Five years left – how are the EU member states contributing to the 20% target for EU's renewable energy consumption; the role of woody biomass.

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Abstract

The European Union has set ambitious targets of raising the share of EU energy consumption produced from renewable resources from 20% by 2020 to 27% by 2030. The aim of this paper is to assess the role of woody biomass in renewable energy as gross final energy consumption in the European Union (the EU-28). The paper identifies leading and lagging countries in biomass development by focusing on their current biomass use and forecasts future perspectives. The research compares and evaluates the role of biomass in renewable energy in the EU-28 focusing on countries' potential resources and policy support. The study shows that all countries are making efforts to reach the 20% target in 2020 and exhibit a trend of increasing renewable energy as gross final energy consumption towards the new target of 2030. Solid biomass plays an important role in reaching the EU's renewable energy targets. The majority of the EU-28 countries are close to reaching their national renewable energy targets and show a very attractive biomass development. Unless energy consumption decreases however, some member states will face serious problems in reaching their renewable energy target-in 2020. Following our analysis, the largest problems occur in those MS having a relative high-energy consumption pattern: France, Germany and the United Kingdom. It is unlikely that they can comply with expected renewable energy demand, unless they mobilize more woody biomass from their available domestic potential (France, Germany) or considerably increase their woody biomass imports (mostly wood pellets) from elsewhere (United Kingdom).

Keywords: Renewable energy, Bioenergy, Biomass, Renewable energy targets, National Renewable Energy Action Plan, European Union,

List of Abbreviations, conversion factors and definitions

AEBIOM European Biomass Association

CFB Circulating fluidized bed

CHP Combined heat and power

CO_2 Carbon dioxide

EEA European Environment Agency

EU European Union

EU-28 Member States of the European Union since January 2013, when Croatia joined the EU

FSC Forest Stewardship Council

GDP Gross Domestic Production

GFEC Gross Final Energy Consumption

GHG Greenhouse Gas

GIC Gross inland consumption

H&C Heating &Cooling sectors

IEA International Energy Agency

IEC Inland Energy Consumption

IRENA International Renewable Energy Agency

JRC Joint Research Centre

MS Member State

NREAP National Renewable Energy Action Plan

R&D Research and Development

RE Renewable Energy

REN 21 Renewable Energy Policy Network for the 21st Century

RES Renewable Energy Sources

RES-E Renewable Energy Sources in Electricity sector

RES-H Renewable Energy Sources in Heating sector

ROC Renewables Obligations Certificate

UK United Kingdom

WBA World Bioenergy Association

Units

GWh Gigawatt-hour(s) = 1,000 MWh

1 MWh ≈ 0.51 tonnes of wood pellets = 8.98 primary GJ, bases on lower heating value of 17.6 GJ per tonne and an efficiency rate for 10% pellet co-firing of 40.1% [1].

Mm^3 = 1,000 000 m^3 = 7.1 PJ (global average) [2].

Definitions

- Bioenergy: Bioenergy refers to energy derived from biofuels.
- Biomass: Refers to the biodegradable fraction of products, waste and residues from agricultural (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste.
- Woody biomass: Refers to the trees and woody plants, including limbs, tops, needles, leaves, and other woody parts, grown in a forest, woodland, or rangeland environment, that are the by-products of forest management.
- Biofuels (=biomass fuel): Fuel produced directly or indirectly from biomass. The fuel may have undergone mechanical, chemical or biological processing or conversion or it may have had a previous use. Biofuel refers to solid, gaseous and liquid biomass-derived fuels.
- Bioliquids. Refers to the liquid fuels made from biomass for energy purposes other than transport (i.e. heating and electricity).
- Gross inland consumption of energy (GIC) is the first aggregate in the national energy balances. It refers to "apparent" consumption and is derived from the formula that takes into account primary production, exports, imports and stock changes. It includes the primary energy from fossil fuels, from renewable energies (biomass, wind, solar, hydro), derived heat and trade of electrical energy.
- Gross final energy consumption (GFEC) is calculated from national energy balances. GFEC starts with the GIC data, after which transformation losses, distribution losses and own consumption of electricity and heat within the energy sector are subtracted. The GFEC data can be divided over the sectors involved in the energy consumption, after the subtraction of non-energy consumption (e.g. use of cokes for chemical products). At the end, we remain with final energy consumption by industry, transport and households [3].

Introduction

Development of renewable energy sources (RES) for energy production has become increasingly significant in European energy markets. The importance of RES has grown due to increasing demand for CO_2-free energy, environmental sustainability and a desire to decrease dependence on fossil fuels. In 2007, the European Union (EU) set a target of raising the share of EU energy consumption produced from renewable resources to 20% by 2020, which is a part of 20-20-20 target with a 20% reduction in EU greenhouse gas emissions (GHG) from 1990 levels and 20% improvement in the EU's energy efficiency. In 2014, European Council [4] specified an EU-wide domestic GHG reduction target of at least 40% below 1990 levels, an EU-wide target of at least 27% of renewables in energy consumption, and an EU-wide indicative, non-binding ambition of at least 27% energy efficiency by 2030, based on 2007 projections of future consumption [5].

Describing the renewable energy policy in the EU-28, Klessmann et al. [6] suggest that despite the existence of the main directive [7] the EU will need additional policy efforts to reach the necessary reduction target. For example, in countries with less advanced infrastructure and energy markets, upgrading of the power grid infrastructure, dismantling of financial barriers in the heat sector, development of sustainability standards for biomass, and lowering of energy demand through increased energy efficiency are all necessary steps.

In addition to the EU target, each EU member has set its own national target for renewable energy share in gross final energy consumption as part of EU targets to 2020. In the EU, renewable energy consumption varies with member states (MS) displaying different renewable consumption profiles, depending on level of economic development, historical factors and policy support. The issue of reaching the 2020 target for renewable energy has been the subject of a lot of research [6,8–15] However, limited work has been done on country comparison in terms of the likelihood of achieving their EU targets in 2020 and the contribution of woody biomass beyond 2020. In 2013, the gross inland consumption (GIC) of energy in the EU-28 was 70 EJ [16]. The total renewable energy (RE) consumption (biomass, solar energy, wind energy, hydro and others) is about 8.2 EJ. Biomass remains the major source of RE in the EU-28, accounting for more than 62% of all renewables [17]. Wood accounts for approximately 80% of the biomass used for renewable energy. However, the specific role of woody biomass, including waste wood resources, remains relatively unknown. Recent projections for 2030 quantify the sustainably realisable additional potential of wood for

energy from EU forests as high as 5 EJ per year, provided intensive wood mobilisation efforts are applied [18].

This study summarizes current available research and focuses on countries' biomass usage status based on current share of all kinds of solid, liquid and gaseous biomass (woody biomass, agricultural biomass and biomass derived from urban and industrial waste), used for energy production. At the end, the woody biomass resource potential for the future development of EU's renewable energy mix is evaluated. Woody biomass is currently used for electricity, heating and cooling. Its current use for transportation fuels is negligible and therefore left out of the scope of the study. The main research questions considered are firstly: what is the expected contribution of all kinds biomass to the total (renewable) energy consumption in each EU country in 2020? Secondly, when we focus on solid biomass for bioenergy, what is the total impact of solid biomass on EU's energy consumption, derived from renewable resources, by 2020? The paper ultimately evaluates the specific contribution of woody biomass, based on the future trends from the forest industries in the EU member states until 2020.

The paper is structured in the following manner: Section 2 describes the methodology used to approach the research topic. Section 3 reviews the share of RE in gross final energy consumption (GFEC) in different EU member states, focusing on the total biomass contribution for electricity and heat production in 2020. Section 4 discusses the possible role of woody biomass in 2020 and the additional biomass supply beyond 2020. Section 5 evaluates the achievability of the targets, what measures might improve the prospect of them being achieved and anything that can be learnt between countries to support that. Section 6 concludes the paper by summing up major trends.

2. Methods and Materials

2.1 Literature review

The EU has set a target of increasing the share of renewables from its current (2013) level of 15% to 20.6%, of which the major part - almost 12% - is derived from biomass, of gross final energy consumption by 2020. The electricity sector has a 14.5% target for bioenergy by 2020 and the heating (and cooling) sector a 65% target by 2020 [19]. Since the EU's renewable energy policy started in 1997 the European states have introduced a series of measures to improve the development of energy from renewable sources. Measuring renewable energy production, both

consumption and potential and analyzing country attractiveness as regards renewables are the main issues studied in the literature regarding the comparative development of RES in Europe [20].

A number of organizations systematically compile and report on the impact of the RE target on RE development. Since 1998, the Eurobserv barometer has evaluated the progress made by RE in each sector and in each member state of the EU. Monitoring and analysis of RES development in the EU, as well as evaluation of RES progression compared to the 2020 objectives of the European Commission are the main issues considered in the Eurobserv barometers [21]. Concerning solid biomass, the Eurobserv barometer publishes data about production and consumption of solid biomass in the electricity and heat sectors as well as informing about new power plants, and combined heat and power (CHP) plants, which use solid biomass in the EU. Since 2011, the International Renewable Energy Agency (IRENA), which is an intergovernmental organization, provides support for countries to achieve their clean energy potential and promotes RES and technologies [22]. The Renewable Energy Policy Network for the 21st Century (REN 21) publishes annual reports about the global state of RE including bioenergy [23]. The European Commission monitors RE development in the EU.

A number of organizations publish reports specifically about the bioenergy sector. The World Bioenergy Association (WBA) [24] collects data about global biomass progress in the world excluding discussion of the state of each EU member states. IEA Bioenergy includes different tasks concerning bioenergy. For example, Task 40 [25] publishes country reports in which bioenergy targets and their implementation are discussed separately for many member states of the EU. The European Biomass Association (AEBIOM) [17] annually publishes statistical reports about different biofuels in different sectors in the EU countries and do not discusses the reasons underlying changes found.

Each member states of the EU has its own National Renewable Action Plan (NREAP) [26] in which the country informs about current RE use and future targets including bioenergy. This issue is a subject of many publications. For example, Banja et al., [27] present snapshot of the current state of RE development in the EU and the progress expected by 2020 based on NREAP of each EU Member State. Klessmann et al., [6] discuss the measurements which need to be done for reaching 2020 targets. However, these studies cover all renewables but do not include detailed discussion of bioenergy. Focusing to bioenergy and biomass in the EU, for example, Scarlat et al., [12] reviews

the policy framework and bioenergy contribution in the EU but excludes description of member states. Several studies cover RE or only bioenergy in a specific country (Table 1).

Table 1: *Journal publications covering RE including bioenergy that study the response of the EU countries to RE targets.*

Study (journal publication)	**Country**
Ćosić et al. [28], Curman et al. [29].	Croatia (HR)
Kythreotou et al. [30].	Cyprus (CY)
Lund and Mathiesen, [8].	Denmark (DK)
Heinimö [31], Laihanen and Karhunen [32], Arasto et al. [14].	Finland (FI)
Arasto et al. [14], Purkus et al. [33], Szarka et al. [34].	Germany (DE)
Fontaras et al. [35], Karkania et al. [36], Kaldellis et al. [37].	Greece (EL)
Róbert et al. [35].	Hungary (HU)
O'Flaherty et al. [39].	Ireland (IE)
Paiano and Lagioia [40].	Italy (IT)
Katinas et al. [41].	Lithuania (LT)
Arasto et al. [14].	Netherlands (NL)
Aslani et al. [11].	Nordic countries
Nilsson et al. [42].	Poland (PL)
Gouveia et al. [43], Ribeiro et al. [44].	Portugal (PT)
Grigoras and Scarlatache [45], Ţăpurică and Tache [46], Zamfir et al. [47].	Romania (RO)
Al-Mansour et al. [48].	Slovenia (SI)
Gómez et al. [9].	Spain (ES)
Routa et al. [49].	Sweden (SE)
Purkus et al. [33].	United Kingdom (UK)
Scarlat et al. [12].	All countries

Overall, previous studies highlight the need for further evaluation of bioenergy in each member state based on country's comparison in terms of fulfilling its own biomass targets. To our knowledge, there is no evidence in the literature on grouping EU member states according to the difference of the share of biomass and the achievement of biomass targets in the EU's renewable energy targets for 2020 according to NREAPs. For example, Pacesila et al., [20] analyze renewable energy in the EU based on EU member states grouping in terms of the share of renewables in total energy produced in each country and the country energy dependence.

2.2 Method

This study compares and evaluates the role of biomass in renewable energy in the EU-28 focusing on countries' potential resources and policy support. The paper is based on reports of several of the most prominent organizations: AEBIOM [16], European Commission [e.g. 4,26,27,50,51], Eurostat [e.g. 16,52–56], International Energy Agency (IEA) [e.g.5,57,58], European Environment Agency (EEA) [32,33], and Hawkins Wright Ltd. [61,62].

Biomass for renewable energy ("bioenergy") is detailed in these reports, with a most common division into solid, liquid and gaseous biomass (see list of definitions). However, categories according to biomass type (woody, agricultural, waste), are usually not included. To identify the role of woody biomass in heat and electricity production including future perspective in European countries, additional information has been collected for this study. Biomass type specific information was collected from the Eurostat database regarding the trade of wood pellets and wood chips [53] and the Joint Research Centre (JRC) database regarding the data for the domestic supplies of wood (forest, forest industries), agricultural residues and waste flows [63]. These latter data are supplied by the MS under the framework of the NREAPs, which give insight into the state-of-the-art of the actual progress of bioenergy use in the EU.

To address the research questions in this study, it was decided to divide the 28 EU member countries into three groups. The division is based on the difference of the share of biomass according to Renewable Energy Progress and the achievement of bioenergy targets in the horizon 2020 according to NREAPs. The EU member states with a surplus or lagging no more than 15% were ranked as Group 1 (Leading countries), countries whose biomass still needs to increase from 15% to 30% as Group 2 (Intermediate countries) and countries whose required biomass share increase is more than 30% as Group 3 (Lagging countries). Table 2 shows these three groups, and 1, 2 and 3 are highlighted in green, orange and red colour respectively. For bioenergy as a whole, the bioenergy be aggregated for solid biomass, liquid biomass and gaseous biomass.

Table 2: *The three groups for the purpose of this study [53,54].*

) Banja et al..,) GFEC = gross final energy consumption; ***) GIC = gross inland energy consumption*

Category other includes 1) tide wave and ocean 2) geothermal energy 3) liquid biofuels.

Nuclear energy is not regarded as a renewable energy source.

	The biomass target for 2020 – realized biomass consumption in 2013		NREAPs target 2020*	2012*	Share of energy from renewable sources in GFEC*		The RE target for 2020 – realized RE consumption in 2013	Total GIC**	Share in GIC*** of total, 2013				
			biomass	biomass	2013	target 2020		2013	Biomass (incl. waste)	Solar (termal+PV)	Hydro power	Wind	Others
			in PJ		in %			in PJ	in PJ (% from total RE)				
	up to 15%	Leading countries (Group 1)											
1	-16,4	Estonia	26,6	31,0	25,6	25,0	-0,6	281	33,6 (94)	0 (0)	0,1 (0)	2 (6)	0 (0)
2	-11,0	Austria	169,6	188,0	32,6	34,0	1,4	1 414	244,8 (59)	9,5 (2)	151,1 (36)	11,3 (3)	1,7 (0)
3	2,0	Slovenia	24,4	23,9	21,5	25,0	3,5	288	28 (59)	1,2 (3)	16,6 (35)	0,01 (0)	1,5 (3)
4	5,5	Finland	323,2	305,5	36,8	38,0	1,2	1 420	366,2 (88)	0,1 (0)	46,2 (11)	2,8 (1)	0 (0)
5	7,1	Poland	264,3	245,6	11,3	15,0	3,7	4 110	326,5 (91)	0,7 (0)	8,8 (3)	21,6 (6)	0,8 (0)
6	9,0	Greece	55,7	50,7	15,0	18,0	3,0	1 020	50,3 (46)	20,9 (19)	22,8 (21)	14,9 (14)	0,6 (0)
7	10,7	Romania	172,7	154,2	23,9	24,0	0,1	1 354	159,7 (69)	1,5 (1)	53,8 (23)	16,3 (7)	1,1 (0)
8	12,9	Sweden	457,7	398,6	52,1	49,0	-3,1	2 057	458,3 (64)	0,6 (0)	220,9 (31)	35,4 (5)	0 (0)
9	14,1	Germany	653,5	561,1	12,4	18,0	5,6	13 577	987,1 (71)	136,0 (10)	82,8 (6)	186 (13)	6,4 (0)
	15%-30%	Intermediate group (Group 2)											
10	15,5	Lithuania	47,2	39,9	23	23,0	0,0	280	46,5 (92)	0,3 (1)	1,9 (3)	2,1 (4)	0 (0)
11	19,1	Latvia	62,7	50,7	37,1	40,0	2,9	187	56,5 (84)	0 (0)	10,5 (15)	0,4 (1)	0,1 (0)
12	20,0	Portugal	110,0	88,0	25,7	31,0	5,3	947	117,5 (53)	4,7 (2)	49,4 (22)	43,2 (19)	7,7 (4)
13	22,9	Czech R.	115,0	88,7	12,4	13,0	0,6	1 766	129,9 (87)	7,9 (5)	9,8 (7)	1,7 (1)	0 (0)
14	23,9	Italy	305,0	232,2	16,7	17,0	0,3	6 699	565,7 (51)	84,7 (8)	190 (17)	53,6 (5)	210,8 (19)
15	25,1	Spain	238,7	178,9	15,4	20,0	4,6	4 973	289,5 (40)	112,1 (15)	132,4 (18)	194 (27)	0,9 (0)
16	25,5	Croatia	19,1	14,2	15,1	20,1	5,0	328	21,8 (41)	0,4 (1)	28,8 (54)	1,9 (4)	0,2 (0)
17	26,9	Hungary	65,6	47,9	9,8	13,0	3,2	952	70,7 (89)	0,1 (0)	0,8 (1)	2,6 (4)	4,9 (6)
18	28,1	Slovakia	35,0	25,2	9,8	14,0	4,2	723	38,9 (66)	2,3 (4)	17,4 (29)	0,02 (0)	0,4 (1)
19	29,3	Denmark	142,5	100,8	27,2	30,0	2,8	758	140 (76)	2,9 (2)	0,05 (0)	40 (22)	0,3 (0)
	over 30%	Lagging countries (Group 3)											
20	39,8	France	750,8	451,3	14,2	23,0	8,8	10 856	632,9 (65)	20,4 (2)	253,8 (26)	57,7 (6)	10,9 (1)
21	44,7	Luxemburg	4,7	2,6	3,6	11,0	7,4	182	5,5 (84)	0,4 (6)	0,4 (6)	0,3 (5)	0 (0)
22	45,8	Belgium	124,9	67,7	7,9	13,0	5,1	2 375	121,2 (83)	0,3 (7)	1,4 (1)	13 (9)	0,2 (0)
23	45,8	Bulgaria	125,0	67,7	19	16,0	-3,0	702	49,2 (65)	5,7 (8)	14,7 (19)	5 (7)	1,3 (1)
24	52,8	Netherlands	123,5	58,4	4,5	14,0	9,5	3 398	116,5 (83)	3,0 (2)	0,4 (0)	20,3 (14)	0,9 (1)
25	55,5	Cyprus	1,8	0,8	8,1	13,0	4,9	92	1,8 (32)	2,9 (52)	0 (0)	0,8 (14)	0,1 (2)
26	57,9	Ireland	24,0	10,1	7,8	16,0	8,2	575	16,7 (47)	0,5 (1)	2,1 (6)	16,4 (45)	0,0
27	62,6	UK	258,1	96,6	5,1	15,0	9,9	8 417	288,3 (68)	15,2 (4)	16,9 (4)	102,4 (24)	0,1 (0)
28	92,1	Malta	0,7	0,05	3,8	10,0	6,2	35	0,2 (40)	0,3 (60)	0 (0)	0 (0)	0 (0)
	23,1	EU-28	4 625	3557,3	15	20,6	5,6	69 765	5 363,8 (7.7)	444,5 (0.6)	1 333,8 (1.9)	845,7 (1.2)	250,9 (0.4)

For the first objective of this paper, we explored the bioenergy situation in each MS based on the group division (Section 3). For the second objective of this paper, finding the total impact of solid biomass to EU energy consumption produced from renewable resources by 2020, we summarized all information for the EU based on the expected future growth opportunities in the member states of biomass for energy (Section 4). Policy support schemes in the country groups studied are presented in Appendix 1.

The limitations of this study revolve around the following aspects:

- Definition of energy consumption. Gross inland consumption (GIC) is the first aggregate of the national energy balance (see list of List of Abbreviations, conversion factors and definitions). After subtraction of transformation losses and transformation and the internal consumption in the energy sector, the gross final energy consumptions (GFEC) can be compiled.

- Period of inventory. The period of study 2005–2013 was chosen as the main starting point. As the member states are still adapting their data to the prescribed template of NREAPs [19], this brief period may be subject to inconsistent data compilation.
- Market changes. The forecast in this study does not include possible changes on the global energy markets, such as changes in fossil fuel prices and significant economic changes in particular member states or in the EU in general Also, when fossil fuel prices would be increased via for example carbon taxes, EU member states could invest in "carbon tax free" RES, to guarantee long term supply of fuels.

3. Role of biomass demands in the RE targets of EU-28 countries

Figure 1 shows the three studied groups on the map. The leading countries of Group 1 (in dark grey), the intermediate countries of Group 2 (in grey) and the lagging countries of Group 3 (in light grey).

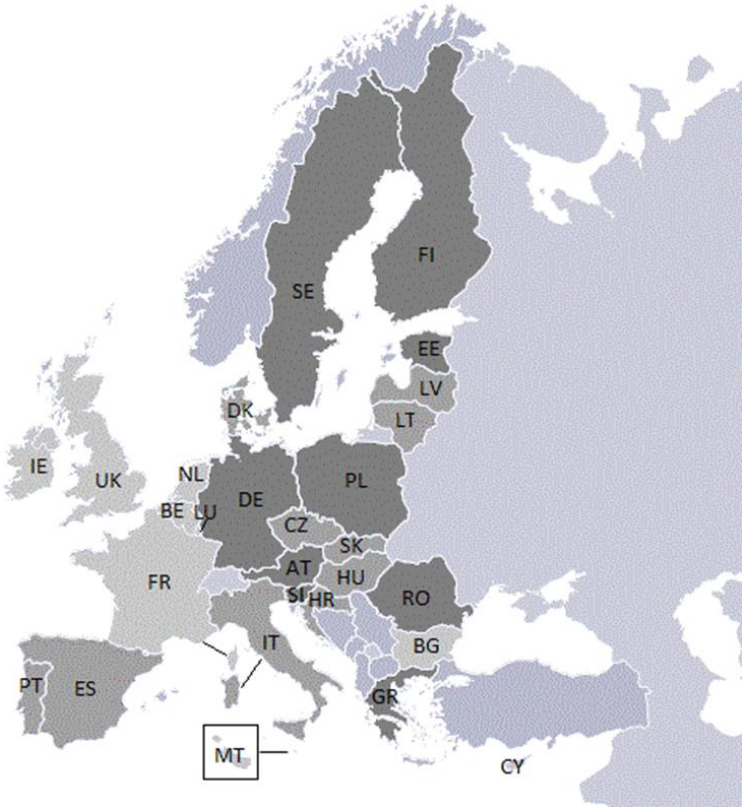

Fig.1. *Overview of the EU-28 countries forming the three studied groups on the map (dark grey = leading, grey = intermediate, light grey= lagging).*

3.1 Leading countries (Group 1)

Leading countries (Group 1) are presented in Figure 2. Estonia and Austria have reached biomass targets according it's NREAP's targets and other countries from Group 1 close its bioenergy targets (Table 2). Most of this countries have large forest resources and forest industry, and therefore the current and future role of woody biomass is considerable (see section 4 for more details). Firstly, biomass has a relative large proportion in the electricity markets of Finland and Sweden, together with nuclear and hydro energy sources [57,64]. Finland is a world leader in use of biomass in the CHP plants, which are used commonly in Finland for district heating and in the industry [31,32]. In Sweden, tax exemptions are the main incentives to support renewable heating from biomass and other sources [65]. Additionally, there is the Swedish Electricity Certificates Act for increasing RES electricity production. The Swedish support for biomass for power production (see Table 3) is relative low with about 2.25 € per GJ of fuel energy [66]. Secondly, Estonia has support schemes for RE promotion (see Appendix 1). Estonia promotes renewable electricity through a premium tariff and subsidies for the reconstruction of bio-CHP plants and also wind generation [65]. Thirdly, Austria has a significant role for biomass heating. The biomass usage for energy production has a long tradition in Austria [67]. Also, renewable energy sources are well developed in the electricity sector. Approximately 65% of electricity is produced from RES, with hydro energy the key resource before biomass [68]. Finally, Polish electricity and heat generated from RS is supported by public funding (Appendix 1). Poland is now the largest hard coal producer and the second largest coal consumer in Europe behind Germany. Bioenergy development in Poland has good perspectives for development, thanks to big power plants, which would like to replace coal with biomass. Poland has world's largest operating circulating fluidized bed (CFB) biomass power plant [69]. Together with the use of woody biomass, Poland requires a certain minimum share of agricultural biomass to be co-fired (10-15% [42]) in power plants or CHP plants. Polish Green Certificates have a tradable certificate of 45 € per MWh, equal to about 5.0 € per primary GJ [66].

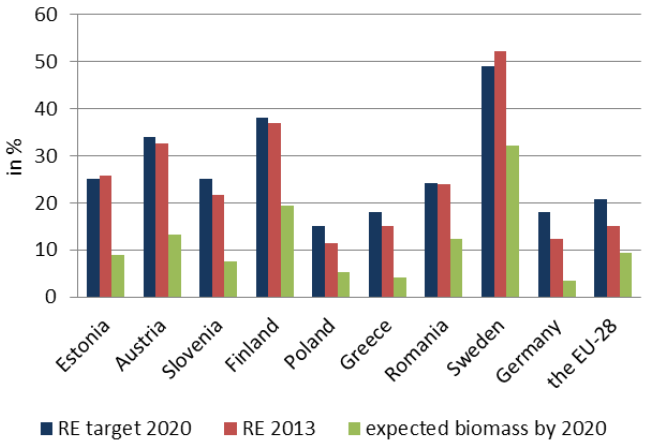

Fig. 2. *The 2020 RES target, the current RES share and the expected 2020 contribution of biomass in electricity and heating production in group 1, all in % of GFEC [52,54].*

Table 3: *Selected subsidy systems for biomass electricity generation in several EU countries. Source: [65*,66, 70**].*

	Support scheme	**In € per MWh of electricity**	**In € per primary GJ[1)]**
Leading countries	Some examples		
Estonia*	Premium tariff	53 (> 5,000 MW capacity) 32 (< 10 MW capacity)	5.92 3.57
Poland	Quota / green certificate	45	5.0
Sweden	Quota / electricity certificates act	20 (2012-2013 average)	2.25
Intermediate countries	Some examples		
Czech Republic*	Feed in tariff Green bonus	4.8-12.1 (up to 100 kW) 1.7-9	0.5-1.35 0.2-1
Italy	Feed in tariff	113 (up to 2,000 MWh)	12.6
Croatia*	Feed-in tariff	~16.9 (≤ 300 kW) ~16.4 (> 300 kW and ≤ 2 MW) ~15.6 (> 2 MW)	1.88 1.83 1.74
Hungary*	Feed-in tariff	4-12 (< 20 MW) 3-9 (20 and 50 MW) 5-7 (> 50 MW)	0.44-1.34 0.33-1.00 0.56-0.78
Denmark	Premium tariff	60 (cofiring)	6.7
Lagging countries	Some examples		
Bulgaria**	Feed in tariff	13 (2010)	1.46
Netherlands	SDE plus premium	67 (extension operating period)	7.5
United Kingdom	Renewable Obligations Certificate	56 (> 5,000 MW capacity)	6.25

1)See list of Abbreviations for conversion factors.

Some countries biomass faces competition with other RES. For example, hydro energy and wood are the most popular renewable sources in Slovenia [48]. Despite the policy documents for RE promotion and anticipated policy changes to improve forest sector's competitiveness, Lindstad et al. [71] suggest that uncertainty regarding future policy implementation exists in Slovenia. Another example is Romania, which have more or less equal promotion for all kinds of RES. First, Romania promotes renewable energy through quota system and subsidies (Appendix 1). One of the Romanian support schemes is applied to the energy sector and a second one offers subsidy programs in the agricultural sector [65]. Romania has a huge resource potential for wind, solar and hydro energy [45]. As such, the Romanian support for bioenergy via cogeneration investments is relative low, when compared with solar and wind energy for electricity production [46]. Due to the fact that in 2014 Romania reached own RE target which was set for 2020, the government decided to reduce the support for the RE by reducing the number of green certificates received by the producers after July 1, 2013 [47].

Greece has potential for an increased bioenergy development [35], including the development of biomass [36]. Decreasing dependence on the import of fossil fuels and decreasing CO_2 emissions are priority targets for the Greek economy [72]. Due to an increase in heating oil taxation, the primary forest market is booming in Greece [73]. There is a need for additional public information regarding RES exploitation [37].

The final country in Group 1 is Germany, where biomass is the main RES with a contribution of about 8.2% of final energy consumption in 2012 [74], followed by another relatively large contribution from offshore wind farms [75]. German electricity production from renewable sources is supported through a market premium scheme. Plants with a capacity of up to 500 kW (and other plants in exceptional cases) can benefit from a feed-in tariff [76]. The use of biomass for electricity production has significantly increased, based on a mix of agricultural biomass like corn residues with manure in CHP's (biogas) [77]. Germany is a leading country in the EU in power generation from biogas, with 49.1 TWh [23]. Depending on the scenario the share of biomass in power and heat will continue increase over the current rate by 4-14% [34].

3.2 Intermediate countries (Group 2)

Lithuania, Latvia and Portugal are the main contributors in Group 2 in terms of achievement of bioenergy targets in the Horizon 2020 (Table 2). Figure 3 presents intermediate countries (Group 2). Firstly, in Lithuania, the replacement of heating oil (in older installations) or natural gas by solid woody biomass for heat production is very popular. In addition, geothermal energy and heat pumps are supported [41]. Secondly, Latvia's current share of renewables is relatively high, thanks to two large hydropower stations with 832 MW and 400 MW respectively. Domestic consumption of domestic (woody) biomass is still limited. The feed-in system is now under revision [65]. Future growth will be focusing on the use of local forest biomass for district heating. Remarkably, Latvia has increased its export of woody biomass (pellets) in a relatively brief period. In 2013, the export of wood pellets from the country reached 27 PJ [53], making Latvia the largest pellet exporter of the EU. Finally, biomass in Portugal is not popular source. In Portugal Gouveia et al. [43] state that the importance of RES in the Portuguese electricity generation sector has grown strongly, mainly due to a considerable increase in the share of onshore wind. According to Ribeiro et al. [44], technologies for solar power plants and hydro power are regarded as the most desirable for further development in near future, provided that they are applied on a local scale. As such they can significantly contribute to the local residents' welfare in Portugal. Remarkably, Ribeiro et al. [44] state that public opinion is less familiar with biomass and as such it is less supported.

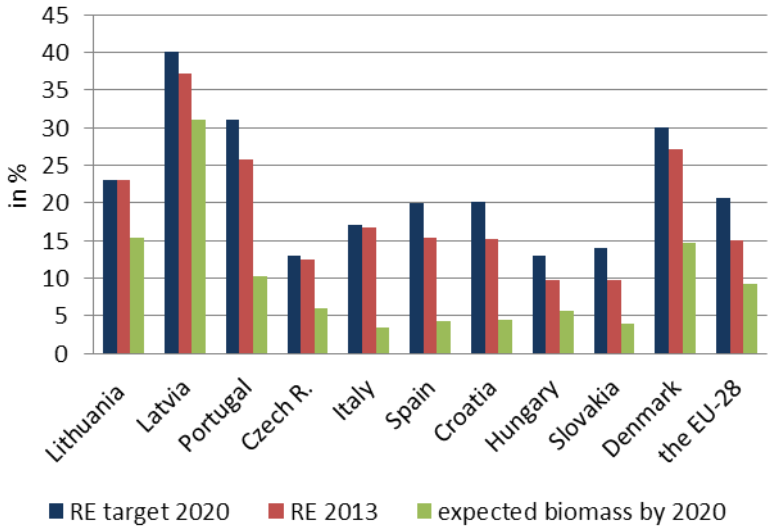

Fig. 3. *The 2020 RES target, the current RES share and the expected 2020 contribution of biomass in electricity and heating production in group 2, all in % of GFEC [52,54].*

The RES contribution of bioenergy in Hungary, Slovakia and Italy can actually be covered by woody biomass, due to their relative large forest resources (see Section 4 for more details); electricity generated from renewable energy sources and waste is promoted through different support schemes (Appendix 1). Firstly, any surplus of electricity produced by a Hungarian CHP plant will be fed into the grid and will be remunerated with the retail electricity price [65]. Secondly, in Slovakia, energy companies are obliged to purchase and pay for renewable electricity exported to the grid. The main RES is woody biomass, however Slovakia (with Romania from 1 Group) has challenges for primary forest fuels supply such as economic and regular restrictions, and lack of adequate equipment and qualified personal for harvesting and processing [73].Finally, Italy has a relative large consumption of energy (Table 1). Energy production from bioenergy has significant grows in Italy. From 2008 to 2013 the bioenergy increase was over 186% which is more significant then other RES [40]. Italy increased tax regulation mechanisms are in place for using biomass in RES-E plants and for the promotion of RES-H [65]. As an example for promotion of heating appliances, there is a deduction for buying and installing pellet stoves. Consequently, the consumption of wood pellets has considerably increased after the high sales of pellet stoves [78]. Additionally, there is a feed-in tariff system applicable for combined heating and cooling (12.6 € per GJ), limited to electricity production up to 2,000 MWh [66] and, there is a guarantee fund in place for supporting district heating network development [65].

Czech Republic and Denmark also have support of RE. Renewable electricity in the Czech Republic is supported via a green bonus which is bonus payments of a statutorily set amount per MWh. The bonus applies to different scales for each RES option: up to 30 kW for photovoltaic, 100 kW for biomass, and 10 MW for hydropower [65]. Danish electricity from renewable sources is promoted mainly through a premium tariff and net metering (Appendix 1). The Danish premium tariff (Law on the promotion of renewable energy) has a bonus of 6.7 € per GJ for co-firing of biomass [66]. Denmark has set up a schema to support the installation of biomass district heating boilers (Heat Supply Act). One of the provisions is to provide financial aid to gas fired CHP that want to switch to biomass fired boilers [62].

In Croatia and Spain, biomass is not main RES. Biomass is the second renewable energy source after hydro in Croatia [27]. However, solid biomass (including biodegradable industrial and municipal waste) is supported by feed-in tariffs in Croatia. RE promotion is also supported by Loans of Environmental Fund and Croatian Bank scheme [65]. Spain is stated to have the best RES

potentials for wind and solar power, followed by biomass. Spain promoted renewable electricity through feed-in and premium tariffs, but that promotion is currently suspended. There are no public support schemes for RES in the heating sector in place [9].

3.3 Lagging countries

The lagging countries group (Group 3), as can be seen in Figure 4, comprises 9 EU countries that are far behind the national target for biomass. France and the UK (with Germany from 1 Group) are among the biggest energy consumers in the EU in absolute terms (Table 2). Thus, renewable energy development in these countries is crucial for achieving the 20% renewables by 2020. France is a major exporter in the EU's electricity markets, having its electricity produced primarily from nuclear power. More recently, France has made considerable progress via increased use of wood pellets use in the heating market. France is one of the main leaders in wood pellets consumption in the EU after the introduction of a specific support program for wood pellet equipment [61]. The UK has the largest gap of current RES use in comparison with its targets. However, the use of wood chips (heating) and wood pellets (electricity) show considerable growth. UK favours the use of 'low cost renewables', which is supposed to include biomass for electricity and heating [62]. The largest growth is related to the co-firing of pellets in large-scale power plants, as supported by the Renewables Obligations Certificate (ROC) scheme [78]. For comparison, the ROC obligations amount up to a price of 6.2 H5 € per GJ [66], as indicated in Table 3.

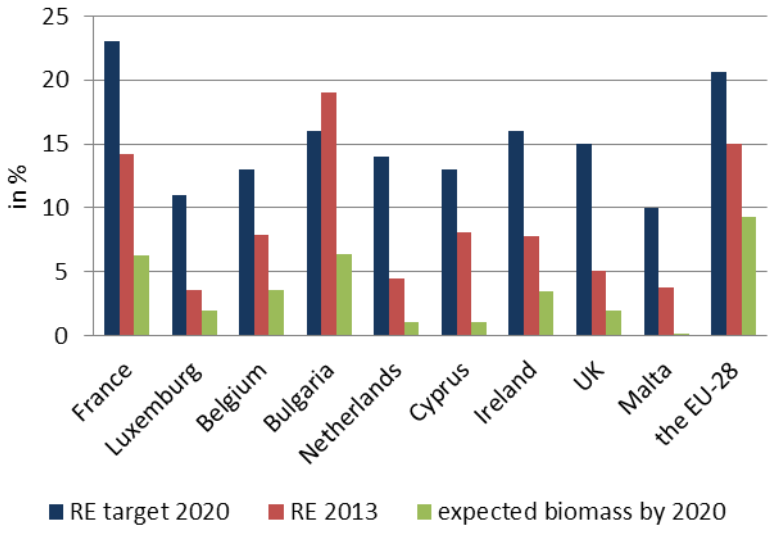

Fig. 4. *The 2020 RES target, the current RES share and the expected 2020 contribution of biomass in electricity and heating production in group 3, all in % of GFEC [52,54].*

Similar to the UK, Belgium and the Netherlands have a strong focus on the use of solid biomass for electricity and heating. The main support instrument for renewable energy in the Netherlands is the SDE+ premium feed-in scheme for electricity (e.g. 7.5 € per GJ for large-scale electricity production; see Table 2), renewable gas and heating purposes. Besides the premium scheme, investments in renewable energy technologies are supported via loans and various tax benefits (Appendix 1). The main technology for achieving RES-E targets is the co-firing of biomass existing coal-fired boilers in the Netherlands [14]. In Belgium renewable energy is a regional matter: only offshore wind and hydropower are governed by national regulations. Every region (Wallonia, Flanders, Brussels Capital) has its own standards of support for renewable energy, based on a national framework. The federal grid operator shall meet public obligations, which include the purchase of green certificates at a minimum price set by law for certain renewable electricity generation technologies [65].

Despite the fact that Bulgaria has already reached their RES 2020 targets (Table 2), bioenergy targets are lagging behind. Bulgaria uses a feed-in tariff of 13 € per MWh produced, equal to about 1.46 € per GJ for renewable electricity (Table 3), including biomass [70]. Concerning the heating and cooling sector, the use of renewable energy technologies in buildings is promoted through a system of tax incentives for building owners [65]. Bulgarian policy sets targets to encourage the creation of favourable conditions for renewable energy development in which nuclear energy is also a key target [79]. The further build up of nuclear energy is actually a key priority in Bulgaria, leaving less emphasis on biomass. Luxemburg has a potential for an innovative and smart green economy by 2020 [5].

Biomass is not the most popular RES in Cyprus, Ireland and Malta. Firstly, solar energy is the most important RE sources in Cyprus. Cyprus promotes renewable electricity generation through a subsidy, but no support scheme for RES H&C (see Appendix 1). Concerning the biomass, biodegradable waste is the main source of biomass [29]. Secondly, biomass has a less prominent role in Ireland which is very heavily dependent on imported fossil fuels but the country has an enormous untapped potential in wind power resources [39,80]. Forecasts suggest that by 2030 Ireland is expected to have approximately 6,800 MW of installed variable renewable capacity (which will be dominated by wind power) and this will represent approximately 50% of installed capacity [80]. The use of biomass is less developed. Finally, in Malta, electricity generated by

domestic PV installations is supported through a feed-in tariff. For H&C, the National Scheme provides a grant of 40% up to 400 € and is not restricted by social criteria [65].

4. Biomass supply potential in EU member states

4.1 The actual contribution of solid biomass use resources for energy

Scarlat et al. [12] show that EU's biomass primary demand is expected to increase from 3.1 EJ in 2005 to 7.4 EJ in 2020. The expected contribution of biomass feedstocks is mostly solid biomass with 5 EJ. Another study [10] suggests that the biomass demand for energy can reach 10 EJ per year by 2020. The NREAPs estimate that about 105 PJ lignocellulosic biofuels could be used in transport in 2020, but this depends on their commercial availability and prices. For 2020, about 15 million tonnes of lignocellulosic biomass (i.e. short rotation crops) would be needed to produce biofuels in addition to existing available sources [81]. Figure 5 and figure 6 present the contribution of solid biomass for the electricity sector and the heating (and cooling) sector respectively. In 2012, the leading countries in the electricity generation from solid biomass were Poland, Finland, Sweden, Germany and Austria from Group 1, Italy and Denmark from Group 2, and the UK, the Netherlands, France and Belgium from Group 3. As a national RE targets, most countries from studied Group 3, which are developed in solid biomass generation have also ambitious expectations of future solid biomass electricity generation (France, the Netherland, the UK and Belgium). In Group 1 and 2, Germany and Spain have ambitious expectations of future solid biomass electricity generation respectively. It is worth mentioning the large share of electricity produced in cogeneration from solid biomass, especially in Poland, Sweden, and Denmark from Groups 1 and 2 respectively in 2012. This is complemented by the UK France and Netherlands from Group 3 by the year 2020 [12].

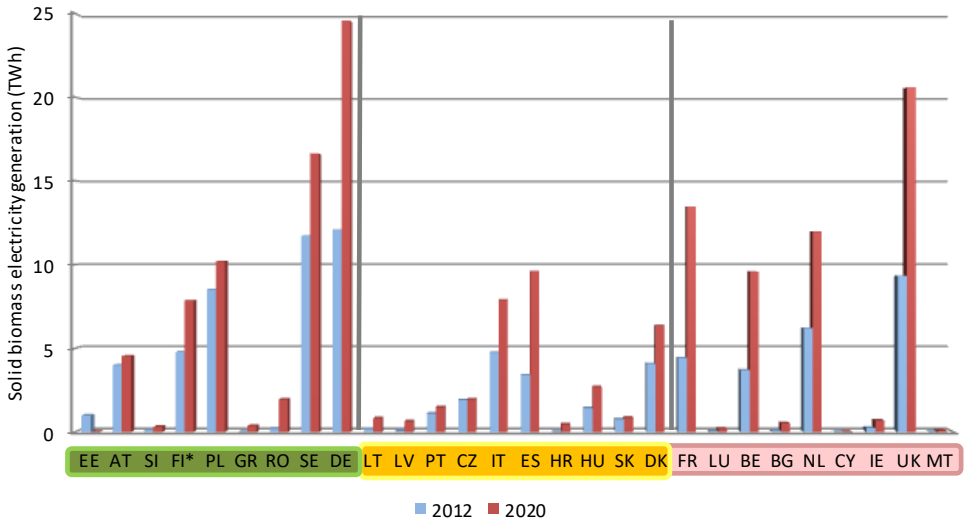

Fig. 5. *Current 2012 and expected 2020 use of solid biomass for electricity in the EU member states (in TWh), adopted from [12,54*]. Groups 1, 2 and 3 are shown in green, orange and red colour respectively.*

The total biomass heating is expected to grow from 2.6 EJ in 2010 to 3.8 EJ in 2020 in the EU [60]. Co-firing of solid biomass with coal becomes popular in most European countries. Biomass use in large coal-fired plants comes on stream in coming years. Use of solid biomass in H&C is very developed in most countries from Group 1 (Poland, Finland, Austria, Romania, Germany and Sweden,) and 2 (Italy and Spain), while in Group 3 only France present a high use of solid biomass in H&C sectors. Solid biomass will play a crucial role in RES-E and lesser role for RES-H for Group 2 and 3 by 2020, while solid biomass is more developed in RES-H in Group 1.

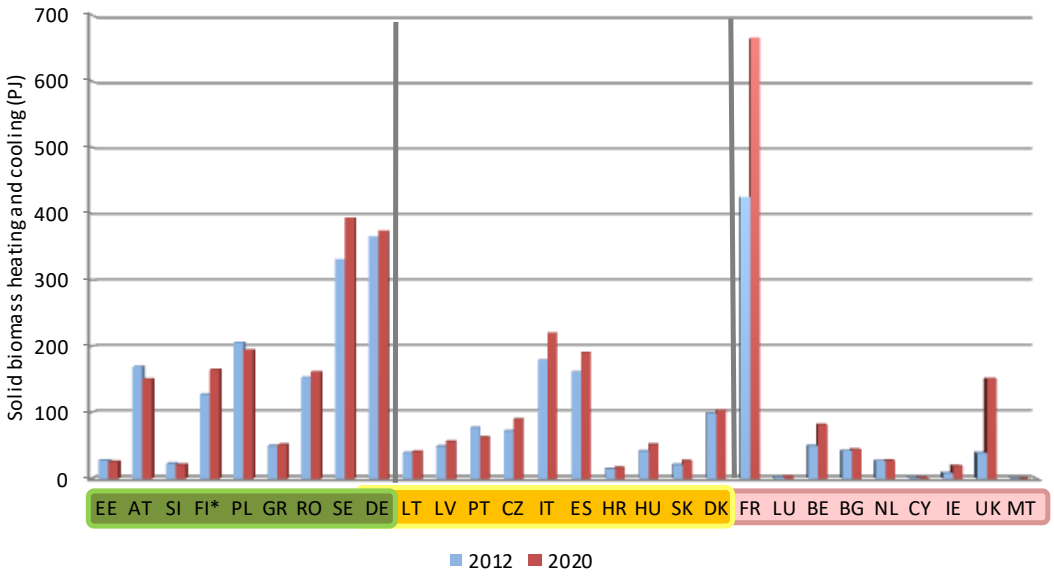

Fig. 6. *Current 2012 and expected 2020 use of solid biomass for heating and cooling in the EU member states (in PJ), adopted from [12,54*]. Groups 1, 2 and 3 are shown in green, orange and red colour respectively.*

A lot of research studies concentrate on current and future woody biomass demand. Most of them concluded that woody biomass demand would increase [10,51,82–85]. Additionally, the RE Directive has a significant influence on this growth [51,83], including national RE targets [49,70]. Figure 7 shows the relation between RE target and expected solid biomass primary demand. Countries from studied Groups 1, 2 and 3 are shown in green, orange and red colour respectively. In countries from Group 1 (in green), solid biomass mostly plays an important role in achieving of RE target. For France (Group 3) and Denmark (Group 2), the highest expected use of solid biomass can positively impact on the increasing RE share in GFEC.

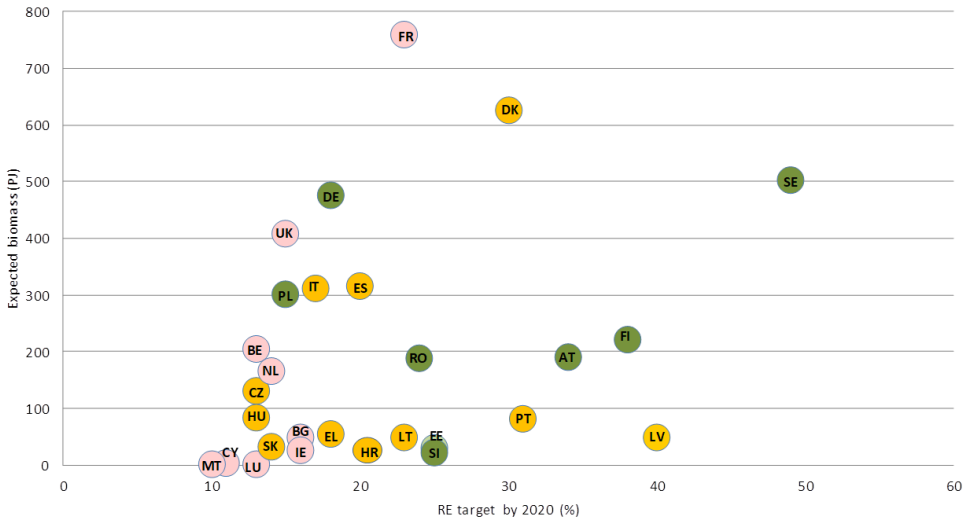

Fig. 7*. RE target and expected use of solid biomass primary demand in EU countries by 2020, from [12,26].*

4.2 The future contribution of solid biomass for energy, specified for wood

There is a clear potential to intensify forest utilization for energy in the EU. Only 60–70% of the annual growth of EU forests is harvested. At present, about 42% of the harvest is eventually used for energy. According to EEA [59], the biomass potentials in the EU is 9.8 EJ, of which 1.6 EJ come from forestry and 4 EJ from agriculture. Elbersen et al. [86] show that the sustainable biomass potential might be even larger in the EU-27 in 2020, reaching about 15.7 EJ, of which 7 EJ from forestry and 6.6 EJ from agriculture. Thus, according to both studies, the biomass potential of the European Union is large enough to ensure the biomass demand needed to reach the bioenergy target set at the EU level [12,83]. In the EU-27, the supply of biomass from forestry sectors will increase from 1.7 EJ in 2006 to 3.1 EJ in 2020 [56]. Figure 8 shows average estimates of annual forest biomass potentials.

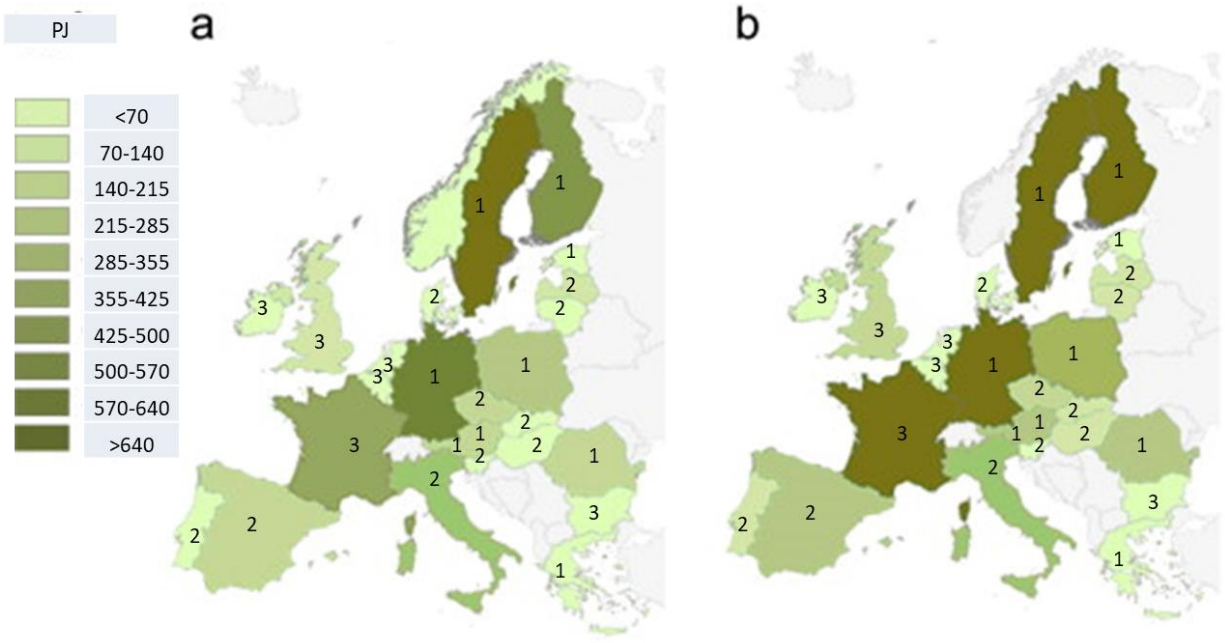

Fig. 8 *Average estimates of annual forest biomass potentials in the EU (plus Norway) (a) total biomass, current conditions (2013), (b) total biomass, and highest potential (2050), adopted from [87]. The leading countries of Group 1 (1), the intermediate countries of Group 2 (2) and the lagging countries of Group 3 (3).*

In the Group 1, Finland is leading in terms of highest biomass potential. In Finland, forest covers approximately 30 million hectares, which account for 68% of the total land area [88]. In the European context, Finland is a "forest giant". The country has over sixteen times more forest per capita than western European countries, on average [33]. Austria has 47% (3.96 million hectares [67]) of land area covered by forests [68]. Within the next 10 years, the countries in the Baltic Sea region (Estonia from Group 1, Lithuania with Latvia from Group 2) expect a large increase of solid biomass consumption by more than 1.1 EJ. Forest resources are growing faster than demand for energy wood every year approximately with 1 EJ in the Baltic Sea region [89].

Countries from Group 2 mostly belong to Central Europe (Figure 1). Development of bioenergy in Central Europe is more challenging than, for example, in Nordic countries. Mergner et al. [90] suggest that Central and Eastern Europe countries face particularly large barriers for achieving the required high level of RE financing. For Hungary, Róbert et al. [38] suggest that, due to a large amount of solid biomass from forestry (including agriculture), the country already has a biomass potential that will be needed to reach the national target by 2020. A high growth in solid biomass development is not expected, because there are uncertainties with agricultural and energy price

development, technological development and environmental issues. Forest covers more than 41% of Slovak territory (1.9 million hectares [88]). It has a large technically exploitable potential of biomass from wood processing industries (16 PJ/year, that is 18% of all RES), while it used only 6.4 PJ in 2010. The technical potential of biomass from forests is 6.7 PJ, of which 6 PJ is used [91]. Croatia has high quantities of agricultural and forestry residues. The country has about 5 PJ of available potential of forestry residues and an average energy potential equal to 5.9 PJ, for forestry residues, wheat straw and corn stover respectively [28]. Stjepan et al. [92], based on interviews with Croatian private forest owners in 2012, concluded that the younger owners were more likely to supply woody biomass, compared with older owners. Germany (Group 1), Spain (Group 2) and France (Group 3) have biomass potential is higher than demand [12].

In Group 3, in Belgium and the Netherlands, the woody biomass demand is slightly less than the potential of the countries. The low biomass potential (Figure 8) and the large expected solid biomass contribution (Figure 7) in the UK can be explained by greatest primary bioenergy potential of household wastes (over 414 PJ by 2050), energy crops (over 360 PJ by 2050) and agricultural residues (over 288 PJ by 2050) [93]. Additionally, the UK has become the world's largest wood pellet importer with more 3 million tonnes of imported wood pellets [94]. In Portugal and Latvia (Group 2) and Ireland (Group 3), the woody biomass demand is close to the potential of the countries.

5. Future progress

Overall, it should be noted that in 2013 gross inland energy consumption in the EU, which reflects the energy necessary to satisfy inland consumption, amounted to about 70 TJ, back to its early 1990s level and down by 9.1% compared to its peak of approximately 77 TJ in 2006 [16]. It seems that Group 3 countries need to reconsider their biomass usage measures and also other kinds of renewable energy sources to reach the RES and biomass targets given in their respective NREAP's. A lot of work is still required to increase the share of bioenergy at the local and regional level. Although all Group 3 countries have considerable renewable energy promotion efforts and policy support measures, their biomass targets are unlikely to be attained by 2020.

Further development of bioenergy in the EU will continue depending on the policy support in each member state. Not all countries have strong support of bioenergy and all have different potentials of woody and other biomass. The achievability of the targets has its constraints, depending on the

situation in the EU countries. Some of the measures that can increase the likelihood of achieving bioenergy targets for the EU are:

1) **"Increasing the sustainable mobilization of forest European forest biomass resources."** Constraints for sustainable wood mobilization can be found in several EU countries. For example, the installed production capacity of wood pellets may jeopardise the maintenance of the forest ecosystem in Portugal due to unsustainable forest utilization for energy purposes [95]. Challenges with implementation of Forest Stewardship Council (FSC) certification exist in Romania [96]. Mechanization and efficiency of forest biomass harvesting varies in the EU countries. For example, in Austria and Italy it is highly mechanized whereas in Greece and Romania it requires improvements [73]. Finland is a good example of having high coverage of forest certification for sustainable forest management [97,98]. Countries can learn from each other, when they undertake joint efforts. An example for joint research on mobilization can be traced via different EU projects, like RERAM [99], SIMWOOD [100], INFRES [101], Proforbiomed [102] or the Biomass Policies [103].
2) **"Sustainability of biomass logistic."** Sustainable biomass logistics and trade within EU [25] and with nearby regions, such as Northwest Russia [104–106] is important issues. An example of joint efforts in the private sector is the sustainable biomass partnership, in which different European energy utilities across Europe work together for complying with sustainability and carbon issues [107]. The Netherlands, as a large (potential) consumer of woody biomass, builds further on existing forest certification principles for woody biomass supplies in its 'encouraging sustainable biomass production' (SDE) program [108]. The Dutch SDE program has some extra requirements on top of the earlier launched UK program called Renewable Obligation Certificates [98,109], in which wood chips and pellets for power and heat production are supported.
3) **"Stable support policy for bioenergy markets."** More stable policy support regarding bioenergy is needed in most EU countries. For example, the UK with multiple biomass resources (agricultural, waste, crops etc.) has a long list of barriers to increasing resource availability for the bioenergy sector and the role of policy support in overcoming these challenges is crucial [12,93]. Increasing the level of financing especially in Central Europe is important [90]. Austria and Germany have current successful policy measurements for agricultural biomass use for energy. Such mechanism can be applicable in many other European countries such as Italy, the

UK, and Luxembourg [98]. Germany makes attractive progress in electricity production from biomass due to policy support, which can be applicable in Austria, France, Slovakia, Slovenia, Belgium, UK and Greece. Policy measures for biomass electricity and heat of Austria can be employed in Germany, Slovakia, Slovenia, Belgium and France [98]. The UK is a forerunner with strong growth of industrial wood pellets usage in co-firing for electricity and wood chips for heating. France is one of the leading countries in non-industrial wood pellets consumption thanks to a specific support program for wood pellet equipment. Baltic countries mostly focus on export of wood pellets due to weak profitability of wood pellets usage on local markets. There are few, if any, incentives in the Baltics for biomass for energy purposes. With more incentives, those countries may increase the use of chips for CHP, and also substitute relative low efficient firewood by more efficient wood pellets in the residential heating sector [110].

4) **"Safeguard a level playing field for both the bioenergy sector, traditional forest industries and others."** Constraints can be found, for example, in Portugal [95] and Germany [111], where the public support for biomass production facilities has created difficulties for existing forest industries. An integrated use of biomass through a cascading approach seems a promising solution [81]. The cascading principle can be implemented based on the use of wood-based fuels as a first resource. However, success is not guaranteed, as several constraints have come across in Sweden [112]. The cascade approach has been re-introduced more recently in Belgium [113] and evaluated for possible introduction in Germany [114].
5) **"Utilisation of biomass potential in heat and CHP production".** Biomass integration of CHP plants in district heating. Fossil fuel taxation in heat production and subsidies for electricity generated in CHP plants have increased solid biomass usage in many countries such as Finland and Estonia (Group 1). Finland has heat bonus in CHP allocated to CHP plants working on biogas and forest fuel [99]. Co-combustion of wood chips has increased in Estonia thanks to a new power production plant and three new CHP plans [115]. In Estonia, CHP are closely linked with district heating which is used by 60% of the population [116] Denmark and the Netherlands (Group 3) have the same opportunities to increase solid biomass share in their CHP plants. Denmark plans to considerably increase use of wood chips in CHPs [117], instead of coal and natural gas. So far, the Netherlands has only invested in some small CHPs, which replace natural gas fired plants [118] linked to district heating around urban areas. Thus, experience of strong

policy for bioenergy support in several countries can be applicable to countries with lower levels of support.

6) **"The reduction of subsidies for fossil fuels."** The value of fossil fuel subsidies amounts to around four times the value of subsidies to renewable energy in the world [119]. EU has a very low level of fossil fuels support with less than 0,9 billion euros which is less than 0.1% of EU-27 GDP (Gross Domestic Production). In 2012, investments into renewable were larger than support to the use of fossil fuels [120]. The phasing out of fossil fuel subsidies, together with other options like closing least efficient coal fired power plants, is suggested to bridge the gap between current policies and the actual wish to keep the global temperature increase below 2^0 C [121,122]. This is highly relevant for future bioenergy.

Overall, countries from studied Group 3 (France, Luxembourg, Belgium, Bulgaria, the Netherlands, Cyprus, Ireland, the UK and Malta) may not achieve their biomass targets without changing their policies and providing stable support schemes. Also, the cost efficient allocation of biomass, and the other kinds of renewable energy sources across the EU Member States should get more attention, as suggested by Bigerna et al. [123].Their evaluation roughly indicate that producing renewable energy from biomass and other RES should strive for re-allocation of existing 2020 individual RES share per country, in order to optimize the lowest technology costs in 2030.

6. Conclusions

This study shows that all European members have actively contributed to RE EU targets; the trend is an increasing renewable energy usage in GFEC throughout the EU. Each EU MS had its preferences for the kind of renewable energy source used depending on the resource potential of the respective countries and also on their historical traditions. Biomass is the main renewable energy source and its development is crucial for the achievement of the RE targets. The expected share of biomass is about 45.1% from total renewable share, followed by wind (17.2%), hydropower (12.9%), biofuels (11.9%) and solar (6.2%) by 2020. EU's biomass primary demand is expected to increase from 5.3 EJ in 2013 to 7.4 EJ in 2020. The expected contribution of biomass feedstocks is solid biomass (5 EJ), biogas (0.9 EJ) and liquid biomass (1.6 EJ; of which 1.2 EJ for transportation fuels). Share of other renewable energy sources will also increase by 2020. Depending on the scenarios, the wind energy production, as expected, will cover 1.2 EJ–1.8 EJ of total EU power demand by 2020 [124]. Hydropower and solar as projected can reach 1.3 EJ and 0.6 EJ respectively by 2020. However, the

individual contribution and developments of biomass to the member states is unbalanced. Hereafter a sum up of the contribution, divided over the actual RES share in the EU member states.

5.1 Leading countries (Group 1)

For countries that already reach their national biomass targets or have a difference less than 15% (Group 1), woody biomass plays an important role for electricity generation and H&C sector, mostly for Finland, and Austria. For Romania, for example, wind and solar are more priority RE sources and biomass is lagging behind. However, this country has a potential for solid biomass use in H&C sectors. Romania and Austria with Lithuania (from 2 Group), have woody biomass potential higher than demand. Thus, woody biomass development is very promising and supply from these countries to other European Members will take place. Finland, Romania, Austria and Sweden have a large biomass potential. For Poland and Slovenia woody biomass supply from other EU countries is important. Germany has seen promising development of biomass. It seems that Group 1 countries have embraced biomass, developed it and now can enjoy the benefits.

5.2 Intermediate countries (Group 2)

Countries whose biomass still needs to increase from 15% to 30% (Group 2) have a realistic likelihood of reaching their own local biomass targets and will probably increase the share of woody biomass more rapidly than in previous years, due to policy support of RE promotion in heat and electricity production. Latvia and Lithuania has seen promising development of biomass and may soon match the performance of Group 1. Italy and Slovakia are likely to increase woody biomass use for heat and electricity production. Italy will be a key importer of woody biomass in the EU. It seems that Group 2 countries have mixed levels of biomass usage and potential. Therefore developing their RES potential has lagged.

5.3 Lagging countries (Group 3)

In countries whose required biomass share increase is more than 30% (Group 3), France and the UK (with Germany from 1 Group) have huge domestic energy consumption; thus, the development of renewables in these countries is crucial and their success will significantly influence the overall EU share of renewables. Solid biomass use in electricity and heat production is therefore important in France and the UK. If these countries can further increase biomass share in GFEC, it will positively affect their national RE targets and, as a result, the total RE share of the EU-28. France (with Germany from Group 1) have large unused potential of solid biomass, while for the UK, development of solid biomass imports, mainly wood pellets, will play a crucial role. Despite the RE

support in the electricity and heat sectors, France and the UK will still not comply with their own RE target due to a large difference between current and expected share of renewables by 2020. For France and Belgium, solid biomass will play a crucial role in RES-E and a smaller role for RES-H by 2020. Belgium and the Netherlands have woody biomass demand higher than potential. Similar to the UK, these two countries will also have to rely on imports from other members states.

This study could serve as the starting point for any future work related to the national RE targets assessment and setting new future RES targets for EU Member States in 2030. Further research should determine which sources have the highest priorities, when regarding bioenergy together with other renewable energy sources, such as wind, water and solar energy. How can each EU member State optimally develop their woody and agricultural biomass potentials, including waste resources and other renewable energy options? For the forest sector specifically, the individual contribution of woody biomass to RES targets would be highly relevant. As such, a future study should preferably categorise the total biomass utilization into woody biomass, agricultural biomass and waste resources.

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