU-28 countries with the highest lignite production, suitable for co-firing with biomass, have been identified. These are Germany, Poland, Czech. Republic, Romania, Hungary, Greece and Bulgaria. These countries have been checked thoroughly at both a NUTS0 and NUTS2 statistical level for their biomass sustainable potential, whilst additional data at NUTS0 level have been delivered for the rest of the European countries. Apart from this, additional information is given concerning the biomass roadside/ market and at-gate cost at different countries. The biomass types investigated cover a wide range of sectors, from agricultural and forest sector to municipal waste. The main outcome of this task is that the most promising crops for co-combustion with lignite in a fluidized bed boiler (FB), both in terms of high potential and low cost, are cereal straw (agriculture) and stemwood final fellings from conifer and non-conifer trees (forest). More specifically, cereal straw presents a high potential for co-firing with lignite, due to its high availability throughout Europe, and especially near European lignite mining areas, such as Bełchatów lignite basin in Poland – cereal straw availability over 1 Mton/year- and Hambach opencast mine in Germany –availability almost equal to 1 Mton/year. Concerning its cost, it should be noted that this crop can be found in low prices in Central and Southeastern Europe –in Hungary for instance, the market price for **big baled straw** (approximately 600 kg bales) is approximately 20 €/t. Another, agriculture residue that presents a moderate potential and can be used for co-firing is maize stover, with its price being slightly lower compared to that of cereal straw. From the forest sector, stemwood and logging residues originating from final fellings and thinnings can be used in the form of wood pellets (WoP) for co-firing. However, the latter biomass feedstock is not considered as a dirty/ opportunity fuel and should not prioritized for investigation in the framework of Task 1.4. From the waste sector refuse derived fuel (RDF) is recommended to be used in the fuel blend. This biomass feedstock has a moderate availability across Europe –a total of almost 30 Mton/year are estimated for the countries with the highest lignite production- and its cost could be equal to zero, depending on the country. Finally, a technically challenging fuel –high ash and moisture content- that is recommended to be tested for co-firing is exhausted olive cake. However, this biomass type can be mostly found in Southern European countries at limited amounts -100 to 800 kton/year, depending on the country- and, thus, it is recommended for co-firing, but, at small scale units or at low rates in the fuel blend.

8 Appendix

This section presents the data on which the previous analysis has been based. It should be noted that values concerning the sustainable biomass potential are given in both absolute -kton dry matter or Mton dry matter- and in area weighted values –AW [kton dm/km^2].

8.1 Agro-biomass potential

Agricultural residues (Straw/stubbles)												
Year	**2020**						**2030**					
Country	Absolute [Mton dm]						Absolute [Mton dm]					
	CS	**MS**	**SBL**	**SUS**	**OSRS**	**RS**	**CS**	**MS**	**SBL**	**SUS**	**OSRS**	**RS**
Austria	1.58	0.9	0.17	0.11	0.08	0	1.55	0.94	0.16	0.17	0.08	0
Belgium	1.15	0.49	0.29	0	0.11	0	1.32	0.41	0.35	0	0.01	0
Bulgaria	3.06	1.22	0.15	2.02	0.15	0.06	3	1.22	0.14	1.8	0.19	0.05
Croatia	0.68	1.20	0.10	0.08	0.04	0	0.58	1.24	0.10	0.09	0.04	0
Cyprus	0	0	0	0	0	0	0	0	0	0	0	0
Czech. Rep.	5.09	0.92	0.25	0.11	0.85	0	5.14	0.68	0.25	0.10	0.94	0
Denmark	1.39	0	0.04	0	0.09	0	1.37	0	0.03	0	0.09	0
Estonia	0	0	0	0	0	0	0	0	0	0	0	0
Finland	1.54	0	0.02	0	0.04	0	1.64	0	0.03	0	0.03	0
France	24.33	6.30	1.30	1.58	3.29	0.07	23.12	6.22	1.32	2.07	2.74	0.10
Germany	21.62	1.72	1.02	0.09	3.58	0	20.95	1.84	0.95	0.06	2.68	0
Greece	0.8	0.63	0.10	0.16	0	0.14	0.9	0.7	0.10	0.22	0	0.16
Hungary	3.53	4.48	0.08	1.36	0.48	0.01	3.24	4.52	0.11	1.18	0.51	0.01
Ireland	0	0	0	0	0	0	0	0	0	0	0	0
Italy	1.72	3.27	0.26	0.20	0	1.30	1.54	3.32	0.38	0.24	0.10	1.18
Latvia	0.19	0	0	0	0.03	0	0.19	0	0.02	0	0.03	0
Lithuania	0.37	0.01	0.03	0	0.07	0	0.35	0.01	0.04	0	0.07	0
Luxembourg	0.10	0	0	0	0.04	0	0.11	0	0	0	0.01	0
Malta	0	0	0	0	0	0	0	0	0	0	0	0
Netherlands	0.79	0.09	0.21	0	0	0	0.74	0.16	0.23	0.01	0.01	0
Poland	16.58	1.74	0.77	0.04	1.22	0	14.29	1.16	0.74	0.06	1.25	0
Portugal	0.07	0.07	0.01	0.05	0	0.08	0.10	0.08	0	0.04	0	0.13
Romania	4.60	4.85	0.14	1.28	0.80	0.06	4.16	4.30	0.13	1.22	1.15	0.06
Slovak Rep.	1.14	0.56	0.07	0.18	0.18	0	1.08	0.54	0.07	0.10	0.21	0
Slovenia	0	0	0	0	0	0	0	0	0	0	0	0
Spain	9.06	1.05	0.35	1.07	0.06	0.36	9.04	1.24	0.36	1.14	0.05	0.33
Sweden	2.06	0.01	0.11	0	0.11	0	1.88	0	0.11	0	0.12	0
UK	4.50	0	0.30	0	0.64	0	4.28	0	0.41	0	0.74	0
Serbia	1.42	3.61	0.27	0.45	0	0	1.56	3.52	0.26	0.43	0.01	0
Turkey	19.85	2.26	0.94	1.19	0.15	0.63	21.49	2.50	0.88	1.10	0.15	0.61
Albania	0.14	0.09	0.01	0	0	0	0.15	0.09	0.01	0	0	0
Bosnia & Herzegovina	0	0	0	0	0	0	0	0	0	0	0	0
FYROM	0.16	0.04	0	0	0	0.01	0.16	0.04	0	0	0	0.01
Kosovo	0.24	0.02	0	0	0	0	0.25	0.03	0	0	0	0
Moldova	0	0	0	0	0	0	0	0	0	0	0	0
Montenegro	0	0.01	0	0	0	0	0	0.01	0	0	0	0
Ukraine	13.74	10.47	5.30	13.0	0.64	0.01	13.74	10.47	5.30	13.0	0.64	0.01
EU-28	**105.9**	**29.51**	5.77	8.33	**11.86**	2.08	**100.6**	**28.58**	**6.03**	8.5	**11.05**	2.02
Europe	**141.5**	**46.01**	**12.3**	**22.97**	**12.65**	2.73	**137.9**	**45.24**	**12.5**	**23.0**	**11.85**	2.65
High lignite	**77.69**	**21.99**	3.79	**6.88**	**7.41**	0.9	**75.81**	**20.98**	3.63	**6.27**	**7.09**	0.89

Table 10. Sustainable agro-biomass potential –straw and stubbles- in absolute level from CS: cereal (wheat) straw, MS: maize stover, SBL: Sugar beet leaves, SUS: sunflower straw, OSRS: oil seed rape straw and RS: rice straw in 2020 and 2030 (NUTS0 level).

Agricultural residues (Woody prunnings & Orchards residues)										
Year	2020					2030				
Country	Absolute [Mton dm]					Absolute [Mton dm]				
	Vineyards	Fruit tree	Olives tree	Citrus tree	Nuts	Vineyards	Fruit tree	Olives tree	Citrus tree	Nuts
Austria	0.04	0.02	0	0	0	0.04	0.02	0	0	0
Belgium	0	0.03	0	0	0	0	0.03	0	0	0
Bulgaria	0	0.01	0	0	0	0	0.01	0	0	0
Croatia	0.01	0.02	0	0	0	0.01	0.02	0	0	0
Cyprus	0	0	0	0.01	0	0	0	0	0.01	0
Czech. Rep.	0	0.03	0	0	0	0	0.03	0	0	0
Denmark	0	0	0	0	0	0	0	0	0	0
Estonia	0	0	0	0	0	0	0	0	0	0
Finland	0	0	0	0	0	0	0	0	0	0
France	0.05	0.10	0	0	0	0.05	0.07	0	0	0
Germany	0.07	0.08	0	0	0	0.07	0.08	0	0	0
Greece	0.01	0.10	0.08	0.01	0	0	0.11	0.09	0.01	0
Hungary	0	0.13	0	0	0	0	0.13	0	0	0
Ireland	0	0	0	0	0	0	0	0	0	0
Italy	0.07	0.17	0.21	0.01	0	0.06	0.15	0.22	0.01	0
Latvia	0	0	0	0	0	0	0	0	0	0
Lithuania	0	0	0	0	0	0	0	0	0	0
Luxembourg	0	0	0	0	0	0	0	0	0	0
Malta	0	0	0	0	0	0	0	0	0	0
Netherlands	0	0.03	0	0	0	0	0.02	0	0	0
Poland	0	0.55	0	0	0	0	0.60	0	0	0
Portugal	0	0	0	0	0	0	0	0	0	0
Romania	0	0.11	0	0	0	0	0.09	0	0	0
Slovak Rep.	0	0.01	0	0	0	0	0.01	0	0	0
Slovenia	0	0	0	0	0	0	0	0	0	0
Spain	0.01	0.13	2.21	0.12	0	0.01	0.11	2.25	0.13	0
Sweden	0	0	0	0	0	0	0	0	0	0
UK	0	0.02	0	0	0	0	0.02	0	0	0
Serbia	0.02	0.15	-	-	-	0.01	0.16	-	-	-
Turkey	0.15	0.78	0.17	0.01	-	0.13	0.77	0.20	0	-
Albania	0	0.04	0.01	0	-	0	0.05	0.01	0	-
Bosnia & Herzegovina	0	0.09	-	0	-	0	0.11	-	0	-
FYROM	0.01	0.03	0	-	-	0	0.04	0	-	-
Kosovo	0	0	-	-	-	0	0	-	-	-
Moldova	0.03	0.12	-	-	-	0.03	0.12	-	-	-
Montenegro	0	0.01	0	0	-	0	0.01	0	0	-
Ukraine	-	-	-	-	-	-	-	-	-	-
EU-28	0.26	**1.54**	**2.5**	0.15	0	0.24	**1.5**	**2.56**	0.16	0
Europe	0.47	**2.76**	**2.68**	0.16	0	0.41	**2.76**	**2.77**	0.16	0
High lignite	0.25	**1.95**	0.25	0.02	0	0.2	**1.83**	0.29	0.01	0

Table 11. Sustainable agro-biomass potential –woody prunnings and orchards residues- in absolute level from a) vineyards, b) fruit tree plantations, c) olives tree plantations, d) citrus tree plantations, and e) nuts plantations in 2020 and 2030 (NUTS0 level).

8.2 Forest biomass potential

Production from forests (Stemwood from final fellings and thinnings)								
Year	**2020**				**2030**			
Country	Absolute [Mton dm]				Absolute [Mton dm]			
	FC	**FNC**	**TC**	**TNC**	**FC**	**FNC**	**TC**	**TNC**
Austria	7.97	0.65	2.71	1.57	7.41	0.8	2.55	1.79
Belgium	1.13	0.28	0.32	0.35	1.04	0.37	0.30	0.33
Bulgaria	0.39	1.48	0.83	0.51	0.47	1.44	0.81	0.52
Croatia	0.05	2.12	0.05	0.99	0.05	2.00	0.04	0.98
Cyprus	0.45	0.61	0.45	0.60	0.41	0.56	0.41	0.55
Czech. Rep.	4.00	1.79	2.28	1.31	3.98	1.80	2.25	1.33
Denmark	0.77	0.19	0.38	0.30	0.72	0.27	0.33	0.30
Estonia	1.65	2.73	0.67	0.69	1.62	2.40	0.66	0.69
Finland	17.73	1.76	9.60	1.46	16.95	2.82	8.92	1.21
France	9.16	16.15	7.18	7.11	8.66	16.23	6.77	5.92
Germany	14.55	11.39	8.52	7.32	15.03	11.13	8.41	7.59
Greece	0.45	0.61	0.45	0.60	0.41	0.56	0.41	0.55
Hungary	0.38	3.07	0.20	1.29	0.53	2.79	0.12	1.35
Ireland	0.73	0.50	0.38	0.05	1.28	0.18	0.42	0.07
Italy	1.10	8.64	1.26	1.70	1.08	8.07	1.14	1.52
Latvia	2.57	3.95	0.64	0.70	2.44	3.92	0.59	0.77
Lithuania	1.71	1.30	0.66	0.54	1.43	1.42	0.67	0.52
Luxembourg	0.08	0.31	0.06	0.03	0.12	0.22	0.06	0.03
Malta	0	0	0	0	0	0	0	0
Netherlands	0.18	0.18	0.17	0.22	0.19	0.17	0.15	0.22
Poland	10.81	4.31	3.32	1.38	10.29	4.01	3.09	1.37
Portugal	1.83	5.52	0.21	0.04	1.93	5.11	0.20	0.05
Romania	3.19	5.51	2.05	3.33	3.35	4.88	1.88	3.33
Slovak Republic	1.47	1.36	0.53	0.97	1.27	1.44	0.67	0.87
Slovenia	1.85	1.48	0.50	0.64	1.75	1.35	0.48	0.65
Spain	4.67	1.97	2.66	0.77	4.85	1.75	2.57	0.76
Sweden	20.90	3.87	14.09	2.72	20.82	5.00	14.10	2.25
UK	6.08	2.97	1.47	1.72	7.28	1.74	1.14	2.14
Serbia	0.27	1.42	0.26	1.39	0.23	1.23	0.23	1.21
Turkey	7.16	2.47	0.64	0.99	6.57	2.56	0.56	0.76
EU-28	115.85	84.7	61.6	38.9	115.4	82.4	59.1	37.7
Northern Europe	45.33	13.8	26	6.41	43.98	15.8	25.3	5.74
High lignite	44.52	34.9	19.6	19.7	43.88	33.2	18.9	19.5

Table 12. Sustainable crop potential from primary production from forests (FC: final fellings conifer trees, FNC: final fellings non-conifer trees, TC: thinnings conifer trees, TNC: thinnings non-conifer trees) in 2020 and 2030 (NUTS0 level).

Primary residues from forests (Loggings and Stumps)												
Year	2020						2030					
Country	Absolute [Mton dm]						Absolute [Mton dm]					
	LFC	LFNC	LTC	LTNC	SFC	SFNC	LFC	LFNC	LTC	LTNC	SFC	SFNC
Austria	1.07	0.10	0.20	0.12	0	0	1.02	0.13	0.18	0.14	0	0
Belgium	0.12	0.03	0.03	0.02	0	0	0.10	0.04	0.03	0.02	0	0
Bulgaria	0.09	0.46	0.17	0.08	0	0	0.11	0.45	0.14	0.08	0	0
Croatia	0	0.16	0	0.04	0	0	0	0.15	0	0.04	0	0
Cyprus	0	0	0	0	0	0	0	0	0	0	0	0
Czech. Rep.	1.08	0.33	0.36	0.14	0	0	1.10	0.34	0.41	0.15	0	0
Denmark	0.13	0.04	0.04	0.03	0	0	0.13	0.06	0.03	0.03	0	0
Estonia	0.12	0.15	0.03	0.03	0	0	0.12	0.13	0.03	0.03	0	0
Finland	2.00	0.25	0.10	0.03	1.61	0.21	2.00	0.40	0.09	0.02	1.57	0.35
France	1.17	2.51	0.46	0.54	0	0	1.17	2.54	0.41	0.45	0	0
Germany	1.20	0.82	0.36	0.28	0	0	1.21	0.83	0.33	0.29	0	0
Greece	0.08	0.07	0.04	0.04	0	0	0.07	0.06	0.04	0.03	0	0
Hungary	0.07	0.58	0.03	0.12	0	0	0.10	0.52	0.02	0.13	0	0
Ireland	0.07	0.05	0.02	0	0	0	0.12	0.02	0.02	0	0	0
Italy	0.13	1.40	0.10	0.15	0	0	0.13	1.33	0.09	0.14	0	0
Latvia	0.33	0.63	0.04	0.06	0	0	0.31	0.62	0.03	0.06	0	0
Lithuania	0.25	0.15	0.02	0.02	0	0	0.21	0.17	0.02	0.02	0	0
Luxembourg	0.01	0.05	0.01	0	0	0	0.02	0.03	0.01	0	0	0
Malta	0	0	0	0	0	0	0	0	0	0	0	0
Netherlands	0.01	0.01	0	0	0	0	0.01	0.01	0	0	0	0
Poland	1.24	0.42	0.12	0.05	0	0	1.19	0.39	0.11	0.05	0	0
Portugal	0.85	1.41	0.04	0	0	0	0.90	1.31	0.04	0	0	0
Romania	0.48	0.93	0.25	0.30	0	0	0.50	0.82	0.19	0.30	0	0
Slovak Republic	0.21	0.24	0.04	0.09	0	0	0.18	0.26	0.09	0.08	0	0
Slovenia	0.19	0.11	0.03	0.03	0	0	0.18	0.10	0.04	0.03	0	0
Spain	1.08	0.49	0.37	0.08	0	0	1.20	0.43	0.35	0.08	0	0
Sweden	3.04	0.53	0.40	0.1	2.40	0.53	3.16	0.69	0.40	0.08	2.40	0.69
UK	0.57	0.67	0.06	0.19	0.32	0.25	0.64	0.38	0.04	0.24	0.37	0.14
Serbia	0.04	0.21	0.02	0.10	0	0	0.04	0.18	0.02	0.08	0	0
Turkey	2.34	0.55	0.09	0.11	0	0	2.14	0.57	0.08	0.08	0	0
EU-28	15.6	12.59	3.32	2.54	4.33	0.99	15.9	12.21	3.14	2.49	4.34	1.18
Northern Europe	5.87	1.75	0.63	0.27	4.01	0.74	5.93	2.07	0.6	0.24	3.97	1.04
High lignite	7.02	4.72	1.51	1.34	0	0	6.82	4.52	1.47	1.3	0	0

Table 13. Sustainable crop potential from primary residues from forests: (LFC: logging residues from final fellings from conifer trees, LFNC: logging residues from final fellings from non-conifer trees, LTC: logging residues from thinnings from conifer trees, LTNC: logging residues from thinnings from non-conifer trees, SFC: stumps from final fellings from conifer trees, SFNC: stumps from final fellings from non-conifer trees) in 2020 and 2030 (NUTS0 level).

8.3 Waste biomass potential

Waste (municipal and wood)								
Year	**2020**				**2030**			
Country	Absolute [Mton dm]				Absolute [Mton dm]			
	BUC	*BSC*	*HPW*	*NHPW*	*BUC*	*BSC*	*HPW*	*NHPW*
Austria	**0.83**	1.17	0.09	0.21	**0.88**	1.24	0.09	0.22
Belgium	0.48	1.45	0.16	0.20	0.53	1.48	0.17	0.33
Bulgaria	0.48	0.09	0.01	0.02	0.45	0.09	0.01	0.03
Croatia	0.29	0.20	0.02	0.05	0.28	0.20	0.03	0.07
Cyprus	0.23	0.04	0.01	0.03	0.24	0.05	0.01	0.03
Czech. Rep.	**0.55**	0.30	0.06	0.25	0.56	0.30	0.08	0.32
Denmark	**0.73**	0.58	0.09	0.46	0.77	0.61	0.09	0.46
Estonia	0.13	0.07	0.01	0.05	0.12	0.07	0.02	0.07
Finland	**0.61**	0.41	0.09	0.25	**0.64**	0.43	0.10	0.28
France	**11.12**	2.13	0.47	0.33	**11.65**	2.22	0.48	0.37
Germany	**9.02**	9.02	0.73	2.84	**8.92**	8.92	0.75	2.94
Greece	**1.78**	0.20	0.07	0.29	**1.68**	0.19	0.07	0.32
Hungary	**0.57**	0.52	0.04	0.18	**0.56**	0.51	0.05	0.23
Ireland	0.33	0.33	0.05	0.09	0.33	0.33	0.05	0.09
Italy	**4.77**	7.16	0.50	1.30	**4.94**	7.41	0.53	1.46
Latvia	0.13	0.05	0.02	0.08	0.11	0.05	0.03	0.10
Lithuania	0.21	0.09	0.02	0.09	0.17	0.07	0.03	0.12
Luxembourg	0.06	0.10	0	0	0.07	0.13	0	0
Malta	0.08	0.02	0	0.01	0.09	0.02	0	0.01
Netherlands	**1.25**	1.52	0.09	0.56	1.28	1.56	0.09	0.57
Poland	**2.65**	0.51	0.29	1.38	**2.59**	0.49	0.36	1.77
Portugal	**1.45**	0.28	0.06	0.25	**1.40**	0.27	0.06	0.27
Romania	**1.96**	0.37	0.04	0.61	**1.89**	0.36	0.05	0.76
Slovak Rep.	0.37	0.16	0.02	0.05	0.36	0.15	0.02	0.07
Slovenia	0.16	0.09	0.01	0.05	0.18	0.09	0.01	0.06
Spain	**7.60**	1.90	0.33	0.74	**7.39**	1.85	0.34	0.82
Sweden	**1.18**	0.78	0.08	0.42	**1.27**	0.85	0.08	0.43
UK	**5.02**	6.13	0.56	1.46	**5.30**	6.48	0.57	1.50
Serbia	**0.91**	0.17	0.03	0.07	**0.70**	0.33	0.04	0.10
Turkey	**9.69**	1.82	0.53	1.18	**8.39**	3.87	0.57	1.39
Albania	0.42	0.08	0.01	0.03	0.35	0.16	0.02	0.05
Bosnia & Herzegovina	0.37	0.07	0.03	0.08	0.28	0.13	0.03	0.11
FYROM	0.23	0.04	0.01	0.03	0.19	0.09	0.01	0.04
Kosovo	0	0	0	0	0	0	0	0
Moldova	0.33	0.06	0.01	0.02	0.26	0.12	0.01	0.03
Montenegro	0.09	0.02	0	0	0.07	0.03	0	0
Ukraine	4.00	0.71	0.16	0.48	3.08	1.32	0.20	0.70
EU-28	54.04	35.67	3.92	12.25	54.65	36.42	4.17	13.7
Europe	70.08	38.64	4.7	14.14	67.97	42.47	5.05	16.12
High lignite	28.14	13.25	1.83	6.92	26.28	15.3	2.01	7.99

Table 14. Sustainable potential of waste in absolute level from municipal waste (BUC: Biowaste unseparately collected–**RDF included**, BSC: Biowaste separately collected) and waste from wood (HPW: Hazardous post-consumer wood, NHPW: Non-Hazardous post-consumer wood) in 2020 and 2030 (NUTS0 level).

Biowaste unseparately collected					
Year		**2020**		**2030**	
Country	*Nuts2 area*	AW [kton dm·km^{-2}]	Absolute [kton dm]	AW [kton dm·km^{-2}]	Absolute [kton dm]
Germany	**Stuttgart**	42	443	41	438
	Karlsruhe	44	303	43	300
	Oberbayern	28	488	28	483
	Berlin	433	386	428	382
	Darmstadt	57	423	56	418
	Düsseldorf	**107**	**568**	**106**	**562**
	Köln	66	486	65	480
	Arnsberg	50	402	50	397
	Schleswig-Holstein	20	313	20	309
	Sachsen-Anhalt	12	255	12	252
	Thuringen	15	245	15	242
	Leipzig	28	110	27	109
	Brandenburg	9	275	9	272
	Dresden	23	179	22	177
	Trier	11	57	11	56
Greece	**Attiki**	**163**	**623**	**154**	**587**
	Central Macedonia	17	313	16	295
	Western Mecedonia	5	46	5	44
Italy	**Veneto**	22	390	23	404
	Lombardia	**33**	**779**	**34**	**807**
	Piemonte	14	350	14	362
	Emilia-Romagna	16	349	16	361
	Lazio	26	442	27	457
	Campania	34	463	35	479
	Puglia	17	325	17	337
	Sicilia	16	402	16	416
Poland	**Mazowieckie**	**10**	**365**	**10**	**357**
	Śląskie	26	319	25	312
	Dolnoslaskie	10	201	10	197
	Lubuskie	5	71	5	69
	Łódzkie	10	175	9	171
Romania	**Nord-Est**	**9**	**321**	**8**	**310**
	Sud - Muntenia	9	305	9	294

Table 15. Sustainable potential of biowaste unseparately collected in 2020 and 2030 in different areas in Europe (NUTS2 level).

8.4 Lignocellulosic biomass potential

Energy grasses, annual & perennial crops										
Year	**2020**					**2030**				
Country	Absolute [Mton dm]					Absolute [Mton dm]				
	MSC	*SGR*	*CRD*	*GR*	*RCG*	*MSC*	*SGR*	*CRD*	*GR*	*RCG*
Austria	**0.14**	0.20	0	0	**0.10**	**0.14**	0.20	0	0	0.10
Belgium	0.15	0.31	0	0.02	0.18	0.20	0.43	0	0.02	0.25
Bulgaria	2.41	1.41	0	0	0.09	1.92	1.14	0	0	0.07
Croatia	0.02	0.04	0.01	0	0.01	0.02	0.03	0.01	0	0.01
Cyprus	0.07	0.12	0	0.10	0	0.07	0.11	0	0.09	0
Czech. Rep.	**0.52**	0.68	0	0	0.43	0.58	0.77	0	0	0.47
Denmark	**0.26**	0.33	0	0	0.15	0.24	0.31	0	0	0.14
Estonia	0.17	0.26	0	0	0.11	0.16	0.24	0	0	0.10
Finland	**0**	0.52	0	0	**0**	**0**	0.62	0	0	0
France	**3.02**	3.84	0	0.04	**0.74**	**4.02**	5.06	0	0.05	0.99
Germany	**1.79**	1.84	0	0	**0.81**	**3.15**	3.22	0	0	1.42
Greece	**0.31**	0.47	0	0.49	**0**	**0.29**	0.43	0	0.45	0
Hungary	**1.28**	1.90	0	0	**0.70**	**1.32**	1.96	0	0	0.72
Ireland	0	0.22	0	0	0.18	0	0.20	0	0	0.16
Italy	**3.12**	3.25	0	2.35	**0.22**	**2.80**	2.92	0	2.12	0.19
Latvia	0.25	0.38	0	0	0.16	0.29	0.44	0	0	0.18
Lithuania	0.80	1.20	0	0	0.49	0.85	1.27	0	0	0.52
Luxembourg	0.02	0.03	0	0	0.01	0.02	0.04	0	0	0.02
Malta	-	-	-	-	-	-	-	-	-	-
Netherlands	**0.27**	0.20	0	0.02	0.02	0.48	0.35	0	0.04	0.04
Poland	**4.47**	6.06	0	0	**2.16**	**5.12**	6.98	0	0	2.50
Portugal	**0.36**	0.55	0	0.35	**0.02**	**0.34**	0.51	0	0.32	0.02
Romania	**6.77**	6.61	0	0	**1.30**	**6.72**	6.60	0	0	1.32
Slovak Rep.	0.19	0.27	0	0	0.13	0.22	0.31	0	0	0.15
Slovenia	0.02	0.01	0	0	0	0.04	0.02	0	0	0.01
Spain	**6.07**	8.25	0	6.50	**0.13**	**6.42**	8.70	0	6.76	0.12
Sweden	**0.29**	0.45	0	0	**0.21**	**0.33**	0.54	0	0	0.25
UK	**0.52**	1.29	0	0.02	**0.50**	**0.66**	1.59	0	0.02	0.61
Serbia	**0.59**	0.84	0	0	**0.30**	**0.56**	0.81	0	0	0.29
Turkey	**11.25**	7.22	0.18	0.02	**0.44**	**10.62**	7.20	0.17	0.01	0.37
Albania	0.61	0.46	0	0	0	0.61	0.46	0	0	0
Bosnia & Herzegovina	2.19	1.62	0	0	0	2.16	1.60	0	0	0
FYROM	0.43	0.34	0	0	0.02	0.43	0.34	0	0	0.02
Kosovo	1.14	0.84	0	0	0.30	1.18	0.88	0	0	0.29
Moldova	0.43	0.64	0	0	0.23	0.43	0.64	0	0	0.23
Montenegro	0.08	0.06	0	0	0	0.07	0.06	0	0	0
Ukraine	4.15	7.32	0	0	3.44	4.15	7.32	0	0	3.44
EU-28	33.29	40.7	0.01	9.89	8.85	36.4	44.99	0.01	9.87	10.36
Europe	54.16	60	0.19	9.91	13.6	56.61	64.3	0.18	9.88	15
High lignite	29.6	27.3	0.18	0.51	6.36	30.54	29.44	0.17	0.46	7.32

Table 16. Sustainable potential of lignocellulosic biomass – energy grass, annual and perennial crops (MSC: Miscanthus, SGR: Switchgrass, CRD: Cardoon, GR: Giant Reed, Reed Canary Grass: Reed Canary Grass) in 2020 and 2030 (NUTS0 level).

Short rotation coppice						
Year	2020			2030		
Country	Absolute [Mton dm]			Absolute [Mton dm]		
	SRCW	*SRCP*	*SRCO*	*SRCW*	*SRCP*	*SRCO*
Austria	**0**	0	0	0	0	0
Belgium	0.09	0	0	0.13	0	0
Bulgaria	0	0	0	0	0	0
Croatia	0	0	0	0	0	0
Cyprus	0	0	0	0	0	0
Czech. Rep.	**0**	0	0	0	0	0
Denmark	**0**	0	0	0	0	0
Estonia	0	0	0	0	0	0
Finland	**0**	0	0	0	0	0
France	**1.23**	0	0.49	1.67	0	0.64
Germany	**0**	0	0	0	0	0
Greece	**0**	0	0	0	0	0
Hungary	**0**	0	0	0	0	0
Ireland	0.44	0	0	0.39	0	0
Italy	**0.69**	0	0.56	0.59	0	0.48
Latvia	0	0	0	0	0	0
Lithuania	0	0	0	0	0	0
Luxembourg	0	0	0	0	0	0
Malta	0	0	0	0	0	0
Netherlands	**0.07**	0	0	0.12	0	0
Poland	**0**	0	0	0	0	0
Portugal	**0**	0	0.06	0	0	0.06
Romania	**0**	0	0	0	0	0
Slovak Rep.	0	0	0	0	0	0
Slovenia	0	0	0	0	0	0
Spain	**0.19**	0	0.17	0.19	0	0.23
Sweden	**0**	0	0	0	0	0
UK	**1.18**	0	0	1.46	0	0
Serbia	**0**	0	0	0	0	0
Turkey	**0.02**	0	0	0.03	0	0
Albania	0	0	0	0	0	0
Bosnia & Herzegovina	0	0	0	0	0	0
FYROM	0	0	0	0	0	0
Kosovo	0	0	0	0	0	0
Moldova	0	0	0	0	0	0
Montenegro	0	0	0	0	0	0
Ukraine	0	0	0	0	0	0
EU-28	3.89	0	1.28	0	4.55	0
Europe	3.91	0	1.28	0	4.58	0
High lignite	0.02	0	0	0	0.03	0

Table 17. Sustainable potential of lignocellulosic biomass – short rotation coppice (SRCW: SRC Willow, SRCP: SRC Poplar, SRCO: Other SRC) in 2020 and 2030 (NUTS0 level).

8.5 Secondary residues potential

By-products and residues from fruit and food processing industry										
Year	2020					2030				
Country	Absolute [Mton dm]					Absolute [Mton dm]				
	OS	*OFP*	*RH*	*PGD*	*CB*	*OS*	*OFP*	*RH*	*PGD*	*CB*
Austria	**0**	0	0	0.01	**0.38**	**0**	0	0	0.01	0.40
Belgium	0	0	0	0	0.75	0	0	0	0	0.76
Bulgaria	0	0.01	0.01	0.01	0.29	0	0.01	0.01	0	0.28
Croatia	0	0	0	0.01	0.11	0	0	0	0.01	0.12
Cyprus	0	0	0	0	0.01	0	0	0	0	0.01
Czech. Rep.	**0**	0	0	0	0.75	0	0	0	0	0.77
Denmark	**0**	0	0	0	1.09	0	0	0	0	1.05
Estonia	0	0	0	0	0.08	0	0	0	0	0.13
Finland	**0**	0	0	0	**0.52**	**0**	0	0	0	0.51
France	**0**	0.02	0.03	0.16	**3.56**	**0.01**	0.03	0.04	0.16	3.75
Germany	**0**	0	0	0.04	**4.59**	**0**	0	0	0.03	4.82
Greece	**0.17**	0.04	0.05	0.01	**0.39**	**0.17**	0.05	0.06	0.01	0.43
Hungary	**0**	0	0	0.01	**0.50**	**0**	0	0	0	0.48
Ireland	0	0	0	0	0.42	0	0	0	0	0.43
Italy	**0.32**	0.22	0.30	0.14	**1.84**	**0.32**	0.23	0.27	0.13	1.80
Latvia	0	0	0	0	0.12	0	0	0	0	0.16
Lithuania	0	0	0	0	0.20	0	0	0	0	0.28
Luxembourg	0	0	0	0	0	0	0	0	0	0
Malta	0	0	0	0	0	0	0	0	0	0
Netherlands	**0**	0	0	0	1.21	0	0	0	0	1.21
Poland	**0**	0	0	0	**2.98**	**0**	0	0	0	3.12
Portugal	**0.04**	0.03	0.04	0.02	**0.32**	**0.05**	0.04	0.05	0.02	0.32
Romania	**0**	0.01	0.01	0.01	**0.77**	**0**	0.01	0.01	0.01	0.61
Slovak Rep.	0	0	0	0	0.17	0	0	0	0	0.19
Slovenia	0	0	0	0	0.06	0	0	0	0	0.06
Spain	**0.59**	0.02	0.19	0.09	**2.85**	**0.62**	0.03	0.18	0.08	2.93
Sweden	**0**	0	0	0	**0.52**	**0**	0	0	0	0.56
UK	**0**	0	0	0	**2.76**	**0**	0	0	0	3.25
Serbia	**0**	-	-	0	**0.23**	**0**	-	-	0	0.24
Turkey	**0.11**	0.18	0.24	0	**3.87**	**0.11**	0.21	0.23	0	3.98
Albania	0.01	-	-	0	0	0.01	-	-	0	0
Bosnia & Herzegovina	0	-	-	0	0.01	0	-	-	0	0.01
FYROM	0	0	0	0	0.02	0	0	0	0	0.02
Kosovo	0	-	-	0	0	0	-	-	0	0
Moldova	0	-	-	-	0.02	0	-	-	-	0.02
Montenegro	0	-	-	0	-	0	-	-	0	-
Ukraine	0	-	-	-	2.95	0	-	-	-	2.95
EU-28	1.12	0.35	0.63	0.51	27.2	1.17	0.4	0.62	0.46	28.43
Europe	1.24	0.53	0.87	0.51	34.3	1.29	0.61	0.85	0.46	35.65
High lignite	0.11	0.2	0.26	0.07	14.2	0.11	0.23	0.25	0.04	14.55

Table 18. Sustainable potential of secondary agricultural residues (OS: Olive-ston, OFP: Other food processing residues, RH: Rice husk, PGD: Pressed grapes dregs, CB: Cereal bran) in 2020 and 2030 (NUTS0 level).

Saw mill residues								
Year	2020				2030			
Country	Absolute [Mton dm]				Absolute [Mton dm]			
	SDC	*SDNC*	*ORC*	*ORNC*	*SDC*	*SDNC*	*ORC*	*ORNC*
Austria	**0.74**	0.01	1.48	0.03	**0.66**	0.01	1.32	0.02
Belgium	0.10	0.02	0.19	0.05	0.10	0.02	0.18	0.04
Bulgaria	0.08	0.02	0.15	0.04	0.08	0.02	0.15	0.04
Croatia	0.02	0.12	0.03	0.18	0.02	0.14	0.03	0.22
Cyprus	0	0	0	0	0	0	0	0
Czech. Rep.	**0.44**	0.03	0.82	0.06	0.45	0.03	0.83	0.06
Denmark	**0.04**	0.02	0.07	0.04	0.04	0.02	0.07	0.04
Estonia	0.20	0.02	0.39	0.05	0.20	0.02	0.38	0.05
Finland	**1.39**	0.01	2.71	0.02	**1.31**	0.01	2.54	0.01
France	**0.56**	0.24	1.07	0.56	**0.70**	0.30	1.34	0.70
Germany	**2.07**	0.10	3.70	0.20	**2.02**	0.10	3.61	0.19
Greece	**0.02**	0.02	0.03	0.04	**0.02**	0.02	0.03	0.05
Hungary	**0.01**	0.04	0.02	0.09	**0.01**	0.04	0.02	0.09
Ireland	0.48	0.01	0.93	0.03	0.49	0.01	0.95	0.03
Italy	**0.06**	0.04	0.10	0.09	**0.06**	0.04	0.11	0.09
Latvia	0.40	0.13	0.74	0.27	0.49	0.16	0.92	0.34
Lithuania	0.13	0.11	0.25	0.22	0.14	0.11	0.27	0.23
Luxembourg	0	0.01	0.01	0.01	0	0	0.01	0.01
Malta	0	0	0	0	0	0	0	0
Netherlands	**0.02**	0.01	0.03	0.02	0.02	0.01	0.03	0.02
Poland	**0.73**	0.12	1.32	0.24	**0.81**	0.13	1.46	0.26
Portugal	**0.08**	0.02	0.16	0.03	**0.08**	0.01	0.15	0.03
Romania	**0.56**	0.33	1.01	0.70	**0.60**	0.36	1.07	0.74
Slovak Rep.	0.14	0.05	0.28	0.13	0.14	0.05	0.28	0.12
Slovenia	0.10	0.02	0.18	0.04	0.13	0.02	0.23	0.05
Spain	**0.16**	0.07	0.31	0.15	**0.15**	0.06	0.28	0.14
Sweden	**2.63**	0.02	4.83	0.04	**2.64**	0.02	4.84	0.04
UK	**0.48**	0.01	0.93	0.03	**0.49**	0.01	0.95	0.03
Serbia	**0.02**	0.07	0.03	0.11	**0.02**	0.08	0.03	0.13
Turkey	**0.53**	0.33	0.98	0.69	**0.57**	0.35	1.04	0.73
Albania	0	0.01	0	0.02	0	0.01	0	0.02
Bosnia & Herzegovina	0.14	0.08	0.23	0.14	0.14	0.08	0.23	0.14
FYROM	0	0.01	0.01	0.01	0	0.01	0.01	0.01
Kosovo	0	0	0	0	0	0	0	0
Moldova	0	0	0	0	0	0	0	0
Montenegro	0.02	0.01	0.03	0.01	0.02	0.01	0.04	0.02
Ukraine	0.18	0.07	0.34	0.15	0.21	0.08	0.39	0.17
EU-28	11.64	1.6	21.74	3.36	11.85	1.72	22.05	3.64
Europe	12.53	2.18	23.36	4.49	12.81	2.34	23.79	4.86
High lignite	4.7	1.13	8.52	2.34	4.85	1.2	8.75	2.46

Table 19. Sustainable potential of secondary residues from wood industry (SDC: Sawdust (conifers), SDNC: Sawdust (non-conifers), ORC: Other residues (conifers), ORNC: Other residues (non-conifers) in 2020 and 2030 (NUTS0 level).

Pulp/ paper industry and further wood processing								
Year	2020				2030			
Country	Absolute [Mton dm]				Absolute [Mton dm]			
	SFWP	*RFW*	*Bark*	*Black Liquor*	*SFWP*	*RFW*	*Bark*	*Black Liquor*
Austria	**0.16**	0.48	0.19	1.27	**0.16**	0.47	0.19	1.27
Belgium	0.04	0.16	0.06	0.26	0.04	0.15	0.06	0.26
Bulgaria	0.04	0.16	0.06	0.26	0.04	0.15	0.06	0.26
Croatia	0.01	0.07	0	0	0.02	0.09	0	0
Cyprus	0	0.05	0	0	0	0.05	0	0
Czech. Rep.	**0.10**	0.51	0.09	0.60	0.10	0.53	0.09	0.60
Denmark	**0.03**	0.21	0	0	0.01	0.17	0	0
Estonia	0.05	0.21	0.03	0.07	0.05	0.22	0.03	0.07
Finland	**0.39**	0.23	1.70	6.82	**0.42**	0.23	1.70	6.82
France	**0.20**	1.04	0.22	1.24	**0.22**	1.20	0.22	1.24
Germany	**0.52**	2.36	0.35	1.59	**0.55**	2.42	0.35	1.59
Greece	**0.01**	0.17	0	0	**0.01**	0.17	0	0
Hungary	**0.06**	0.41	0	0	**0.08**	0.49	0	0
Ireland	0.03	0.05	0	0	0.03	0.05	0	0
Italy	**0.22**	1.44	0.03	0.03	**0.22**	1.50	0.03	0.03
Latvia	0.17	0.23	0	0	0.19	0.27	0	0
Lithuania	0.05	0.38	0	0	0.07	0.44	0	0
Luxembourg	0.02	0	0	0	0.02	0	0	0
Malta	0	0.01	0	0	0	0.01	0	0
Netherlands	**0**	0.34	0	0	0	0.35	0	0
Poland	**0.46**	2.70	0.14	0.88	**0.48**	2.94	0.14	0.88
Portugal	**0.06**	0.41	0.35	2.40	**0.07**	0.40	0.35	2.40
Romania	**0.47**	1.23	0	0	**0.54**	1.37	0	0
Slovak Rep.	0.02	0.20	0.10	0.68	0.03	0.22	0.10	0.68
Slovenia	0.07	0.17	0.01	0	0.08	0.22	0.01	0
Spain	**0.23**	0.99	0.27	1.85	**0.24**	0.96	0.27	1.85
Sweden	**0.06**	0.50	1.90	7.83	**0.07**	0.54	1.90	7.83
UK	**0.06**	1.41	0.02	0	**0.06**	1.48	0.02	0
Serbia	**0.02**	0.07	0	0	**0.02**	0.08	0	0
Turkey	**0.41**	1.17	0.01	0	**0.44**	1.25	0.01	0
Albania	0	0.02	0	0	0	0.03	0	0
Bosnia & Herzegovina	0.01	0.08	0.01	0.08	0.01	0.09	0.01	0.08
FYROM	0	0.02	0	0	0	0.02	0	0
Kosovo	0	0.01	0	0	0	0.01	0	0
Moldova	0	0.08	0	0	0	0.09	0	0
Montenegro	0	0.01	0	0	0	0.01	0	0
Ukraine	0.19	0.27	0	0	0.20	0.31	0	0
EU-28	3.53	16.12	5.52	25.78	3.8	17.09	5.52	25.78
Europe	4.16	17.85	5.54	25.86	4.47	18.98	5.54	25.86
High lignite	2.18	9.15	0.76	4.01	2.37	9.84	0.76	4.01

Table 20. Sustainable potential of secondary residues from wood industry (SFWP: Residues from industries producing semi-finished wood based panels, RFW: Residues from further wood processing) in 2020 and 2030 (NUTS0 level).

8.6 Biomass potential in selected European countries (NUTS0/NUTS2 level)

8.6.1 Germany

Production from forests (Stemwood, stumps, logging residues from final fellings and thinnings)				
Year	**2020**		**2030**	
	AW [kton dm·km^{-2}]	Absolute [kton dm]	AW [kton dm·km^{-2}]	Absolute [kton dm]
Final fellings from nonconifer trees (stemwood)	32	11,391	31	11,131
Final fellings from conifer trees (stemwood)	41	14,546	42	15,028
Thinnings from nonconifer trees (stemwood)	20	7,321	21	7,589
Thinnings from conifer trees (stemwood)	24	8,520	24	84,12
Total (stemwood)	-	**41,778**	-	**42,160**
Final fellings from nonconifer trees (loggings)	**2**	**823**	**2**	**830**
Final fellings from conifer trees (loggings)	**3**	**1,200**	**3**	**1,213**
Thinnings from nonconifer trees (loggings)	1	279	1	292
Thinnings from conifer trees (loggings)	1	359	1	332
Final fellings from nonconifer trees (stumps)	0	0	0	0
Final fellings from conifer trees (stumps)	0	0	0	0
Total (logging residues and stumps)	-	**2,661**	-	**2,667**
Total forest production	-	**44,439**	-	**44,827**
Agricultural residues (Straw/stubbles)				
Cereal (wheat) straw	60	21,624	59	20,945
Maize stover	5	1,724	5	1,844
Sugar beet leaves	3	1,016	3	949
Sunflower straw	0	89	0	61
Oil seed rape straw	10	3,584	8	2,684
Rice straw	0	0	0	0
Total (straw/stubbles)	-	**28,037**	-	**26,483**
Agricultural residues (Woody prunnings and orchards residues)				
Vineyards	0	67	0	66
Fruit tree plantations	0	82	0	78
Olives/Citrus/Nuts tree plantations	0	0	0	0
Total (prunnings& orchards residues)	-	149	-	144
Secondary residues (pulp & paper industry, industry utilizing agricultural products) and biowaste (unseparately collected)				
Sawdust (conifers)	6	2,071	6	2,021
Sawdust (nonconifers)	0	103	0	101
Other (conifers)	10	3,697	10	3,609
Other (nonconifers)	1	197	1	193
From semi-finished wood based panels	1	515	2	551
From further woodprocessing	7	2,362	7	2,421
Bark	1	348	1	348
Black liquor	4	1,591	4	1,591
Olive-ston/ rice husk/ pressed grapes dregs	0/0/0	0/0/35	0/0/0	0/0/34
Cereal bran	13	4,586	13	4,823
Total (secondary residues)	-	**15,505**	-	**15,692**
Biowaste unseparately collected	25	9,016	25	8,918
Energy grasses, annual & perennial crops				
Miscanthus	5	1,790	9	3,148
Switchgrass	5	1,835	9	3,221
Reed canary grass	2	808	4	1,420
Total (energy grasses etc.)	-	**4,433**	-	**7,789**

Table 21. Sustainable biomass potential in Germany in 2020 and 2030 (NUTS0 level).

Agricultural residues (Straw/stubbles)																
	Cereal straw				*Maize stover*				*Sugar beet leaves*				*Oil seed rape straw*			
	AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]	
Area	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Stuttgart	82	83	870	880	10	11	106	119	4	4	43	38	8	6	82	60
Karlsruhe	47	46	324	317	20	22	138	151	1	1	10	7	4	2	26	16
Freiburg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tübingen	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oberbayern	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Niederbayern	15	16	159	165	9	9	89	97	1	1	13	11	1	1	9	6
Oberpfalz	61	59	590	572	5	5	49	48	2	2	18	18	6	4	59	36
Oberfranken	70	71	507	512	1	1	7	9	1	1	4	4	8	5	61	37
Mittelfranken	73	71	532	511	3	3	20	21	2	2	16	17	8	5	56	38
Unterfranken	103	105	877	900	5	5	38	41	9	9	73	75	10	6	87	54
Schwaben	1	1	9	9	0	0	1	1	0	0	0	0	0	0	1	1
Berlin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brandenburg	9	9	262	270	1	1	24	28	0	0	0	0	1	1	35	22
Bremen	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Hamburg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Darmstadt	62	48	463	359	6	7	46	55	2	5	16	40	5	3	37	23
Gießen	58	48	312	258	1	1	5	6	0	0	0	0	8	5	43	28
Kassel	65	54	543	448	0	0	2	2	0	0	0	0	10	7	84	54
Mecklenburg-Vorpommern	127	127	2929	2930	2	2	38	46	4	3	84	78	32	22	741	503
Braunschweig	139	139	1126	1126	1	1	8	9	18	16	144	131	15	14	120	111
Hannover	131	132	1188	1195	6	5	51	47	11	10	102	88	15	11	136	102
Lüneburg	36	34	560	532	2	2	30	27	2	1	26	22	3	2	54	35
Weser-Ems	15	15	218	223	10	12	153	179	0	0	1	1	1	1	20	17
Düsseldorf	53	50	280	264	10	10	53	51	8	6	45	31	2	2	13	12
Köln	67	64	493	473	1	1	10	9	16	12	121	90	2	2	17	15
Münster	71	69	489	479	43	42	296	292	0	0	1	1	4	4	29	27
Detmold	98	97	642	634	15	15	100	97	2	2	16	14	16	14	102	91
Arnsberg	38	37	308	296	4	3	29	27	1	1	6	5	7	6	54	48
Koblenz	47	42	376	339	0	0	3	3	1	0	4	4	11	10	90	83
Trier	20	17	101	83	0	0	1	1	0	0	0	1	3	3	16	14
Rheinhessen-Pfalz	70	66	476	449	10	12	68	81	10	10	71	71	6	5	38	32
Saarland	29	26	74	66	0	1	1	1	0	0	0	0	4	2	9	6
Chemnitz	97	94	634	616	8	10	54	65	0	1	0	3	21	13	138	87
Dresden	97	94	771	749	8	10	65	79	0	1	0	4	21	13	168	106
Leipzig	97	94	387	376	8	10	33	39	0	1	0	2	21	13	84	53
Sachsen-Anhalt	125	118	2568	2430	8	8	165	161	8	7	160	149	30	28	617	568
Schleswig-Holstein	54	52	848	806	0	0	4	5	1	0	9	7	12	8	182	120
Thüringen	105	103	1706	1675	2	3	37	45	2	2	31	35	23	17	378	279

Table 22. Sustainable agro biomass potential–straw/stubbles- in several areas of Germany (NUTS2 level) for reference years 2020 (Y20) and 2030 (Y30). *With red are marked areas in Germany near lignite mining areas*

Production from forests (Stemwood from final fellings and thinnings)																
	Final fellings nonconifer trees				*Final fellings conifer trees*				*Thinnings from nonconifer trees*				*Thinnings conifer trees*			
Area	AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]	
	Y20	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Stuttgart	42	42	443	439	30	27	311	283	27	28	284	300	12	12	123	126
Karlsruhe	44	45	302	314	179	163	1237	1125	32	36	224	249	73	77	502	532
Freiburg	42	44	394	418	87	76	823	718	32	36	305	340	30	31	278	290
Tübingen	31	32	281	291	33	29	299	269	21	23	196	207	13	14	118	124
Oberbayern	29	29	516	506	128	116	2238	2041	19	20	341	349	41	43	721	748
Niederbayern	24	24	248	243	53	47	551	490	15	16	158	160	15	15	154	155
Oberpfalz	22	22	209	214	125	121	1209	1174	16	17	153	164	38	36	365	346
Oberfranken	24	24	176	174	71	70	515	503	16	16	114	118	22	21	158	149
Mittelfranken	28	28	201	200	70	71	510	516	18	19	131	137	18	15	134	112
Unterfranken	68	65	578	556	103	99	882	846	40	40	343	341	37	37	314	316
Schwaben	22	22	217	217	45	41	452	414	15	16	153	162	15	15	148	152
Berlin	25	26	23	23	13	17	12	15	19	20	17	18	16	15	14	14
Brandenburg	19	20	575	595	30	39	877	1161	13	14	389	408	36	34	1066	1003
Bremen	37	37	15	15	27	36	11	15	36	40	14	16	34	32	14	13
Hamburg	40	28	365	343	15	21	136	187	25	24	226	222	23	22	211	199
Darmstadt	85	71	633	529	30	30	262	222	39	42	289	316	19	19	138	144
Gießen	77	64	414	343	22	23	119	122	33	36	178	192	16	17	85	91
Kassel	66	53	551	442	56	54	466	446	28	30	231	247	37	41	307	333
Mecklenburg-Vorpommern	24	27	561	620	14	18	312	406	17	17	389	389	17	16	391	375
Braunschweig	47	43	382	348	13	18	103	143	28	27	225	218	21	20	170	160
Hannover	40	38	365	343	15	21	136	187	25	24	226	222	23	22	211	199
Lüneburg	16	18	247	279	13	19	207	300	13	14	206	210	27	25	417	394
Weser-Ems	13	14	199	211	8	11	113	160	10	10	155	157	14	13	205	197
Düsseldorf	24	28	129	148	4	5	21	29	23	25	124	130	4	4	22	20
Köln	34	37	249	269	10	14	73	101	25	25	181	185	12	14	91	100
Münster	17	19	115	134	17	22	116	152	15	15	101	105	18	19	124	131
Detmold	23	22	149	143	26	34	168	222	15	15	95	98	29	31	190	205
Arnsberg	46	46	368	368	16	22	132	178	29	30	231	237	21	23	172	188
Koblenz	56	55	452	447	18	22	144	177	39	39	319	315	16	14	127	114
Trier	51	50	253	247	48	62	238	303	37	36	180	177	45	41	222	200
Rheinhessen-Pfalz	46	45	313	311	37	39	251	270	33	33	229	228	21	18	144	126
Saarland	48	45	123	116	15	17	39	43	55	57	142	147	19	20	49	50
Chemnitz	14	14	91	89	47	46	305	302	10	11	67	72	25	25	163	165
Dresden	17	19	137	147	40	43	319	340	15	16	116	126	28	28	224	223
Leipzig	13	15	52	59	10	12	41	49	12	13	47	51	10	10	40	39
Sachsen-Anhalt	20	21	403	422	13	18	271	376	14	14	286	295	20	19	407	385
Schleswig-Holstein	20	18	306	288	4	5	55	81	10	11	161	173	7	7	110	102
Thüringen	44	38	718	617	47	52	762	847	20	20	317	328	25	24	402	383

Table 23. Sustainable forest biomass potential–production from forests (Stemwood) - in several areas of Germany (NUTS2 level) for reference years 2020 (Y20) and 2030 (Y30). *With red are marked areas in Germany near lignite mining areas*

Primary residues from forests (Loggings)																
	Final fellings nonconifer trees				*Final fellings conifer trees*				*Thinnings from nonconifer trees*				*Thinnings conifer trees*			
	AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]	
Area	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Stuttgart	4	4	45	45	4	4	47	42	2	2	17	18	1	1	12	12
Karlsruhe	2	2	16	15	4	3	26	23	1	1	6	7	1	1	6	6
Freiburg	2	3	22	24	3	3	28	24	1	1	10	11	1	1	6	6
Tübingen	3	3	30	31	6	5	53	47	1	1	12	13	1	1	13	13
Oberbayern	3	3	48	48	13	12	227	207	1	1	18	19	3	3	45	44
Niederbayern	2	2	23	23	7	7	77	69	1	1	8	8	1	1	13	13
Oberpfalz	1	1	9	10	17	16	167	158	0	0	3	4	3	3	31	31
Oberfranken	1	1	6	7	4	3	25	25	0	0	2	2	0	0	4	3
Mittelfranken	1	1	9	9	6	6	45	46	0	0	3	3	1	1	6	5
Unterfranken	2	2	17	17	1	1	8	8	1	1	7	7	0	0	2	1
Schwaben	2	2	22	23	7	6	68	62	1	1	9	9	1	1	14	14
Berlin	3	4	3	3	2	3	2	3	1	1	1	1	2	1	1	1
Brandenburg	1	1	28	30	2	3	59	78	0	0	4	5	1	1	22	18
Bremen	6	6	2	3	4	6	2	2	3	3	1	1	3	3	1	1
Hamburg	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Darmstadt	3	3	23	20	1	1	10	10	1	1	6	7	0	0	3	3
Gießen	7	6	37	31	3	3	17	16	2	2	9	10	1	1	7	7
Kassel	7	6	59	48	5	4	39	36	2	2	14	15	2	2	16	16
Mecklenburg-Vorpommern	2	2	49	56	1	1	26	34	1	1	13	13	1	1	16	14
Braunschweig	3	3	24	24	1	1	6	9	1	1	8	8	1	0	5	4
Hannover	3	3	26	25	0	1	4	6	1	1	8	8	0	0	4	4
Lüneburg	2	2	24	27	1	2	19	27	0	0	6	7	1	1	11	9
Weser-Ems	1	1	16	17	1	1	15	20	0	0	4	4	1	1	11	10
Düsseldorf	2	3	13	15	0	0	1	1	1	1	7	8	0	0	1	1
Köln	1	1	6	7	0	0	1	1	0	0	3	3	0	0	1	1
Münster	1	2	9	11	1	2	8	11	0	0	2	2	0	0	0	0
Detmold	0	0	3	3	0	0	1	2	0	0	1	1	0	0	0	0
Arnsberg	3	3	21	22	1	1	7	9	1	1	8	8	1	1	6	6
Koblenz	4	4	30	31	2	2	14	16	2	2	12	12	1	1	7	6
Trier	4	4	21	21	2	3	12	15	2	2	8	8	1	1	7	5
Rheinhessen-Pfalz	3	3	18	18	2	2	11	12	1	1	8	8	1	1	6	5
Saarland	6	5	15	14	2	2	5	5	4	4	9	10	1	1	2	2
Chemnitz	2	2	10	10	8	8	50	49	1	1	4	5	3	3	17	16
Dresden	2	2	12	14	5	5	41	42	1	1	5	6	2	2	15	14
Leipzig	1	1	4	6	1	1	2	3	1	1	2	3	0	0	2	1
Sachsen-Anhalt	2	2	32	37	1	1	17	26	1	1	13	14	1	1	18	15
Schleswig-Holstein	2	2	33	31	0	1	5	8	0	0	7	7	0	0	2	2
Thüringen	3	3	55	50	3	4	53	60	1	1	17	17	2	1	25	21

Table 24. Sustainable forest biomass potential–primary residues from forests (loggings) - in several areas of Germany (NUTS2 level) for reference years 2020 (Y20) and 2030 (Y30). *With red are marked areas in Germany near lignite mining areas*

Energy grasses, annual & perennial crops												
	Miscanthus				*Switchgrass*				*Reed canary grass*			
Area	AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]	
	Y20	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Stuttgart	6	11	69	121	4	7	42	75	3	4	26	47
Karlsruhe	2	4	16	28	3	6	24	42	1	2	10	17
Freiburg	4	7	38	66	2	4	19	34	1	3	13	24
Tübingen	5	10	50	89	3	6	31	55	2	4	20	35
Oberbayern	8	14	135	238	2	4	43	77	1	3	26	46
Niederbayern	4	8	45	80	7	12	68	119	3	5	30	52
Oberpfalz	5	10	53	94	2	4	20	35	2	3	17	31
Oberfranken	3	5	21	37	4	8	32	56	2	3	13	23
Mittelfranken	8	14	56	99	3	5	21	37	3	4	18	32
Unterfranken	7	12	59	103	3	5	22	38	2	4	18	31
Schwaben	4	7	42	74	6	11	63	110	3	5	28	49
Berlin	0	0	0	0	0	0	0	0	0	0	0	0
Brandenburg	1	2	29	52	1	1	22	38	0	0	0	0
Bremen	0	0	0	0	0	0	0	0	0	0	0	0
Hamburg	0	0	0	0	0	0	0	0	0	0	0	0
Darmstadt	5	9	40	71	3	6	24	44	2	3	14	26
Gießen	6	10	31	55	2	4	12	21	2	3	10	18
Kassel	3	5	25	45	5	8	38	67	2	4	17	29
Mecklenburg-Vorpommern	4	7	97	171	6	11	145	256	3	5	61	108
Braunschweig	4	8	36	63	7	12	54	93	3	5	24	41
Hannover	5	9	47	83	8	14	71	124	3	6	31	55
Lüneburg	7	13	114	198	7	13	112	194	0	0	2	3
Weser-Ems	5	9	80	137	8	14	120	205	4	6	53	90
Düsseldorf	8	14	42	75	5	9	26	47	3	5	16	28
Köln	9	16	68	121	3	6	26	45	3	5	22	38
Münster	7	11	45	79	10	17	68	118	4	7	29	50
Detmold	6	10	36	64	8	15	54	96	4	6	24	42
Arnsberg	5	10	44	78	2	4	16	29	2	3	14	25
Koblenz	4	7	31	56	4	8	35	62	2	4	17	30
Trier	3	6	16	28	5	8	24	42	2	4	11	18
Rheinhessen-Pfalz	4	7	27	49	6	11	41	73	2	4	16	29
Saarland	3	5	8	13	5	8	12	20	2	3	5	8
Chemnitz	5	9	33	58	7	13	49	86	3	6	21	38
Dresden	5	9	39	69	7	13	58	103	3	6	26	46
Leipzig	5	9	20	35	7	13	29	52	3	6	13	22
Sachsen-Anhalt	6	11	124	217	8	13	156	271	3	5	53	93
Schleswig-Holstein	6	10	93	163	9	16	139	244	4	7	60	106
Thüringen	5	9	80	143	7	13	120	214	3	6	51	91

Table 25. Sustainable lignocellulosic biomass potential –energy grasses, annual and perennial crops - in several areas of Germany (NUTS2 level) for reference years 2020 (Y20) and 2030 (Y30). *With red are marked areas in Germany near lignite mining areas*

Secondary residues and municipal waste																
	Sawdust (conifers)				*Other (conifers)*				*Black liquor*				*Biowaste unseparately collected*			
	AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]	
Area	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Stuttgart	11	11	114	111	19	19	204	199	7	7	73	73	42	41	443	438
Karlsruhe	6	6	40	39	10	10	72	70	15	15	104	104	44	43	303	300
Freiburg	8	8	80	78	15	15	143	139	7	7	62	62	26	26	243	241
Tübingen	12	12	109	107	21	21	195	191	3	3	31	31	22	22	200	197
Oberbayern	5	5	84	82	9	8	150	146	5	5	94	94	28	28	488	483
Niederbayern	5	5	54	53	9	9	96	94	3	3	31	31	13	13	131	130
Oberpfalz	5	4	44	43	8	8	78	76	1	1	10	10	12	12	119	118
Oberfranken	2	2	17	16	4	4	29	29	1	1	10	10	16	16	118	116
Mittelfranken	6	6	43	42	11	10	77	75	1	1	10	10	26	26	190	187
Unterfranken	7	7	60	59	13	12	107	105	6	6	52	52	17	17	145	143
Schwaben	8	8	81	80	15	14	146	142	5	5	52	52	20	19	197	195
Berlin	13	13	12	12	24	23	21	21	0	0	0	0	433	428	386	382
Brandenburg	6	6	189	185	11	11	338	330	2	2	52	52	9	9	275	272
Bremen	18	18	7	7	32	31	13	13	0	0	0	0	181	179	72	73
Hamburg	7	6	5	5	12	11	9	8	0	0	0	0	268	265	198	196
Darmstadt	5	5	36	35	9	8	64	63	6	6	42	42	57	56	423	418
Gießen	4	4	20	20	7	7	36	36	0	0	0	0	21	21	115	113
Kassel	7	7	57	56	12	12	102	100	6	6	52	52	16	16	134	133
Mecklenburg-Vorpommern	3	3	76	74	6	6	135	132	0	0	10	10	8	8	176	175
Braunschweig	2	2	18	18	4	4	33	32	1	1	10	10	22	22	177	175
Hannover	4	4	38	37	8	7	68	67	3	3	31	31	26	26	236	233
Lüneburg	1	1	22	21	3	2	39	38	1	1	10	10	12	12	186	184
Weser-Ems	3	3	39	38	5	5	70	69	6	6	83	83	18	18	273	270
Düsseldorf	8	8	43	42	14	14	76	74	18	18	94	94	107	106	568	562
Köln	4	4	29	28	7	7	52	51	20	20	146	146	66	65	486	480
Münster	13	12	88	86	23	22	156	153	3	3	21	21	41	41	286	283
Detmold	22	22	146	143	40	39	261	255	6	6	42	42	34	34	224	222
Arnsberg	11	11	90	88	20	20	161	157	8	8	62	62	50	50	402	397
Koblenz	8	8	68	67	15	15	122	119	6	6	52	52	20	20	163	161
Trier	14	13	68	66	25	24	121	118	0	0	0	0	11	11	57	56
Rheinhessen-Pfalz	3	3	21	20	5	5	37	36	9	9	62	62	32	32	221	219
Saarland	6	6	16	16	11	11	29	28	0	0	0	0	43	43	112	110
Chemnitz	5	5	35	34	10	9	62	61	13	13	83	83	26	25	167	165
Dresden	5	5	42	41	9	9	74	73	5	5	42	42	23	22	179	177
Leipzig	3	3	13	13	6	6	23	23	8	8	31	31	28	27	110	109
Sachsen-Anhalt	3	3	56	54	5	5	99	97	2	2	31	31	12	12	255	252
Schleswig-Holstein	2	2	31	31	4	4	56	55	3	3	52	52	20	20	313	309
Thüringen	5	5	78	76	9	8	139	136	3	3	52	52	15	15	245	242

Table 26. Sustainable biomass potential– Secondary residues from pulp & paper industry and municipal waste unseparately collected- in several areas of Germany (NUTS2 level) for reference years 2020 (Y20) and 2030 (Y30). *With red are marked areas in Germany near lignite mining areas*

8.6.2 Poland

Production from forests (Stemwood, stumps, logging residues from final fellings and thinnings)				
Year	**2020**		**2030**	
	AW [kton dm·km^{-2}]	Absolute [kton dm]	AW [kton dm·km^{-2}]	Absolute [kton dm]
Final fellings from nonconifer trees (stemwood)	14	4,308	13	4,011
Final fellings from conifer trees (stemwood)	35	10,810	33	10,292
Thinnings from nonconifer trees (stemwood)	4	1,383	4	1,370
Thinnings from conifer trees (stemwood)	11	3,319	10	3,086
Total (stemwood)	-	**19,820**	-	**18,759**
Final fellings from nonconifer trees (loggings)	1	418	1	392
Final fellings from conifer trees (loggings)	4	1,241	4	1,185
Thinnings from nonconifer trees (loggings)	0	49	0	48
Thinnings from conifer trees (loggings)	0	119	0	108
Final fellings from nonconifer trees (stumps)	0	0	0	0
Final fellings from conifer trees (stumps)	0	0	0	0
Total (logging residues and stumps)	-	**1,827**	-	**1,733**
Total forest production	-	**21,647**	-	**20,492**
Agricultural residues (Straw/stubbles)				
Cereal (wheat) straw	53	16,582	46	14,289
Maize stover	6	1,744	4	1,157
Sugar beet leaves	2	771	2	743
Sunflower straw	0	41	0	60
Oil seed rape straw	4	1,222	4	1,254
Rice straw	0	0	0	0
Total (straw/stubbles)	-	**20,360**	-	**17,503**
Agricultural residues (Woody prunnings and orchards residues)				
Vineyards	0	0	0	0
Fruit tree plantations	2	577	2	549
Olives/Citrus/Nuts tree plantations	0	0	0	0
Total (prunnings& orchards residues)	-	577	-	549
Secondary residues (pulp & paper industry, industry utilizing agricultural products) and biowaste (unseparately collected)				
Sawdust (conifers)	2	732	3	808
Sawdust (nonconifers)	0	117	0	130
Other (conifers)	4	1,318	5	1,455
Other (nonconifers)	1	235	1	259
From semi-finished wood based panels	1	456	2	483
From further woodprocessing	9	2,703	9	2,937
Bark	0	144	0	144
Black liquor	3	882	3	882
Olive-ston/ rice husk/ pressed grapes dregs	0/0/0	0/0/0	0/0/0	0/0/0
Cereal bran	10	2,977	10	3,115
Total (secondary residues)	-	**9,564**	**-**	**10,213**
Biowaste unseparately collected	9	2,653	8	2,593
Energy grasses, annual & perennial crops				
Miscanthus	14	4,471	16	5,115
Switchgrass	19	6,062	22	6,982
Reed canary grass	7	2,157	8	2,498
Total (energy grasses etc.)	-	**12,690**	**-**	**14,595**

Table 27. Sustainable biomass potential in Poland in 2020 and 2030 (NUTS0 level).

Agricultural residues (Straw/stubbles)																
	Cereal straw				*Maize stover*				*Sugar beet leaves*				*Oil seed rape straw*			
	AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]	
Area	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Kujawsko-Pomorskie	76	65	1359	1163	9	5	163	94	7	7	131	121	11	13	205	231
Warmińsko-Mazurskie	29	21	690	513	1	1	30	23	0	0	9	8	3	2	66	54
Pomorskie	29	26	519	469	1	1	18	17	1	1	21	20	3	2	48	43
Wielkopolskie	74	63	2197	1881	9	6	255	194	6	6	175	176	6	7	190	213
Zachodnio-pomorskie	50	45	1132	1008	2	1	34	18	1	1	33	33	7	7	153	158
Lubuskie	24	20	330	277	4	3	57	45	0	0	6	6	2	1	21	18
Lubelskie	89	76	2245	1920	4	3	108	63	4	4	101	92	3	4	86	103
Podkarpackie	44	37	779	666	4	3	65	62	1	1	19	18	2	2	32	35
Świętokrzyskie	53	40	621	466	2	1	19	15	2	2	28	28	1	1	13	14
Podlaskie	31	22	622	439	1	0	18	9	1	1	14	14	0	0	7	8
Łódzkie	69	59	1260	1069	3	1	60	25	1	1	13	14	2	2	32	36
Mazowieckie	54	46	1905	1624	4	2	134	75	2	2	73	70	2	2	61	69
Dolnośląskie	78	75	1562	1498	23	15	456	299	4	4	88	87	8	7	165	145
Opolskie	98	98	919	918	26	15	244	146	6	5	52	51	12	11	116	103
Małopolskie	0	0	4	4	0	0	0	0	0	0	0	0	0	0	0	0
Śląskie	35	30	438	374	7	6	81	71	0	0	6	5	2	2	26	23

Table 28. Sustainable agro biomass potential–straw/stubbles- in several Polish areas (NUTS2 level) for 2020 (Y20) and 2030 (Y30). *With red are marked Polish areas near lignite mines.*

Production from forests (Stemwood from final fellings and thinnings)																
	Final fellings nonconifer trees				*Final fellings conifer trees*				*Thinnings nonconifer trees*				*Thinnings conifer trees*			
	AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]	
Area	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Kujawsko-Pomorskie	6	6	117	100	32	29	570	529	2	2	34	36	10	10	183	174
Warmińsko-Mazurskie	21	20	516	470	47	43	1132	1032	6	6	142	146	12	11	291	265
Pomorskie	16	16	294	284	51	48	926	868	5	4	86	80	15	14	266	250
Wielkopolskie	10	10	305	289	29	30	869	890	3	3	90	89	13	12	377	358
Zachodnio-pomorskie	24	22	530	500	42	41	935	915	7	6	146	136	11	10	246	219
Lubuskie	17	16	231	217	61	60	852	843	4	4	60	53	17	14	244	202
Lubelskie	10	9	240	230	18	19	441	475	4	4	99	106	6	5	152	135
Podkarpackie	31	29	550	526	41	38	733	681	11	11	203	193	14	13	245	223
Świętokrzyskie	7	6	82	74	30	31	351	367	3	3	30	32	10	9	121	108
Podlaskie	20	15	395	312	30	29	614	580	4	4	79	87	11	10	213	211
Łódzkie	6	5	111	91	24	23	429	420	1	2	26	28	7	7	136	126
Mazowieckie	7	6	239	227	16	16	577	581	2	2	79	82	5	5	192	167
Dolnośląskie	16	16	318	323	51	44	1020	885	7	7	142	132	14	15	289	292
Opolskie	8	7	76	70	34	31	316	293	3	3	31	32	10	10	93	92
Małopolskie	11	11	163	168	23	21	343	315	5	5	82	81	6	6	96	89
Śląskie	12	11	142	130	57	50	702	621	4	5	55	57	14	14	174	174

Table 29. Sustainable forest biomass potential–production from forests (Stemwood) - in several Polish areas (NUTS2 level) for 2020 (Y20) and 2030 (Y30). *With red are marked Polish areas near lignite mines.*

	Primary residues from forests (Loggings)															
	Final fellings nonconifer trees				*Final fellings conifer trees*				*Thinnings nonconifer trees*				*Thinnings conifer trees*			
	AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]	
Area	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Kujawsko-Pomorskie	1	1	15	13	4	4	74	69	0	0	2	2	0	0	5	5
Warmińsko-Mazurskie	2	2	57	52	5	4	113	102	0	0	6	6	0	0	11	10
Pomorskie	2	2	36	35	8	7	139	131	0	0	4	3	1	1	12	11
Wielkopolskie	1	1	34	32	3	3	101	104	0	0	4	4	0	0	13	12
Zachodnio-pomorskie	2	2	53	51	5	5	104	101	0	0	5	5	0	0	8	7
Lubuskie	1	1	21	20	8	8	113	111	0	0	1	1	1	1	10	8
Lubelskie	1	1	23	22	1	2	35	38	0	0	3	4	0	0	3	3
Podkarpackie	2	2	33	33	4	4	73	67	0	0	6	5	0	0	9	8
Świętokrzyskie	1	1	11	10	5	5	57	59	0	0	2	2	1	1	8	7
Podlaskie	1	1	25	20	2	1	32	30	0	0	0	0	0	0	1	1
Łódzkie	1	1	16	13	4	4	76	74	0	0	1	1	0	0	8	7
Mazowieckie	1	1	26	25	2	2	74	74	0	0	3	3	0	0	7	6
Dolnośląskie	2	2	32	33	5	4	96	83	0	0	6	6	1	1	11	10
Opolskie	1	1	9	8	4	4	41	38	0	0	1	1	0	0	2	2
Małopolskie	1	1	12	12	2	2	36	33	0	0	3	3	0	0	5	4
Śląskie	1	1	16	14	6	6	77	70	0	0	2	3	1	1	8	7

Table 30. Sustainable forest biomass potential–primary residues from forests (loggings) - in several Polish areas (NUTS2 level) for 2020 (Y20) and 2030 (Y30). *With red are marked Polish areas near lignite mines.*

	Energy grasses, annual & perennial crops											
	Miscanthus				*Switchgrass*				*Reed canary grass*			
	AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]	
Area	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Kujawsko-Pomorskie	12	15	223	263	19	22	333	393	8	9	144	169
Warmińsko-Mazurskie	23	27	556	649	17	20	416	486	0	0	0	0
Pomorskie	12	13	224	243	18	20	335	363	8	8	137	148
Wielkopolskie	15	19	448	572	22	29	670	856	10	12	290	371
Zachodnio-pomorskie	12	14	265	310	18	21	398	465	8	9	169	197
Lubuskie	9	11	127	150	14	16	189	224	6	7	82	97
Lubelskie	14	17	354	427	21	25	527	636	9	11	232	280
Podkarpackie	12	13	222	237	19	20	332	355	8	9	147	157
Świętokrzyskie	14	16	168	184	21	24	251	275	9	10	111	122
Podlaskie	16	16	313	315	12	12	234	235	0	0	0	0
Łódzkie	19	21	349	385	23	27	423	484	0	0	0	0
Mazowieckie	14	15	486	523	20	22	726	780	9	9	312	335
Dolnośląskie	14	18	289	353	22	26	431	527	10	12	192	234
Opolskie	20	26	190	249	30	40	285	374	13	18	127	166
Małopolskie	8	7	120	112	19	19	285	290	8	8	118	120
Śląskie	11	12	138	143	18	19	228	238	8	8	98	102

Table 31. Sustainable lignocellulosic biomass potential –energy grasses, annual and perennial crops - in several areas of Poland (NUTS2 level) for reference years 2020 (Y20) and 2030 (Y30). *With red are marked Polish areas near lignite mines.*

Secondary residues and municipal waste																
	Sawdust (conifers)				*Other (conifers)*				*Black liquor*				*Biowaste unseparately collected*			
Area	AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]	
	Y20	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Kujawsko-Pomorskie	2	2	31	34	3	3	56	62	1	1	26	26	8	8	145	142
Warmińsko-Mazurskie	2	3	56	61	4	5	100	111	0	0	0	0	4	4	100	98
Pomorskie	3	4	62	69	6	7	112	124	1	1	26	26	9	8	158	154
Wielkopolskie	3	4	99	109	6	7	178	197	3	3	78	78	8	8	239	233
Zachodnio-pomorskie	3	3	62	68	5	5	111	123	2	2	52	52	5	5	111	109
Lubuskie	3	3	43	48	6	6	77	86	7	7	104	104	5	5	71	69
Lubelskie	1	1	33	36	2	3	59	65	0	0	0	0	6	6	150	147
Podkarpackie	3	3	54	59	5	6	96	106	0	0	0	0	8	8	147	144
Świętokrzyskie	2	2	23	25	4	4	41	45	0	0	0	0	8	7	88	86
Podlaskie	2	2	36	39	3	4	64	71	0	0	0	0	4	4	83	81
Łódzkie	1	2	26	29	3	3	48	53	3	3	52	52	10	9	175	171
Mazowieckie	1	1	40	45	2	2	73	80	3	3	104	104	10	10	365	357
Dolnośląskie	2	2	32	36	3	3	58	64	3	3	52	52	10	10	201	197
Opolskie	2	3	23	26	4	5	42	46	14	14	130	130	7	7	70	68
Małopolskie	4	4	59	65	7	8	107	118	5	5	78	78	15	15	231	226
Śląskie	4	5	53	58	8	8	95	104	15	15	182	182	26	25	319	312

Table 32. Sustainable biomass potential– Secondary residues from pulp & paper industry and municipal waste unseparately collected- in several areas of Poland (NUTS2 level) for reference years 2020 (Y20) and 2030 (Y30). *With red are marked areas in Poland near lignite mining areas*

8.6.3 Romania

Production from forests (Stemwood, stumps, logging residues from final fellings and thinnings)				
Year	**2020**		**2030**	
	AW [kton dm·km^{-2}]	Absolute [kton dm]	AW [kton dm·km^{-2}]	Absolute [kton dm]
Final fellings from nonconifer trees (stemwood)	23	5,506	20	4,879
Final fellings from conifer trees (stemwood)	13	3,186	14	3,347
Thinnings from nonconifer trees (stemwood)	14	3,334	14	3,333
Thinnings from conifer trees (stemwood)	9	2,049	8	1,877
Total (stemwood)	-	**14,075**	-	**13,436**
Final fellings from nonconifer trees (loggings)	4	925	3	816
Final fellings from conifer trees (loggings)	2	478	2	501
Thinnings from nonconifer trees (loggings)	1	295	1	295
Thinnings from conifer trees (loggings)	1	247	1	193
Final fellings from nonconifer trees (stumps)	0	0	0	0
Final fellings from conifer trees (stumps)	0	0	0	0
Total (logging residues and stumps)	-	**1,945**	-	**1,805**
Total forest production	-	**16,020**	-	**15,241**
Agricultural residues (Straw/stubbles)				
Cereal (wheat) straw	19	4,599	17	4,155
Maize stover	20	4,851	18	4,302
Sugar beet leaves	1	135	1	131
Sunflower straw	5	1,281	5	1,224
Oil seed rape straw	3	800	5	1,146
Rice straw	0	59	0	60
Total (straw/stubbles)	-	**11,725**	-	**11,018**
Agricultural residues (Woody prunnings and orchards residues)				
Vineyards	0	3	0	2
Fruit tree plantations	0	110	0	88
Olives/Citrus/Nuts tree plantations	0/0/0	0/0/0	0/0/0	0/0/0
Total (prunnings& orchards residues)	-	**113**	-	**90**
Secondary residues (pulp & paper industry, industry utilizing agricultural products) and biowaste (unseparately collected)				
Sawdust (conifers)	2	559	2	594
Sawdust (nonconifers)	1	334	1	355
Other (conifers)	4	1,006	4	1,069
Other (nonconifers)	3	695	3	738
From semi-finished wood based panels	2	466	2	539
From further woodprocessing	5	1,227	6	1,365
Bark	0	0	0	0
Black liquor	0	0	0	0
Olive-ston/ rice husk/ pressed grapes dregs	0/0/0	0/13/8	0/0/0	0/14/6
Cereal bran	3	766	3	614
Total (secondary residues)	-	5,074	-	5,374
Biowaste unseparately collected	8	**1,958**	8	**1,890**
Energy grasses, annual & perennial crops				
Miscanthus	28	6,765	28	6,722
Switchgrass	28	6,614	28	6,598
Reed canary grass	5	1,302	6	1,315
Total (energy grasses etc.)	-	**14,681**	-	**14,635**

Table 33. Sustainable biomass potential in Romania in 2020 and 2030 (NUTS0 level).

Agricultural residues (Straw/stubbles)																
	Cereal straw				*Maize stover*				*Sunflower straw*				*Oil seed rape straw*			
Area	AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]	
	Y20	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Nord-Vest	7	8	244	260	11	11	384	385	2	2	56	58	0	0	9	13
Centru	1	1	23	20	1	1	21	18	0	0	6	6	0	0	4	6
Nord-Est	11	9	400	330	29	26	1072	975	5	6	199	223	2	4	81	135
Sud-Est	22	18	793	632	29	24	1019	874	13	12	460	426	8	11	272	377
Sud - Muntenia	41	35	1414	1209	25	18	859	612	11	9	368	314	10	14	349	487
București - Ilfov	11	10	20	18	8	6	14	10	3	2	5	4	2	3	4	5
Sud-Vest Oltenia	38	38	1101	1099	28	26	822	772	3	3	101	98	2	3	66	99
Vest	19	18	604	588	21	20	661	656	3	3	85	96	0	1	14	22

Table 34. Sustainable agro biomass potential–straw/stubbles- in several areas in Romania (NUTS2 level) for 2020 (Y20) and 2030 (Y30).

Production from forests (Stemwood from final fellings and thinnings)																
	Final fellings nonconifer trees				*Final fellings conifer trees*				*Thinnings nonconifer trees*				*Thinnings conifer trees*			
Area	AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]	
	Y20	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Nord-Vest	25	22	849	759	15	16	510	536	16	16	535	532	10	9	329	300
Centru	26	22	870	763	21	22	705	740	17	17	589	588	13	12	455	415
Nord-Est	28	25	1015	905	17	18	635	668	17	17	623	622	11	10	409	373
Sud-Est	16	14	565	495	8	8	273	286	7	7	255	260	5	4	176	161
Sud - Muntenia	15	13	527	463	9	9	310	325	9	9	303	305	6	5	199	183
București - Ilfov	10	9	18	16	4	5	8	8	5	5	9	9	3	3	5	5
Sud-Vest Oltenia	20	17	574	506	11	12	334	351	12	12	339	340	7	7	213	197
Vest	34	30	1088	972	13	14	412	432	21	21	681	678	8	8	263	243

Table 35. Sustainable forest biomass potential–production from forests (Stemwood) - in several areas in Romania (NUTS2 level) for 2020 (Y20) and 2030 (Y30).

Primary residues from forests (Loggings)																
	Final fellings nonconifer trees				*Final fellings conifer trees*				*Thinnings nonconifer trees*				*Thinnings conifer trees*			
Area	AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]	
	Y20	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Nord-Vest	4	4	141	125	2	2	68	72	1	1	47	47	1	1	36	28
Centru	3	3	117	103	2	2	79	83	1	1	40	40	1	1	38	30
Nord-Est	6	6	229	203	4	4	133	140	2	2	73	73	2	1	67	52
Sud-Est	3	3	109	94	1	2	53	55	1	1	24	25	1	1	25	19
Sud - Muntenia	2	2	82	71	1	1	43	45	1	1	28	28	1	1	25	20
București - Ilfov	1	1	2	2	1	1	1	1	0	0	1	1	0	0	1	1
Sud-Vest Oltenia	3	2	75	66	2	2	45	47	1	1	24	24	1	1	25	20
Vest	5	5	170	151	2	2	55	58	2	2	58	57	1	1	30	24

Table 36. Sustainable forest biomass potential–primary residues from forests (loggings) - in several areas in Romania (NUTS2 level) for 2020 (Y20) and 2030 (Y30).

Energy grasses, annual & perennial crops												
	Miscanthus				*Switchgrass*				*Reed canary grass*			
	AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]	
Area	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Nord-Vest	10	11	356	366	16	16	531	545	7	7	227	233
Centru	6	7	202	232	9	10	300	345	4	4	131	151
Nord-Est	12	11	445	406	18	16	662	603	7	7	265	241
Sud-Est	54	53	1940	1888	42	41	1510	1470	2	2	71	69
Sud - Muntenia	43	41	1492	1417	37	35	1272	1207	4	4	135	128
București - Ilfov	120	135	216	244	88	99	158	179	0	0	0	0
Sud-Vest Oltenia	48	49	1404	1427	39	39	1129	1148	3	3	81	83
Vest	22	23	710	742	33	34	1052	1100	12	13	392	410

Table 37. Sustainable lignocellulosic biomass potential –energy grasses, annual and perennial crops - in several areas in Romania (NUTS2 level) for reference years 2020 (Y20) and 2030 (Y30).

Secondary residues and municipal waste																
	Sawdust (conifers)				*Other (conifers)*				*Other (non-conifers)*				*Biowaste unseparately collected*			
	AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]	
Area	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Nord-Vest	3	3	92	97	5	5	165	175	3	4	114	121	7	7	253	244
Centru	5	5	160	170	8	9	288	306	6	6	199	211	7	7	230	222
Nord-Est	3	4	123	131	6	6	222	236	4	4	153	163	9	8	321	310
Sud-Est	1	1	31	33	2	2	56	59	1	1	38	41	7	7	247	239
Sud - Muntenia	2	2	56	59	3	3	100	107	2	2	69	74	9	9	305	294
București - Ilfov	7	8	13	14	13	14	24	26	9	10	17	18	123	119	222	214
Sud-Vest Oltenia	1	1	28	29	2	2	50	53	1	1	34	36	7	7	201	194
Vest	2	2	56	60	3	3	102	108	2	2	70	74	6	5	178	172

Table 38. Sustainable biomass potential– Secondary residues from pulp & paper industry and municipal waste unseparately collected- in several areas in Romania (NUTS2 level) for reference years 2020 (Y20) and 2030 (Y30).

8.6.4 Hungary

Production from forests (Stemwood, stumps, logging residues from final fellings and thinnings)				
Year	**2020**		**2030**	
	AW [kton dm·km-2]	Absolute [kton dm]	AW [kton dm·km-2]	Absolute [kton dm]
Final fellings from nonconifer trees (stemwood)	30	3,071	30	2,788
Final fellings from conifer trees (stemwood)	4	382	6	526
Thinnings from nonconifer trees (stemwood)	14	1,287	15	1,352
Thinnings from conifer trees (stemwood)	2	202	1	124
Total (stemwood)	-	**4,942**	-	**4,790**
Final fellings from nonconifer trees (loggings)	6	580	6	524
Final fellings from conifer trees (loggings)	1	66	1	98
Thinnings from nonconifer trees (loggings)	1	117	1	125
Thinnings from conifer trees (loggings)	0	34	0	18
Final fellings from nonconifer trees (stumps)	0	0	0	0
Final fellings from conifer trees (stumps)	0	0	0	0
Total (logging residues and stumps)	-	**797**	-	**765**
Total forest production	-	**5,739**	-	**5,555**
Agricultural residues (Straw/stubbles)				
Cereal (wheat) straw	38	4344	35	4001
Maize stover	48	4476	49	4517
Sugar beet leaves	1	83	1	111
Sunflower straw	15	1360	13	1183
Oil seed rape straw	5	475	5	508
Rice straw	0	9	0	9
Total (straw/stubbles)	-	**10,747**	**-**	**10,329**
Agricultural residues (Woody prunnings and orchards residues)				
Vineyards	0	0	0	0
Fruit tree plantations	1	131	1	134
Olives/Citrus/Nuts tree plantations	0/0/0	0/0/0	0/0/0	0/0/0
Total (prunnings& orchards residues)	-	**131**	-	**134**
Secondary residues (pulp & paper industry, industry utilizing agricultural products) and biowaste (unseparately collected)				
Sawdust (conifers)	0	11	0	12
Sawdust (nonconifers)	0	41	0	44
Other (conifers)	0	19	0	21
Other (nonconifers)	1	86	1	94
From semi-finished wood based panels	1	60	1	79
From further woodprocessing	4	409	5	494
Bark	0	0	0	0
Black liquor	0	0	0	0
Olive-ston/ rice husk/ pressed grapes dregs	0/0/0	0/1/5	0/0/0	0/1/4
Cereal bran	5	503	5	475
Total (secondary residues)	-	**1,135**	-	**1,224**
Biowaste unseparately collected	6	570	6	563
Energy grasses, annual & perennial crops				
Miscanthus	14	1281	14	1316
Switchgrass	20	1904	21	1956
Reed canary grass	8	701	8	720
Total (energy grasses etc.)	-	**3,886**	-	**3,992**

Table 39. Sustainable biomass potential in Hungary in 2020 and 2030 (NUTS0 level).

Agricultural residues (Straw/stubbles)																
	Cereal straw				*Maize stover*				*Sunflower straw*				*Oil seed rape straw*			
Area	AW [kton dm·km⁻²]		Absolute [kton dm]		AW [kton dm·km⁻²]		Absolute [kton dm]		AW [kton dm·km⁻²]		Absolute [kton dm]		AW [kton dm·km⁻²]		Absolute [kton dm]	
	Y20	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Central Hungary	28	21	196	147	25	20	174	138	12	9	85	62	4	4	30	31
Central Transdanubia	39	38	437	423	47	48	521	535	14	14	159	150	4	4	50	47
Western Transdanubia	53	51	605	578	52	55	591	622	9	8	106	90	11	12	120	134
Southern Transdanubia	36	34	514	488	89	95	1270	1352	9	7	132	101	4	4	58	55
Northern Hungary	27	24	364	316	13	12	168	163	14	12	182	155	7	9	98	119
Northern Great Plain	29	24	518	521	47	44	840	787	22	22	383	390	3	3	49	49
Southern Great Plain	49	47	891	870	50	50	912	919	17	13	313	234	4	4	70	74

Table 40. Sustainable agro biomass potential–straw/stubbles- in several areas of Hungary (NUTS2 level) for 2020 (Y20) and 2030 (Y30). *With red are marked areas near lignite mines.*

Production from forests (Stemwood from final fellings and thinnings)																
	Final fellings nonconifer trees				*Final fellings conifer trees*				*Thinnings nonconifer trees*				*Thinnings conifer trees*			
Area	AW [kton dm·km⁻²]		Absolute [kton dm]		AW [kton dm·km⁻²]		Absolute [kton dm]		AW [kton dm·km⁻²]		Absolute [kton dm]		AW [kton dm·km⁻²]		Absolute [kton dm]	
	Y20	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Central Hungary	39	37	270	258	2	5	16	34	13	12	90	85	2	1	15	8
Central Transdanubia	36	26	394	289	4	4	39	49	15	19	168	206	1	1	13	8
Western Transdanubia	48	39	540	442	16	14	176	164	18	19	201	217	5	3	58	39
Southern Transdanubia	47	38	661	539	4	5	57	74	18	21	261	296	2	1	24	13
Northern Hungary	37	35	493	475	4	6	53	84	23	24	307	319	2	1	27	14
Northern Great Plain	22	24	387	428	1	2	13	28	9	8	154	134	1	0	11	5
Southern Great Plain	18	19	326	357	2	5	28	94	6	5	105	94	3	2	54	38

Table 41. Sustainable forest biomass potential–production from forests (Stemwood) - in several areas in Hungary (NUTS2 level) for 2020 (Y20) and 2030 (Y30).

Primary residues from forests (Loggings)																
	Final fellings nonconifer trees				*Final fellings conifer trees*				*Thinnings nonconifer trees*				*Thinnings conifer trees*			
Area	AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]	
	Y20	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Central Hungary	9	9	63	61	1	1	4	9	2	1	11	10	0	0	3	1
Central Transdanubia	6	4	63	47	1	1	8	10	1	2	14	18	0	0	3	1
Western Transdanubia	8	7	95	77	2	2	25	24	2	2	19	21	1	0	9	5
Southern Transdanubia	10	9	149	121	1	1	13	17	2	2	27	31	0	0	5	2
Northern Hungary	6	6	85	81	1	1	8	13	2	2	26	28	0	0	3	1
Northern Great Plain	3	3	49	54	0	0	2	4	0	0	8	6	0	0	1	0
Southern Great Plain	4	5	76	83	0	1	7	22	1	1	12	10	1	0	10	6

Table 42. Sustainable forest biomass potential–logging residues from forests - in several areas in Hungary (NUTS2 level) for 2020 (Y20) and 2030 (Y30).

8.6.5 Greece

Production from forests (Stemwood, stumps, logging residues from final fellings and thinnings)				
Year	2020		2030	
	AW [kton dm·km-2]	Absolute [kton dm]	AW [kton dm·km-2]	Absolute [kton dm]
Final fellings from nonconifer trees (stemwood)	5	610	4	557
Final fellings from conifer trees (stemwood)	3	453	3	413
Thinnings from nonconifer trees (stemwood)	5	601	4	549
Thinnings from conifer trees (stemwood)	3	447	3	408
Total (stemwood)	-	**2,111**	-	**1,927**
Final fellings from nonconifer trees (loggings)	1	68	0	63
Final fellings from conifer trees (loggings)	1	81	1	74
Thinnings from nonconifer trees (loggings)	0	36	0	33
Thinnings from conifer trees (loggings)	0	43	0	39
Final fellings from nonconifer trees (stumps)	0	0	0	0
Final fellings from conifer trees (stumps)	0	0	0	0
Total (logging residues and stumps)	-	**228**	-	**209**
Total forest production	-	**2,339**	-	**2,136**
Agricultural residues (Straw/stubbles)				
Cereal (wheat) straw	6	796	7	897
Maize stover	5	627	5	699
Sugar beet leaves	1	96	1	94
Sunflower straw	1	164	2	222
Oil seed rape straw	0	0	0	0
Rice straw	1	142	1	162
Total (straw/stubbles)	-	**1,825**	-	**2,074**
Agricultural residues (Woody prunnings and orchards residues)				
Vineyards	0	5	0	3
Fruit tree plantations	1	102	1	109
Olives/Citrus/Nuts tree plantations	1/0/0	77/14/0	1/0/0	71/14/0
Total (prunnings& orchards residues)	-	**198**	-	**197**
Secondary residues (pulp & paper industry, industry utilizing agricultural products) and biowaste (unseparately collected)				
Sawdust (conifers)	0	15	0	18
Sawdust (nonconifers)	0	19	0	23
Other (conifers)	0	28	0	32
Other (nonconifers)	0	41	0	48
From semi-finished wood based panels	0	14	0	13
From further woodprocessing	1	167	1	181
Bark/Black liquor	0	0	0	0
Olive ston	1	172	1	169
Rice husk/ pressed grapes dregs	0/0	51/10	0/0	57/10
Cereal bran	3	394	3	428
Total (secondary residues)	-	**911**	-	**979**
Biowaste unseparately collected	13	1,781	13	1,679
Energy grasses, annual & perennial crops				
Miscanthus	2	314	2	288
Switchgrass	4	467	3	428
Giant reed	4	485	3	453
Total (energy grasses etc.)	-	**1,266**	-	**1,169**

Table 43. Sustainable biomass potential in Greece in 2020 and 2030 (NUTS0 level).

Agricultural residues (Straw/stubbles)																
	Cereal straw				*Maize stover*				*Sunflower straw*				*Oil seed rape straw*			
Area	AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]	
	Y20	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Attiki	0	1	2	2	0	0	0	0	0	0	0	0	0	0	0	0
North Aegean	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
South Aegean	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crete	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
East Macedonia, Thrace	10	15	143	212	18	19	249	276	10	13	135	181	2	2	27	35
Central Macedonia	15	14	279	271	8	9	153	162	1	2	25	36	5	6	104	113
Western Macedonia	15	15	141	146	6	9	61	85	0	0	2	3	0	0	0	0
Epirus	1	1	11	11	1	1	11	8	0	0	0	0	0	0	1	1
Thessaly	10	11	135	151	4	5	63	70	0	0	1	2	0	0	1	1
Ionian islands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Western Greece	4	4	41	50	7	7	79	83	0	0	0	0	1	1	6	7
Central Greece	3	3	43	53	1	1	10	14	0	0	0	0	0	0	3	5
Peloponnese	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0

Table 44. Sustainable agro biomass potential–straw/stubbles- in several Greek areas (NUTS2 level) for 2020 (Y20) and 2030 (Y30). *With red are marked Greek areas near lignite mines.*

Secondary residues and municipal waste																
	Olive ston				*Rice husk*				*Cereal bran*				*Biowaste unseparately collected*			
Area	AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]	
	Y20	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Attiki	1	1	5	5	0	0	0	0	45	45	173	172	163	154	623	587
North Aegean	8	9	33	34	0	0	0	0	5	6	19	22	9	8	34	32
South Aegean	1	1	3	3	0	0	0	0	1	1	5	6	11	10	56	53
Crete	6	6	54	52	0	0	0	0	2	2	18	20	12	12	103	97
East Macedonia, Thrace	0	0	3	4	0	1	6	8	2	2	25	29	7	7	101	95
Central Macedonia	0	0	5	7	2	2	38	40	2	2	37	43	17	16	313	295
Western Macedonia	0	0	0	0	0	0	0	0	1	2	14	16	5	5	46	44
Epirus	0	0	1	1	0	0	1	1	1	1	9	11	6	6	56	53
Thessaly	0	0	2	2	0	0	0	0	2	2	30	34	8	8	117	110
Ionian islands	0	0	0	0	0	0	0	0	1	1	3	3	15	14	34	32
Western Greece	2	2	21	20	0	0	2	3	2	2	21	24	10	9	112	105
Central Greece	0	0	1	2	0	0	3	4	1	1	17	20	6	6	92	87
Peloponnese	3	3	42	40	0	0	0	1	2	2	24	28	6	6	94	89

Table 45. Sustainable biomass potential– Secondary residues from industry utilizing agricultural products and municipal waste unseparately collected- in several areas of Greece (NUTS2 level) for reference years 2020 (Y20) and 2030 (Y30). *With red are marked Greek areas near lignite mines.*

Energy grasses, annual & perennial crops												
	Miscanthus				*Switchgrass*				*Giant reed*			
Area	AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]	
	Y20	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Attiki	4	3	14	13	3	3	11	10	12	11	45	41
North Aegean	2	2	7	6	1	1	5	5	6	5	23	19
South Aegean	2	2	9	10	1	1	7	8	6	6	30	33
Crete	4	4	34	34	6	6	54	53	6	6	49	48
East Macedonia, Thrace	1	0	16	3	2	0	24	5	1	0	18	4
Central Macedonia	2	1	29	13	2	1	45	21	2	1	37	17
Western Macedonia	1	0	6	2	1	0	9	3	1	0	7	2
Epirus	2	2	17	22	3	4	27	34	2	3	22	28
Thessaly	2	1	25	18	3	2	38	27	2	2	30	22
Ionian islands	2	2	4	4	3	3	7	7	3	3	7	7
Western Greece	7	6	75	73	10	10	117	115	9	9	102	100
Central Greece	2	3	35	42	4	4	55	67	3	4	51	61
Peloponnese	3	3	43	46	4	5	68	73	4	5	65	70

Table 46. Sustainable lignocellulosic biomass potential –energy grasses, annual and perennial crops - in several areas of Greece (NUTS2 level) for reference years 2020 (Y20) and 2030 (Y30). *With red are marked Greek areas near lignite mines.*

8.6.6 Czech. Republic

Production from forests (Stemwood, stumps, logging residues from final fellings and thinnings)				
Year	**2020**		**2030**	
	AW [kton dm·km^{-2}]	Absolute [kton dm]	AW [kton dm·km^{-2}]	Absolute [kton dm]
Final fellings from nonconifer trees (stemwood)	23	1,793	23	1,799
Final fellings from conifer trees (stemwood)	51	3,995	50	3,981
Thinnings from nonconifer trees (stemwood)	17	1,313	17	1,334
Thinnings from conifer trees (stemwood)	29	2,283	29	2,252
Total (stemwood)	-	**9,384**	-	**9,366**
Final fellings from nonconifer trees (loggings)	4	333	4	344
Final fellings from conifer trees (loggings)	14	1,084	14	1,100
Thinnings from nonconifer trees (loggings)	2	140	2	147
Thinnings from conifer trees (loggings)	5	360	5	407
Final fellings from nonconifer trees (stumps)	0	0	0	0
Final fellings from conifer trees (stumps)	0	0	0	0
Total (logging residues and stumps)	-	**1917**	-	**1998**
Total forest production	-	**11,301**	-	**11,364**
Agricultural residues (Straw/stubbles)				
Cereal (wheat) straw	65	5088	65	5139
Maize stover	12	921	9	676
Sugar beet leaves	3	246	3	254
Sunflower straw	1	108	1	102
Oil seed rape straw	11	847	12	940
Rice straw	0	0	0	0
Total (straw/stubbles)		**7,210**		**7,111**
Agricultural residues (Woody prunnings and orchards residues)				
Vineyards	0	0	0	0
Fruit tree plantations	0	32	0	31
Olives/Citrus/Nuts tree plantations	0/0/0	0/0/0	0/0/0	0/0/0
Total (prunnings& orchards residues)	-	**32**	-	**31**
Secondary residues (pulp & paper industry, industry utilizing agricultural products) and biowaste (unseparately collected)				
Sawdust (conifers)	6	442	6	448
Sawdust (nonconifers)	0	31	0	31
Other (conifers)	10	821	11	831
Other (nonconifers)	1	62	1	62
From semi-finished wood based panels	1	96	1	100
From further woodprocessing	7	514	7	529
Bark	1	87	1	87
Black liquor	8	601	8	601
Olive-ston/ rice husk/ pressed grapes dregs	0/0/0	0/0/2	0/0/0	0/0/2
Cereal bran	9	756	10	771
Total (secondary residues)	-	**3,412**	-	**3,460**
Biowaste unseparately collected	7	554	7	561
Energy grasses, annual & perennial crops				
Miscanthus	7	522	7	584
Switchgrass	9	679	10	773
Reed canary grass	5	432	6	472
Total (energy grasses etc.)	-	**1,633**	-	**1829**

Table 47. Sustainable biomass potential in Czech. Republic in 2020 and 2030 (NUTS0 level).

Agricultural residues (Straw/stubbles)																
	Cereal straw				*Maize stover*				*Sugar beet leaves*				*Oil seed rape straw*			
Area	AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]	
	Y20	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Prague	49	43	24	22	5	2	2	1	2	2	1	1	8	8	4	4
Střední Čechy (Central Bohemia	99	100	1096	1104	11	7	119	74	6	6	69	66	19	21	208	235
Jihozápad (Southwest)	47	46	832	814	4	2	75	32	0	0	0	0	9	10	165	172
Severozápad (Northwest)	54	57	470	491	5	2	43	18	1	1	5	5	7	8	61	71
Severovýchod (Northeast)	60	64	752	790	13	6	165	71	5	5	68	68	14	17	176	216
Jihovýchod (Southeast)	88	88	1227	1228	26	26	361	359	2	3	34	37	11	11	147	156
Střední Morava (Central Moravia)	69	70	639	643	15	12	143	115	7	8	61	70	8	8	77	75

Table 48. Sustainable agro biomass potential–straw/stubbles- in several areas of Czech. Republic (NUTS2 level) for 2020 (Y20) and 2030 (Y30).

8.6.7 Bulgaria

Production from forests (Stemwood, stumps, logging residues from final fellings and thinnings)				
Year	**2020**		**2030**	
	AW [kton dm·km^{-2}]	Absolute [kton dm]	AW [kton dm·km^{-2}]	Absolute [kton dm]
Final fellings from nonconifer trees (stemwood)	13	1,476	13	1,442
Final fellings from conifer trees (stemwood)	4	393	4	467
Thinnings from nonconifer trees (stemwood)	5	514	5	521
Thinnings from conifer trees (stemwood)	7	826	7	811
Total (stemwood)	-	**3,209**	-	**3,241**
Final fellings from nonconifer trees (loggings)	4	459	4	452
Final fellings from conifer trees (loggings)	1	88	1	106
Thinnings from nonconifer trees (loggings)	1	77	1	78
Thinnings from conifer trees (loggings)	2	167	1	141
Final fellings from nonconifer trees (stumps)	0	0	0	0
Final fellings from conifer trees (stumps)	0	0	0	0
Total (logging residues and stumps)	-	**791**	-	**777**
Total forest production	-	**4,000**	-	**4,018**
Agricultural residues (Straw/stubbles)				
Cereal (wheat) straw	28	3062	27	2996
Maize stover	11	1220	11	1217
Sugar beet leaves	1	148	1	144
Sunflower straw	18	2020	16	1798
Oil seed rape straw	1	151	2	192
Rice straw	1	60	0	50
Total (straw/stubbles)	-	**6,661**	-	**6,397**
Agricultural residues (Woody prunnings and orchards residues)				
Vineyards	0	0	0	0
Fruit tree plantations	0	7	0	8
Olives/Citrus/Nuts tree plantations	0/0/0	0/0/0	0/0/0	0/0/0
Total (prunnings& orchards residues)	-	**7**	-	**8**
Secondary residues (pulp & paper industry, industry utilizing agricultural products) and biowaste (unseparately collected)				
Sawdust (conifers)	1	82	1	82
Sawdust (nonconifers)	0	21	0	21
Other (conifers)	1	149	1	148
Other (nonconifers)	0	41	0	41
From semi-finished wood based panels	0	28	0	30
From further woodprocessing	1	142	1	147
Bark	0	19	0	19
Black liquor	1	130	1	130
Olive-ston/ rice husk/ pressed grapes dregs	0/0/0	0/13/5	0/0/0	0/11/4
Cereal bran	3	289	3	283
Total (secondary residues)	-	**919**	-	**916**
Biowaste unseparately collected	4	481	4	447
Energy grasses, annual & perennial crops				
Miscanthus	22	2409	17	1918
Switchgrass	13	1412	10	1139
Reed canary grass	1	86	1	69
Total (energy grasses etc.)	-	**3,907**	-	**3,126**

Table 49. Sustainable biomass potential in Bulgaria in 2020 and 2030 (NUTS0 level).

Agricultural residues (Straw/stubbles)																
	Cereal straw				*Maize stover*				*Sunflower straw*				*Oil seed rape straw*			
Area	AW [kton dm·km-2]		Absolute [kton dm]		AW [kton dm·km-2]		Absolute [kton dm]		AW [kton dm·km-2]		Absolute [kton dm]		AW [kton dm·km-2]		Absolute [kton dm]	
	Y20	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Northwestern	37	36	703	690	19	18	369	343	32	29	601	560	0	0	0	0
Northern Central	44	44	657	655	25	25	371	364	33	30	486	447	0	0	0	0
Northeastern	51	54	743	788	27	29	396	420	35	31	510	450	0	0	1	2
Southeastern	15	11	297	213	0	1	9	10	8	5	165	90	8	10	150	190
Southwestern	10	9	195	177	2	2	48	48	2	2	43	44	0	0	0	0
Southern Central	21	21	466	472	1	1	27	31	10	9	214	208	0	0	0	0

Table 50. Sustainable agro biomass potential–straw/stubbles- in several areas of Bulgaria (NUTS2 level) for 2020 (Y20) and 2030 (Y30).

Production from forests (Stemwood from final fellings and thinnings)																
	Final fellings nonconifer				*Final fellings conifer*				*Thinnings nonconifer*				*Thinnings conifer*			
Area	AW [kton dm·km-2]		Absolute [kton dm]		AW [kton dm·km-2]		Absolute [kton dm]		AW [kton dm·km-2]		Absolute [kton dm]		AW [kton dm·km-2]		Absolute [kton dm]	
	Y20	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Northwestern	12	12	232	220	1	1	18	21	4	4	80	82	2	2	36	35
Northern Central	11	11	163	161	1	1	11	13	4	4	53	54	2	2	25	24
Northeastern	12	12	172	173	0	0	4	5	4	4	55	57	1	1	17	17
Southeastern	13	13	266	256	4	5	80	96	4	5	86	91	13	13	264	264
Southwestern	18	18	359	356	3	4	68	83	7	7	142	138	7	7	141	137
Southern Central	13	12	284	275	9	11	212	248	4	4	98	100	15	15	344	334

Table 51. Sustainable forest biomass potential–production from forests (Stemwood) - in several areas in Bulgaria (NUTS2 level) for 2020 (Y20) and 2030 (Y30).

Primary residues from forests (Loggings)																
	Final fellings nonconifer				*Final fellings conifer*				*Thinnings nonconifer*				*Thinnings conifer*			
Area	AW [kton dm·km-2]		Absolute [kton dm]		AW [kton dm·km-2]		Absolute [kton dm]		AW [kton dm·km-2]		Absolute [kton dm]		AW [kton dm·km-2]		Absolute [kton dm]	
	Y20	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Northwestern	3	3	57	54	0	0	4	5	0	0	8	9	0	0	6	5
Northern Central	4	4	61	61	0	0	4	4	1	1	9	9	0	0	6	5
Northeastern	4	4	54	54	0	0	1	1	1	1	8	9	0	0	3	3
Southeastern	3	3	67	65	1	1	17	21	1	1	11	12	2	2	49	42
Southwestern	5	5	109	109	1	1	16	20	1	1	21	20	1	1	30	25
Southern Central	5	5	112	110	2	2	46	55	1	1	19	19	3	3	72	61

Table 52. Sustainable forest biomass potential– Primary residues from forests (loggings) - in several areas in Bulgaria (NUTS2 level) for 2020 (Y20) and 2030 (Y30).

Energy grasses, annual & perennial crops												
	Miscanthus				*Switchgrass*				*Reed canary grass*			
Area	AW [kton dm·km-2]		Absolute [kton dm]		AW [kton dm·km-2]		Absolute [kton dm]		AW [kton dm·km-2]		Absolute [kton dm]	
	Y20	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Northwestern	33	28	638	530	25	20	468	388	0	0	0	0
Northern Central	18	15	268	219	14	11	203	166	0	0	7	6
Northeastern	13	10	184	143	15	11	215	165	4	3	54	42
Southeastern	41	31	809	617	6	5	115	90	0	0	0	0
Southwestern	3	2	55	49	3	3	64	57	1	1	15	13
Southern Central	20	16	454	361	15	12	346	273	0	0	10	8

Table 53. Sustainable lignocellulosic biomass potential –energy grasses, annual and perennial crops - in several areas of Bulgaria (NUTS2 level) for reference years 2020 (Y20) and 2030 (Y30).

8.6.8 Finland

Production from forests (Stemwood, stumps, logging residues from final fellings and thinnings)				
Year	2020		2030	
	AW [kton dm·km^{-2}]	Absolute [kton dm]	AW [kton dm·km^{-2}]	Absolute [kton dm]
Final fellings from nonconifer trees (stemwood)	5	1,755	8	2,815
Final fellings from conifer trees (stemwood)	53	17,732	50	16,949
Thinnings from nonconifer trees (stemwood)	4	1,463	4	1,208
Thinnings from conifer trees (stemwood)	28	9,599	26	8,924
Total (stemwood)	-	**30,549**	-	**29,896**
Final fellings from nonconifer trees (loggings)	1	245	1	402
Final fellings from conifer trees (loggings)	6	2002	6	1996
Thinnings from nonconifer trees (loggings)	0	27	0	22
Thinnings from conifer trees (loggings)	0	98	0	89
Final fellings from nonconifer trees (stumps)	1	214	1	345
Final fellings from conifer trees (stumps)	5	1611	5	1571
Total (logging residues and stumps)	-	**4,197**	-	**4,425**
Total forest production	-	**34,746**	-	**34,321**
Agricultural residues (Straw/stubbles)				
Cereal (wheat) straw	5	1540	5	1644
Maize stover	0	0	0	0
Sugar beet leaves	0	24	0	28
Sunflower straw	0	0	0	0
Oil seed rape straw	0	40	0	27
Rice straw	0	0	0	0
Total (straw/stubbles)	-	**1,604**	-	**1,699**
Agricultural residues (Woody prunnings and orchards residues)				
Vineyards	0	0	0	0
Fruit tree plantations	0	2	0	2
Olives/Citrus/Nuts tree plantations	0	0	0	0
Total (prunnings& orchards residues)	-	**2**	-	**2**
Secondary residues (pulp & paper industry, industry utilizing agricultural products) and biowaste (unseparately collected)				
Sawdust (conifers)	4	1394	4	1309
Sawdust (nonconifers)	0	7	0	7
Other (conifers)	8	2705	8	2542
Other (nonconifers)	0	15	0	14
From semi-finished wood based panels	1	388	1	418
From further woodprocessing	1	229	1	231
Bark	5	1696	5	1696
Black liquor	20	6821	20	6821
Olive-ston/ rice husk/ pressed grapes dregs	0	0	0	0
Cereal bran	2	519	2	513
Total (secondary residues)	-	**13,774**	-	**13,551**
Biowaste unseparately collected	2	612	2	641
Energy grasses, annual & perennial crops				
Miscanthus	0	0	0	0
Switchgrass	2	516	2	619
Reed canary grass	0	0	0	0
Total (energy grasses etc.)	-	**516**	**-**	**619**

Table 54. Sustainable biomass potential in Finland in 2020 and 2030 (NUTS0 level).

Production from forests (Stemwood from final fellings and thinnings)																
	Final fellings nonconifer trees				*Final fellings conifer trees*				*Thinnings from nonconifer trees*				*Thinnings conifer trees*			
Area	AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]	
	Y20	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Pohjois-Suomi	5	7	1051	1637	39	38	8926	8525	4	3	850	698	25	23	5641	5262
Lansi-Suomi	5	9	323	602	76	70	4848	4536	5	4	325	265	33	31	2151	1996
Etela-Suomi	6	10	221	341	84	84	2929	2936	5	4	187	157	40	37	1399	1291
Helsinki-Uusimaa	15	22	142	211	97	96	910	900	9	8	89	77	39	36	370	340
Aland	13	18	18	24	65	39	89	53	9	7	12	10	28	26	38	35

Table 55. Sustainable forest biomass –production from forests- potential in several areas of Finland (NUTS2 level) for 2020 (Y20) and 2030 (Y30).

Primary residues from forests (Loggings and Stumps from final fellings)																
	Loggings (nonconifer trees)				*Loggings (conifer trees)*				*Stumps (nonconifer trees)*				*Stumps (conifer trees)*			
Area	AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]	
	Y20	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Pohjois-Suomi	1	1	140	220	4	4	889	852	1	1	123	190	3	3	742	708
Lansi-Suomi	1	2	55	105	10	10	635	621	1	1	48	90	8	7	509	484
Etela-Suomi	1	1	27	42	10	11	361	398	1	1	23	36	8	8	274	291
Helsinki-Uusimaa	2	4	23	35	12	13	117	125	2	3	20	29	9	9	85	88
Aland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 56. Sustainable forest biomass –production from forests- potential in several areas of Finland (NUTS2 level) for 2020 (Y20) and 2030 (Y30).

Secondary residues from pulp & paper industry & saw mill residues																
	Sawdust (conifer trees)				*Other (conifer trees)*				*Bark*				*Black liquor*			
Area	AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]	
	Y20	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Pohjois-Suomi	3	2	588	552	5	5	1141	1072	2	2	415	415	7	7	1671	1671
Lansi-Suomi	7	6	432	406	13	12	839	789	10	10	623	623	39	39	2506	2506
Etela-Suomi	8	7	272	255	15	14	528	496	17	17	589	589	67	67	2367	2367
Helsinki-Uusimaa	10	10	96	90	20	19	187	175	7	7	69	69	30	30	278	278
Aland	4	4	6	5	8	7	11	10	0	0	0	0	0	0	0	0

Table 57. Sustainable biomass potential– Secondary residues from pulp & paper industry and municipal waste unseparately collected- in several areas of Finland (NUTS2 level) for reference years 2020 (Y20) and 2030 (Y30).

8.6.9 Sweden

Production from forests (Stemwood, stumps, logging residues from final fellings and thinnings)				
Year	**2020**		**2030**	
	AW [kton dm·km^{-2}]	Absolute [kton dm]	AW [kton dm·km^{-2}]	Absolute [kton dm]
Final fellings from nonconifer trees (stemwood)	9	3,865	11	5,002
Final fellings from conifer trees (stemwood)	46	20,902	46	20,822
Thinnings from nonconifer trees (stemwood)	6	2,718	5	2,246
Thinnings from conifer trees (stemwood)	31	14,087	31	14,104
Total (stemwood)	-	**41,572**	-	**42,174**
Final fellings from nonconifer trees (loggings)	1	533	2	691
Final fellings from conifer trees (loggings)	7	3,043	7	3,159
Thinnings from nonconifer trees (loggings)	0	101	0	84
Thinnings from conifer trees (loggings)	1	395	1	396
Final fellings from nonconifer trees (stumps)	1	533	2	692
Final fellings from conifer trees (stumps)	5	2,397	5	2,407
Total (logging residues and stumps)	-	**7,002**	-	**7,429**
Total forest production	-	**48,574**	-	**49,603**
Agricultural residues (Straw/stubbles)				
Cereal (wheat) straw	5	2,056	4	1,877
Maize stover	0	5	0	4
Sugar beet leaves	0	114	0	106
Sunflower straw	0	0	0	0
Oil seed rape straw	0	108	0	120
Rice straw	0	0	0	0
Total (straw/stubbles)	-	**2,283**	-	**2,107**
Agricultural residues (Woody prunnings and orchards residues)				
Vineyards	0	0	0	0
Fruit tree plantations	0	3	0	2
Olives/Citrus/Nuts tree plantations	0/0/0	0/0/0	0/0/0	0/0/0
Total (prunnings& orchards residues)	-	**3**	-	**2**
Secondary residues (pulp & paper industry, industry utilizing agricultural products) and biowaste (unseparately collected)				
Sawdust (conifers)	6	2,634	6	2,638
Sawdust (nonconifers)	0	18	0	18
Other (conifers)	11	4,830	11	4,836
Other (nonconifers)	0	38	0	38
From semi-finished wood based panels	0	63	0	71
From further woodprocessing	1	498	1	538
Bark	4	1,902	4	1,902
Black liquor	17	7,834	17	7,834
Olive-ston/ rice husk/ pressed grapes dregs	0/0/0	0/0/0	0/0/0	0/0/0
Cereal bran	1	515	1	562
Total (secondary residues)	-	**18,332**	-	**18,437**
Biowaste unseparately collected	3	1,175	3	1,274
Energy grasses, annual & perennial crops				
Miscanthus	1	287	1	329
Switchgrass	1	454	1	536
Reed canary grass	0	208	1	246
Total (energy grasses etc.)	-	**949**	-	**1,111**

Table 58. Sustainable biomass potential in Sweden in 2020 and 2030 (NUTS0 level).

Production from forests (Stemwood from final fellings and thinnings)																
	Final fellings nonconifer trees				*Final fellings conifer trees*				*Thinnings from nonconifer trees*				*Thinnings conifer trees*			
Area	AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]	
	Y20	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Ovre Norrland	5	6	848	1011	25	22	4111	3667	2	2	371	304	16	16	2715	2655
Mellersta Norrland	7	10	530	739	51	50	3958	3837	6	5	485	411	33	33	2522	2560
Norra Mellansverige	4	7	320	509	70	66	5049	4731	6	5	404	334	44	44	3139	3203
Ostra Mellansverige	7	10	291	431	55	55	2392	2372	7	5	295	237	35	36	1536	1541
Stockholm	46	59	327	420	78	74	550	527	30	23	214	166	52	53	372	377
Vastsverige	11	15	396	521	48	57	1660	1978	8	7	289	238	39	39	1342	1338
Smaland med oarna	10	14	377	510	72	83	2592	2990	8	7	294	240	55	54	1965	1933
Sydverige	54	60	776	861	41	50	590	721	25	22	366	317	34	34	496	496

Table 59. Sustainable forest biomass –production from forests- potential in several areas of Sweden (NUTS2 level) for 2020 (Y20) and 2030 (Y30).

Primary residues from forests (Loggings and Stumps from final fellings)																
	Loggings (nonconifer trees)				*Loggings (conifer trees)*				*Stumps (nonconifer trees)*				*Stumps (conifer trees)*			
Area	AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]	
	Y20	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Ovre Norrland	1	1	92	111	3	3	468	415	1	1	124	147	3	2	450	401
Mellersta Norrland	1	1	59	84	7	7	532	518	1	1	77	108	6	6	477	462
Norra Mellansverige	1	1	40	64	9	9	681	665	1	1	48	76	8	8	589	559
Ostra Mellansverige	1	2	50	75	11	11	468	485	1	2	45	67	7	7	288	289
Stockholm	4	6	30	40	14	14	101	100	3	4	20	27	7	6	46	45
Vastsverige	1	2	37	52	6	8	215	267	1	1	38	51	4	5	147	178
Smaland med oarna	2	2	57	77	12	15	441	532	2	2	56	77	9	11	323	378
Sydverige	10	13	169	188	10	12	138	177	9	10	125	138	5	7	76	95

Table 60. Sustainable forest biomass –production from forests- potential in several areas of Sweden (NUTS2 level) for 2020 (Y20) and 2030 (Y30).

Secondary residues from pulp & paper industry & saw mill residues																
	Sawdust (conifer trees)				*Other (conifer trees)*				*Bark*				*Black liquor)*			
Area	AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]		AW [kton dm·km^{-2}]		Absolute [kton dm]	
	Y20	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**	**Y20**	**Y30**
Ove Norrland	2	2	303	304	3	3	556	557	1	1	138	138	3	3	570	570
Mellersta Norrland	2	2	175	175	4	4	321	321	3	3	242	242	13	13	997	997
Norra Mellansverige	7	7	487	487	12	12	892	894	6	6	415	415	24	24	1709	1709
Ostra Mellansverige	5	5	232	233	10	10	426	427	7	7	311	311	30	30	1282	1282
Stockholm	12	12	88	88	23	23	162	162	5	5	35	35	20	20	142	142
Vastsverige	11	11	365	366	19	19	670	671	10	10	346	346	41	41	1424	1424
Smaland med oarna	21	21	752	753	38	38	1379	1381	8	8	277	277	32	32	1139	1139
Sydverige	16	16	231	231	29	29	423	424	10	10	138	138	40	40	570	570

Table 61. Sustainable biomass potential– Secondary residues from pulp & paper industry and municipal waste unseparately collected- in several areas of Sweden (NUTS2 level) for reference years 2020 (Y20) and 2030 (Y30).

8.7 *Biomass cost*

Cost [euro/ton dm]								
	Crops							
Country	Final fellings nonconifer (stemwood)	Final fellings conifer (stemwood)	Thinnings nonconifer (stemwood)	Thinnings conifer (stemwood)	Final fellings nonconifer (loggings)	Final fellings conifer (loggings)	Thinnings nonconifer (loggings)	Thinnings conifer (loggings)
Germany	28-34	32-36	30-33	38-47	31	38	27-34	42-43
Poland	18	23-24	22-25	31-32	21	25-26	23-25	29
Greece	29	36	35	54	16	52	16	67
Bulgaria	19-22	26-27	23-25	32-33	12	31-38	12	36-40
Slovenia	24-26	29-31	30-32	38-41	13-34	33-41	13-40	38-49
Czech. Rep.	20	24	25	29	22-23	27	25-26	30
Romania	23-24	28-29	27-29	35-37	32-36	41-43	39-44	46-54
Hungary	18-19	25	22-26	31-32	13-24	25-26	13-25	29-31
Slovak. Rep.	20-21	25-26	24	31	24-25	28-29	26-28	32-33
Serbia	20	26	26	37	12	29	12	35
Finland	35	39	62-108	64-72	19-37	43-44	19-50	54-56
Sweden	36-37	41	69-91	62-71	20-41	48-49	20-57	60-62
Estonia	21	27	32	38	25	31	31	37
Latvia	21	24	34	37	24	28	29	34
Lithuania	19	24	25	34	23	27	27	32
France	28-33	33-40	33-45	38-45	33-34 (18 south part)	39-45	33-43 (18 south part)	42-51
Italy	35-41	39-45	52-81	51-68	18	55-75	18	64-95
Spain	26-27	32-33	38-42	40-43	16	20	16	20

Table 62. Roadside cost for forestry (**year 2020**).

Cost [euro/ton dm]											
	Crops										
Country	Cereal straw	Maize stover	Sugarbeet leaves	Sunflower	Oil seed rape	Rice	Vineyards	Fruit tree	Olives tree	Citrus tree	Nuts
Germany	28-29	26	70-74	31-33	24-25	40-45	-	148-600	-	-	288-332
Poland	17-21	13	37	16	14-15	22	-	62-90	-	-	36-42
Greece*	45	23	64	30	35	34	232-372	124-140	180-182	255	40-54
Bulgaria	14	10	26-27	12	12	15-16	121-127	42-45	-	-	21-23
Slovenia	19-30	15-21	40-60	18-28	16-24	30	190-292	121-162	-	-	44-287
Czech. Rep.	19	16	42	19	16	24	-	94-403	-	-	293
Romania	16-18	11	28-30	13-14	13-14	17-18	154-414	48-81	-	-	20-27
Hungary	17	13	35	16	14	20	164-517	54-55	-	-	28-57
Slovak. Rep.	30	21	60	28	24	30	290-292	121-162	-	-	44-284
Serbia	16	10-11	27-28	12	13	17	127-139	47-53	-	-	22-27
Finland	41-42	29	82	36-37	34	49-50	-	257-767	-	-	295-300
Sweden	37	32	88	40-42	31-32	51-54	-	291-868	-	-	291-346
Estonia	24	16	41	19	20	24	-	139	-	-	279
Latvia	20	14	37	17	17	22	-	168	-	-	66
Lithuania	17	13	34	16	14	20	-	110	-	-	70
France	30-31	28	76-77	35-40	26-27	44-45	394-1198	136-575	206-596	90-187	59-322
Italy	36-42	25-27	71-79	31-32	29-34	43-50	276-421	130-377	305-946	186-548	71-78
Spain	33-35	21-22	58-61	27-30	27-36	35-51	166-308	125-382	179-192	67-423	32-99

Table 63. Roadside cost for agricultural residues and energy crops (**year 2020**).

9 Abbreviations

AW	Area weighted
BSC	Biowaste (separately collected) and waste from wood
BUC	Biowaste unseparately collected–RDF included
CB	Cereal bran
CRD	Cardoon
CFB	Circulating fluidized bed boilers
CS	Cereal straw
CHP	Combined heat and power
d.b.	dry base
d.m.	dry matter
EBS	Ersatzbrennstoff, (alternative fuel)
EFISCEN	European Forest Information SCENario
EU	European Union
FAO	Food and Agriculture Organization
FBC	Fluidized bed combustor
FC	Final fellings conifer trees
FNC	Final fellings non-conifer trees
GR	Giant reed
HPW	Hazardous post-consumer wood
LFC	Logging residues from final fellings from conifer trees
LFNC	Logging residues from final fellings from non-conifer trees
LRC	Lowest rank of coal
LTC	Logging residues from thinnings from conifer trees
LTNC	Logging residues from thinnings from non-conifer trees
MS	Maize stover
MS	Miscanthus
MSW	Mixed municipal waste
NHPW	Non-hazardous post-consumer wood
NUTS0	National level
NUTS2	Basic regions for the application of regional policies
NUTS3	Small regions for specific diagnoses (sub-regional level)
OECD	Organization for Economic Co-operation and Development
OFP	Other food processing residues
ORC	Other residues conifers
ORNC	Other residues non-conifers
OS	Olive-stones
OSRS	Oil seed rape straw
PGD	Pressed grapes dregs
RCG	Reed canary grass
RDF	Refuse derived fuel
RES	Renewable energy resources
RH	Rice husk
RFW	Residues from further wood processing
RS	Rice straw
SBL	Sugar beet leaves
SBS	Sekundärbrennstoff (secondary fuel)
SDC	Sawdust from conifer trees
SDNC	Sawdust from non-conifer trees
SFC	Stumps from final fellings from conifer trees
SFNC	Stumps from final fellings from non-conifer trees

SFWP	Residues from industries producing semi-finished wood based panels
SGR	Switch grass
SOC	Soil organic carbon
SRC	Short rotation coppice
SRCW	SRC willow
SRCP	SRC poplar
SRCO	Other SRC (including eucalyptus)
SUS	Sunflower straw
TC	Thinnings conifer trees
TNC	Thinnings non-conifer trees
UAA	Utilized agricultural land
VAT	Value added tax
WoP	Wood pellets

10 References

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