Delivery of sustainable supply of non-food biomass to support a

"resource-efficient" Bioeconomy in Europe

S2Biom Project Grant Agreement n°608622

D6.2
Report on benchmarking of country policy approaches

Version 2.0

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About the S2Biom project

The S2Biom project - Delivery of sustainable supply of non-food biomass to support a "resource-efficient" Bioeconomy in Europe - supports the sustainable delivery of non-food biomass feedstock at local, regional and pan European level through developing strategies, and roadmaps that will be informed by a "computerized and easy to use" toolset (and respective databases) with updated harmonized datasets at local, regional, national and pan European level for EU28, Western Balkans, Moldova, Turkey and Ukraine. Further information about the project and the partners involved are available under www.s2biom.eu.

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About this document

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List of Abbreviations

CAP	Common Agricultural Policy
CHP	Combined Heat and Power
EU / EU28	European Union
DBH	Diameter at breast height
FSC	Forest Stewardship Council
GDP	Gross Domestic Product
GHG	Greenhouse Gases
LSU	Livestock Units
MSW	Municipal Solid Waste
na	Not Available
NAI	Net Annual Increment
PEFC	Programme for the endorsement of forest certification
PPS	Purchasing Power Standard
RE	Renewable Energy
SFM	Sustainable Forest Management
SNG	Synthetic Natural Gas (bio-methane)
TE	Total Energy
TOE	Tonnes of oil equivalent
UAA	Utilised Agricultural Area
WP	Work Package

1 Introduction and methodology

1.1 Introduction

Developing a robust biobased economy requires both (i) the access to renewable feedstock in sufficient quantities, with guaranteed quality, and at a competitive price, (ii) stimulating market demand, and (iii) policy and market measures that ensure that competing uses of land and feedstock measures such as food supply and other important markets that require protection are safeguarded. To ensure a plentiful, reliable supply of affordable biomass feedstock, the EU Member States and other countries are developing supportive programmes, enabling the establishment of cost-effective supply chains, providing raw materials of known and consistent quality. One of the most important examples of an approach to regulate biobased feedstock production is the Common Agricultural Policy (CAP)[1]. Of course the Renewable Energy Directive has created a market for renewable energy (including biofuels and bioenergy) in Europe. Also, the European Commission's Lead Market Initiative[2] suggested a synchronized approach to stimulate demand for innovative biobased products.

In order to assess the effectiveness of the various policies and approaches that are introduced to establish a reliable, affordable supply of biomass feedstock, it is necessary to describe and assess the specificities of the biomass resources used and relate them to the specific policy goals.

In Task 6.1 national regulatory and economic frameworks are collected in a policy database[3] and in WP9 different case studies are elaborated. In this report we compare the achievements in different countries, in relation to the country characteristics, and dig into a number of **representative cases and countries where supportive policies have been applied**. The analysis will focus on the one hand on policies aiming at the supply side and on the other hand on policy frameworks that create a market for and support the deployment of bioenergy and biobased products. Important in this respect is to consider how sustainability[4] of the supply chains and resource efficiency are taken into account in the policy frameworks and how the use of biomass is balanced between sectors.

To benchmark the national policy approaches, the countries are compared in terms of a set of performance criteria. The analysis focuses on:

- the role of renewable energy and bioenergy (solid biomass, biogas, MSW and liquid biofuels) in the energy mix;

[1] http://ec.europa.eu/agriculture/index_en.htm
[2] http://ec.europa.eu/growth/sectors/biotechnology/bio-based-products_en
[3] https://s2biom.vito.be/
[4] Sustainability indicators are subject of WP5 of the S2BIOM project.

- share of CHP compared to electricity only and heat only applications (for distribution);
- management of forests and wood removals (for energy and industrial wood);
- importance of wood processing industries in relation to energy use of woody biomass;
- domestic supply versus imports/exports of solid biomass;
- municipal waste collection and treatment;
- production, consumption and imports/exports of liquid biofuels;

1.2 Methodology for benchmarking

The benchmark analysis of the national policies in this report consists of three different steps:

i) Step 1 - Clustering of countries depending on their specific characteristics, *i.e.* indicators;
ii) Step 2 - Defining performance criteria for benchmarking;
iii) Step 3 - Linking country characteristics and performance criteria to policy frameworks in relation to cases (specific feedstocks and value chains);

Within the benchmark analysis all 37 different countries (*i.e.* EU28, Western Balkans, Moldova, Turkey and Ukraine) are covered. Taking into account the large differences between the countries, they are clustered based on specific country characteristics to allow a targeted benchmark of the policy frameworks.

To benchmark the performance and impact of national policies we define different performance criteria. These performance criteria are mainly linked to the usage of specific types of biomass and the mobilization of the biomass (*i.e.* the amount of biomass used in relation to its potential and sustainable resource management) and to the structure of the value chain (*i.e.* resource efficiency and the link between material and energy use).

For a number of representative cases the performance criteria are linked to the policy frameworks in specific country clusters. Where possible, the selected cases have a link with the case studies selected in WP9. The cases are: mobilizing forest based feedstocks for use in energy and materials, mobilizing straw for energy, biomass based district heating, large scale biomass imports (incl. sustainability criteria), support for energy crops, mechanisms for supporting advanced biofuels, and introducing bio-methane as transport fuel.

2 Clustering of countries based on indicators

Countries/regions have different specific backgrounds and certain policy approaches may only be successful in a specific context. We will therefore try to cluster countries in groups with comparable background. Mind that countries are not uniform, regions within a country can have different characteristics. So lessons from e.g. forest based countries may also be applicable for forest based regions, even if the country as a whole is less forestry based.

In order to cluster the countries, a three-step procedure is used. First, indicators are selected and data is gathered, mostly from Eurostat. Second, the indicators are scored based on a reference value (*i.e.* EU28 average). Finally, similarities between countries based on the indicators are identified and the clusters are defined.

For each country a table with a list of indicators is made in Excel. Factsheets per country are available in Annex. Indicators are selected based on their relevance for biomass utilization and mobilization in a specific country. The indicators are grouped into different categories: (1) population and land surface, (2) GDP (Gross Domestic Product) and trade, (3) energy consumption, (4) agriculture and (5) forestry. For the clustering of countries different databases are used to collect information concerning the various indicators that enable the detection of similarities between the countries. Data is identified for the year 2013 when available. To allow comparison, some indicator values are expressed per capita. In case no data were available for 2013 for such an indicator, the population of the year for which the information was available, is used to remain consistent. For most indicators Eurostat data[5] is used (accessed in October/November 2015); only when the data was not available in Eurostat, other databases are consulted are information was gathered via the partners.

To have a reference concerning the level of the values (low – medium – high), in a second step, the EU percentiles are used. When a value is lower than the 25th EU percentile, it is indicated to be low and provided a green colour. In case an indicator's value is higher than the 75th EU percentile, it is indicated to be high and provided a red colour. If the indicator's value is somewhere between the 25th and 75th EU percentile, it is provided an orange colour and indicated as being of medium level. This step is only performed for those parameters that allow a comparison, e.g. indicators expressed in percentages or per capita. **Note that the colours only indicate the level of an indicator (high/medium/low) and do not indicate whether a value is good or bad.**

Finally, in the third step, for each of the categories (*i.e.* group of indicators) we identified the countries that have a similar scoring pattern in order to have a substantiated basis for benchmarking the countries using performance criteria. The results of this analysis are shown in Annex I of this report. The methodology used in

[5] http://ec.europa.eu/eurostat

this project is very similar to the methodology used within the Biomass Policies project (D3.1 – Policy landscapes), but is extended to the 37 countries of S2Biom.

In the remainder of this section we will discuss the results in more detail for the five indicator categories.

2.1 Population and land surface

In the first category of indicators we selected data concerning the population number and the total area of a country. Using this information we calculated the population density and available land area per capita. Data was available for the year 2013 in the Eurostat database. An overview per country is provided in Table 1.

Table 1: Population and land surface

Country	Population	Area	Population density	Land area
	Million n° 2013	km²	n°/km²	ha/capita
Belgium	11.2	30,528	366	0.27
Bulgaria	7.3	110,900	66	1.52
Czech Republic	10.5	78,866	133	0.75
Denmark	5.6	42,916	131	0.77
Germany	80.5	357,168	225	0.44
Estonia	1.3	45,227	29	3.43
Ireland	4.6	69,797	66	1.52
Greece	11.0	131,957	83	1.20
Spain	46.7	505,991	92	1.08
France	65.6	632,834	104	0.97
Croatia	4.3	87,661	49	2.06
Italy	59.7	302,073	198	0.51
Cyprus	0.9	9,251	94	1.07
Latvia	2.0	64,573	31	3.19
Lithuania	3.0	65,300	46	2.20
Luxembourg	0.5	2,586	208	0.48
Hungary	9.9	93,024	107	0.94
Malta	0.4	316	1333	0.07
Netherlands	16.8	41,540	404	0.25
Austria	8.5	83,879	101	0.99
Poland	38.1	312,679	122	0.82
Portugal	10.5	92,212	114	0.88
Romania	20.0	238,391	84	1.19
Slovenia	2.1	20,273	102	0.98
Slovakia	5.4	49,036	110	0.91
Finland	5.4	338,435	16	6.24
Sweden	9.6	438,576	22	4.59
United Kingdom	63.9	248,528	257	0.39
Albania	2.9	28,750	101	0.99
Bosnia and Herzegovina	3.8	51,209	75	1.34
Macedonia	2.0	25,713	80	1.25
Kosovo*	1.8	10,887	167	0.60
Moldova	3.6	33,846	105	0.95
Montenegro	0.6	13,812	45	2.22
Serbia	7.2	77,474	93	1.08

Country	Population	Area	Population density	Land area
	Million n° 2013	km²	n°/km²	ha/capita
Turkey	75.6	785,347	96	1.04
Ukraine	45.4	603,549	75	1.33

Source: Eurostat data 2013

Concerning the population density, Malta, the Netherlands, and Belgium have the highest concentration of inhabitants per km², whereas Finland, Sweden, Estonia and Latvia have the lowest population density. Note that for the available land area per capita (ha/capita) it is the other way round.

Based on the indicator values we clustered the countries based on the population density and the total land surface of the country which gives a clustering pattern as graphically presented in Figure 1. The biggest group of countries can be found in the common category of 'small to average size & low to average population density'. Finland and Sweden can be qualified as large size with low population density. Belgium, the Netherlands and Malta have small size and high population density.

The country clusters will be used in the third step in which we benchmark the national policies and identify success factors.

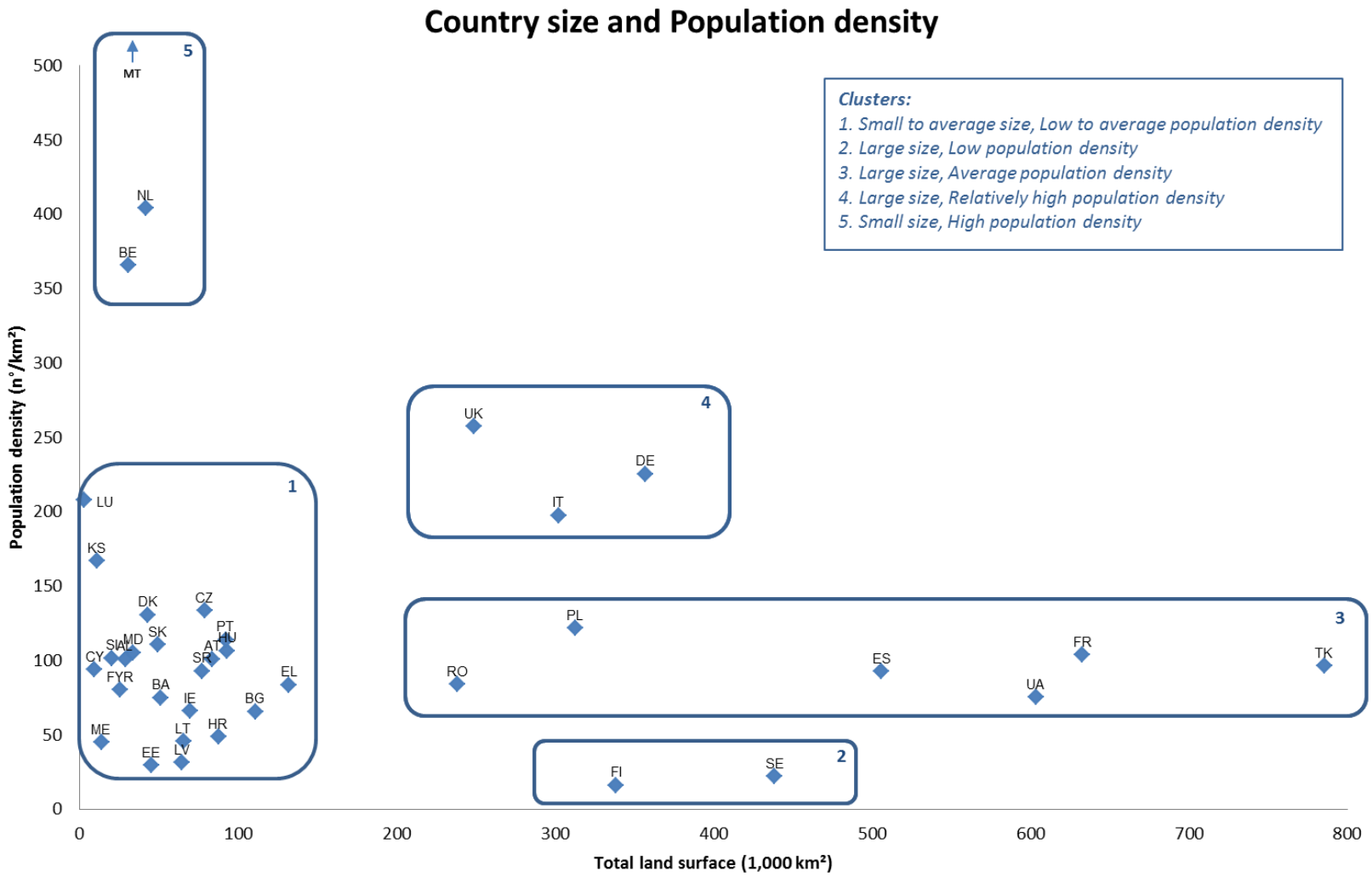

Figure 1: Country clusters – population density and land surface

2.2 GDP and importance of trade

Information concerning GDP is expressed in million euro (€) and in 1,000 euro per capita. In addition the purchasing power standard (PPS) is used, expressed with EU28 average = 100. Using the imports and exports expressed in million euros we calculated the cross border movements per capita, which are calculated as the sum of the imports and exports.

Table 2: GDP and trade

Country	GDP	GDP/capita		Cross border movements
	million €	€ 1,000	PPS	€1,000/capita
Belgium	382,692	34	119	19.67
Bulgaria	39,940	5	45	2.65
Czech Republic	149,491	14	82	4.59
Denmark	248,975	44	124	9.31
Germany	2,737,600	34	122	9.78
Estonia	18,613	14	73	4.59
Ireland	164,050	36	130	11.26
Greece	182,054	17	73	3.58
Spain	1,022,988	22	94	4.36
France	2,059,852	31	107	5.23
Croatia	43,128	10	61	2.14
Italy	1,560,024	26	99	5.72
Cyprus	16,504	19	89	2.36
Latvia	23,372	12	64	3.14
Lithuania	34,631	12	73	7.18
Luxembourg	45,478	85	258	12.77
Hungary	97,948	10	66	3.96
Malta	7,263	17	86	6.76
Netherlands	602,658	36	131	21.54
Austria	313,067	37	128	8.49
Poland	389,695	10	67	2.29
Portugal	165,690	16	78	2.86
Romania	142,245	7	54	1.42
Slovenia	35,275	17	82	6.79
Slovakia	72,134	13	75	4.96
Finland	193,443	36	113	8.25
Sweden	420,849	44	127	9.53
United Kingdom	1,899,098	30	109	7.30
Albania	9,629	3.3	28	0.60
Bosnia and Herzegovina	13,674	3.6	29	1.11
Macedonia	8,112	3.9	36	1.33
Kosovo*	5,327	2.9	na	0.85
Moldova	6,010	1.7	na	1.68
Montenegro	3,327	5.4	40	1.95
Serbia	34,263	4.8	37	1.35
Turkey	620,682	8.2	53	2.47
Ukraine	143,482	3.2	na	2.33

Source: Eurostat data 2013
na = not available

Countries with the highest absolute GDP are Germany, France and the United Kingdom, which is also in relation to their high population. When expressed per

capita, Luxembourg, Netherlands, Ireland, Austria, Denmark and Sweden score highest. Countries with the lowest GDP are mainly the non-EU countries that are taken into account in this project, as well as Bulgaria and Romania in the EU. The highest cross border movements per capita appear in the Netherlands, Belgium, Luxembourg and Ireland.

We can cluster the different countries based on the total GDP per capita and the trade orientation (see Figure 2). In case the cross border movements per capita are high, a country is defined to be trade oriented. There seems to be a clear correlation between GDP and cross border movements. The Netherlands and Belgium clearly score higher with their international harbours.

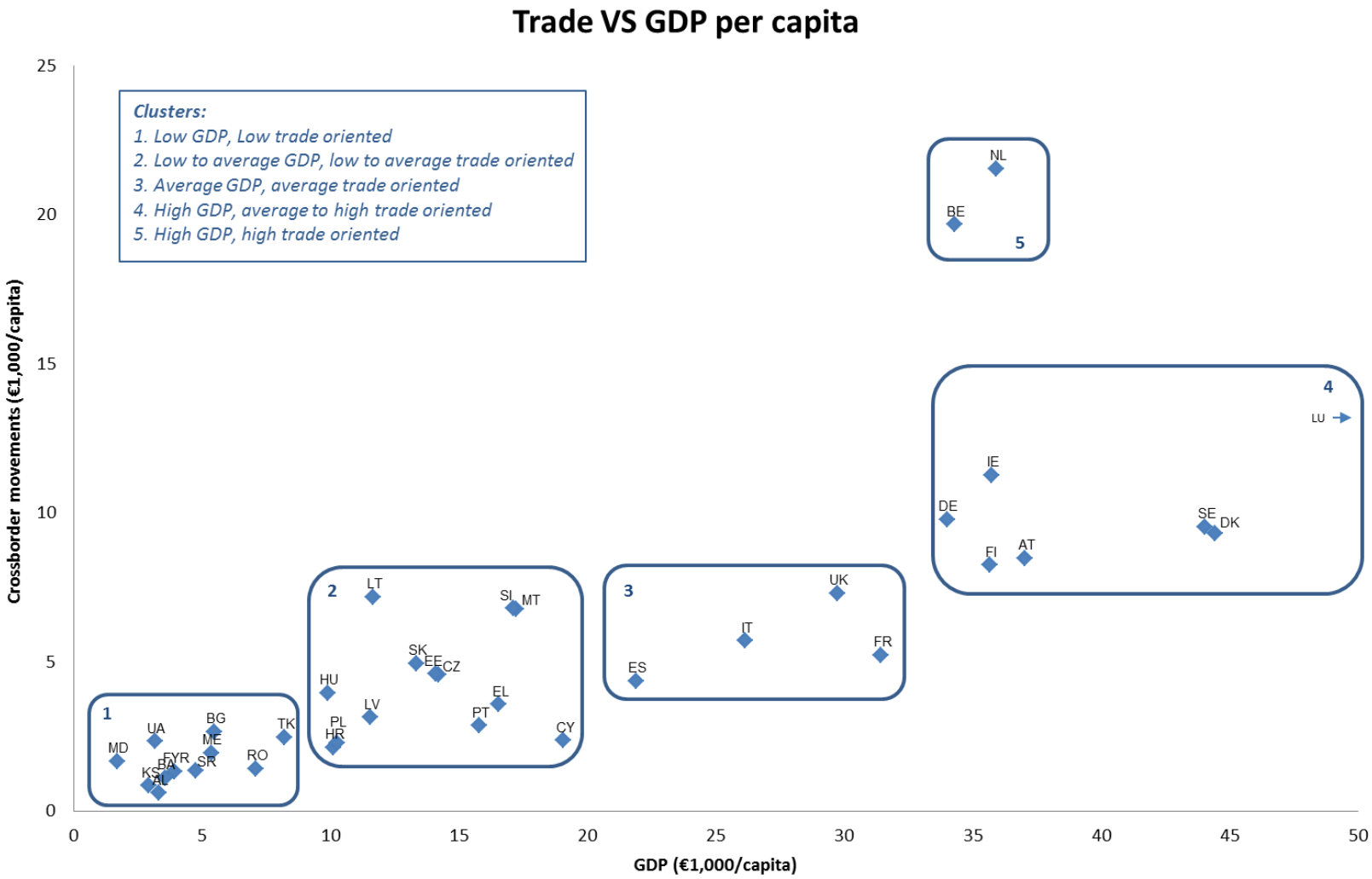

Figure 2: Country clusters – Cross-border movements and GDP per capita

2.3 Energy

In this group of indicators we collected information concerning the primary energy consumption in a country (expressed in tonnes oil equivalents – toe per capita) and the energy import dependence (percentage of energy consumption). An overview of the data concerning energy per country is provided in the table below.

Table 3: Energy

Country	Primary energy consumption toe/capita	Energy dependence %
Belgium	4.25	77.5
Bulgaria	2.24	37.8
Czech Republic	3.77	27.9
Denmark	3.18	12.3
Germany	3.76	62.7
Estonia	4.92	11.9
Ireland	2.92	89.0
Greece	2.15	62.1
Spain	2.43	70.5
France	3.75	47.9
Croatia	1.71	52.3
Italy	2.58	76.9
Cyprus	2.54	96.4
Latvia	2.17	55.9
Lithuania	1.92	78.3
Luxembourg	8.01	96.9
Hungary	2.12	52.3
Malta	1.90	104.1
Netherlands	3.93	26.0
Austria	3.77	62.3
Poland	2.45	25.8
Portugal	2.03	73.5
Romania	1.54	18.6
Slovenia	3.25	47.1
Slovakia	2.99	59.6
Finland	6.04[a]	48.7
Sweden	4.93[a]	31.6
United Kingdom	3.05	46.4
Albania	0.80[b]	25.1[b]
Bosnia and Herzegovina	1.69[b]	29.8[b]
Macedonia	1.33[b]	46.8[b]
Kosovo*	1.29[b]	24.2[b]
Moldova	0.86[b]	91.0[b]
Montenegro	1.65[b]	27.2[b]
Serbia	2.08[b]	24.1[b]
Turkey	1.54[b]	74.4[b]
Ukraine	2.56[c]	27.2[c]

Source: Eurostat data 2013
[a] Finland and Sweden have energy intensive industry, mainly forest industry, which is using 50% of total energy.
[b] IEA data 2013
[c] Received via partner (Renewable Energy Agency Ukraine)

The countries with the highest primary energy consumption per capita are Luxembourg, Finland, Sweden and Estonia. The countries with the lowest primary energy consumption per capita are mainly found in the non-EU countries, with the lowest in Albania, Kosovo* and Moldova.

There are 9 countries with an energy dependence of more than 70%: Malta, Luxembourg, Cyprus, Ireland, Lithuania, Belgium, Italy, Portugal and Turkey. On the other hand, Estonia and Denmark have an energy dependence of less than 15%.

There doesn't seem to be a clear correlation between primary energy consumption and energy dependence.

On the other hand, GDP and energy consumption are clearly related.

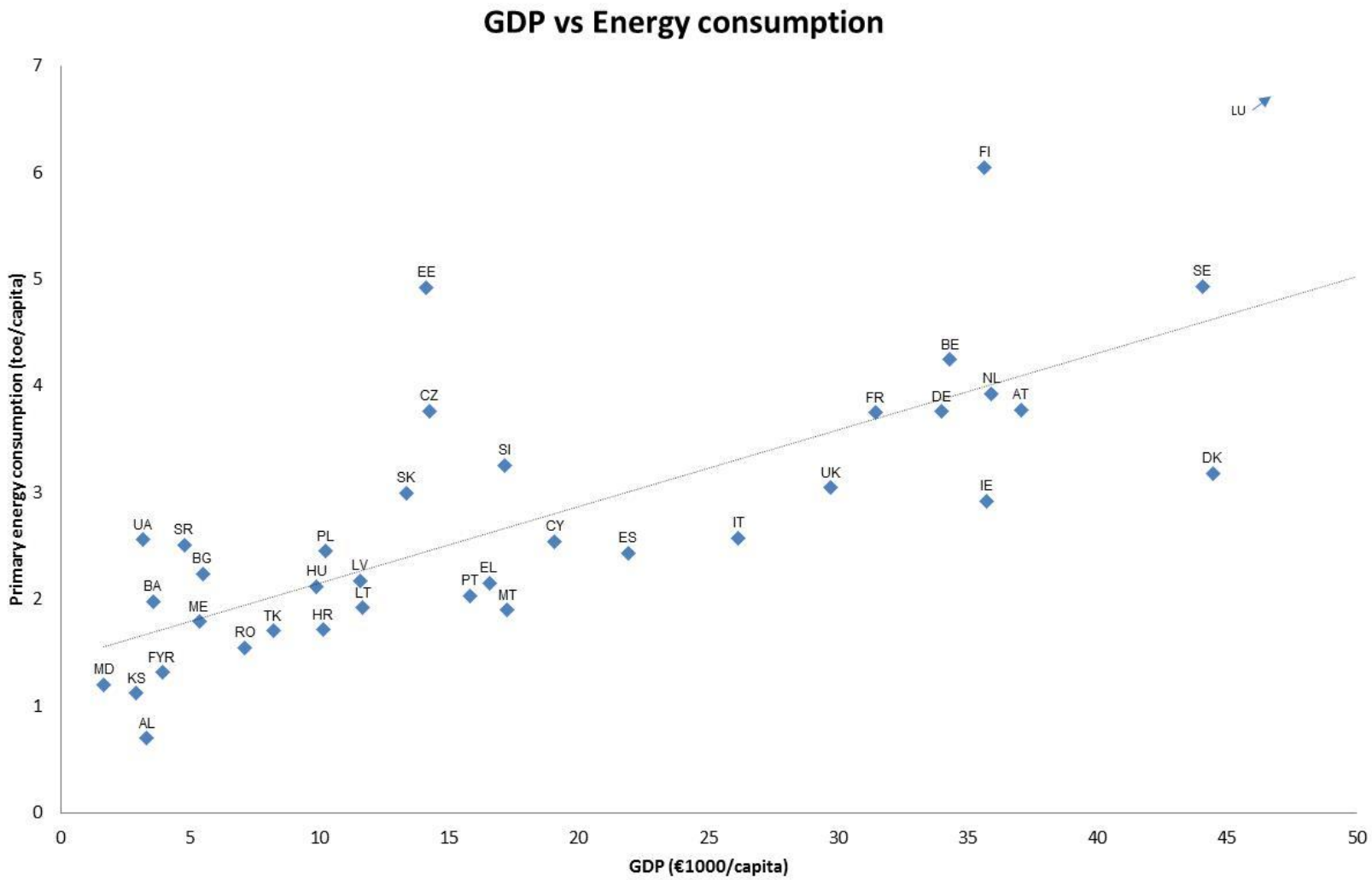

Figure 3: Relation between primary energy consumption and GDP

2.4 Forestry

For forestry, information is gathered concerning the total forest area on the one hand and the forest increment per year on the other hand.

Table 4: Forestry

Country	Forest area		Forest increment (NAIonFAWS) per year		
	1000 ha	ha/capita	1000 m³	m³/ha	m³/capita
Belgium	688	0.062	4,610	6.78	0.43
Bulgaria	3,870	0.531	14,361	3.56	1.93
Czech Republic	2,719	0.259	20,463	7.69	1.96
Denmark	609	0.109	6,263	11.43	1.13
Germany	11,698	0.145	118,590	10.71	1.45
Estonia	2,382	1.804	11,514	5.24	8.64
Ireland	752	0.164	6,678	8.83	1.47
Greece	4,088	0.372	4,511	1.14	0.41
Spain	18,562	0.397	35,479	1.92	0.76
France	19,374	0.296	82,871	5.16	1.28
Croatia	3,010	0.706	8,144	4.23	1.89
Italy	9,437	0.158	32,543	3.50	0.55
Cyprus	173	0.200	47	0.12	0.06
Latvia	3,484	1.721	19,680	5.83	9.28
Lithuania	2,267	0.763	11,030	5.07	3.51
Luxembourg	87	0.161	650	7.49	1.29
Hungary	2,117	0.214	9,775	4.77	0.98
Malta	na	na	na	na	na
Netherlands	462	0.028	2,738	7.50	0.17
Austria	3,929	0.465	25,136	6.45	3.01
Poland	9,591	0.252	62,300	6.63	1.64
Portugal	3,226	0.308	19,087	5.51	1.81
Romania	6,967	0.348	29,260	4.40	1.44
Slovenia	1,256	0.610	9,165	7.29	4.48
Slovakia	1,978	0.366	13,465	6.96	2.50
Finland	24,744	4.560	93,379	4.21	17.45
Sweden	30,226	3.163	79,347	2.81	8.49
United Kingdom	3,195	0.050	23,113	7.98	0.37
Albania	812[a]	0.280	224	0.29	0.08
Bosnia and Herzegovina	2,185	0.570	5,480	2.51	1.43
Macedonia	1,018	0.493	4,566	4.00	2.22
Kosovo*	0*	0.265*	1,556*	3.23*	0.87*
Moldova	412	0.116	1,462	3.70	0.41
Montenegro	849	1.368	2,020	3.72	3.26
Serbia	2,407[a]	0.335	5,232	1.86	0.72
Turkey	11,745	0.155	35,664	3.08	0.49
Ukraine	10,015	0.221	45,000	4.61	0.98
Source:					

For forest area: World bank data 2013, *2012
For net annual forest increment on forests available for wood supply (NAIoFAWS): Forest Europe data 2010, *2012
[a] According to FAOSTAT (2013) the forest area in 1000 ha in Albania and Serbia is respectively 773 and 2,717.
Note: Net annual forest increment on forests available for wood supply is not a given constant but a result of forest management practices (that are subject to change) and is influenced by changing climate conditions.
na = not available

The largest forest area per capita can be found in Finland and Sweden. The lowest area per capita is available in Malta, the Netherlands, the UK and Belgium.

For forest increment, expressed in m³ per hectare, the highest growth rates are identified for Denmark and Germany, whereas the lowest increment per hectare is found in Cyprus, Albania and other Mediterranean countries.

Using the forest area per capita and the forest increment we clustered the countries in five clusters.

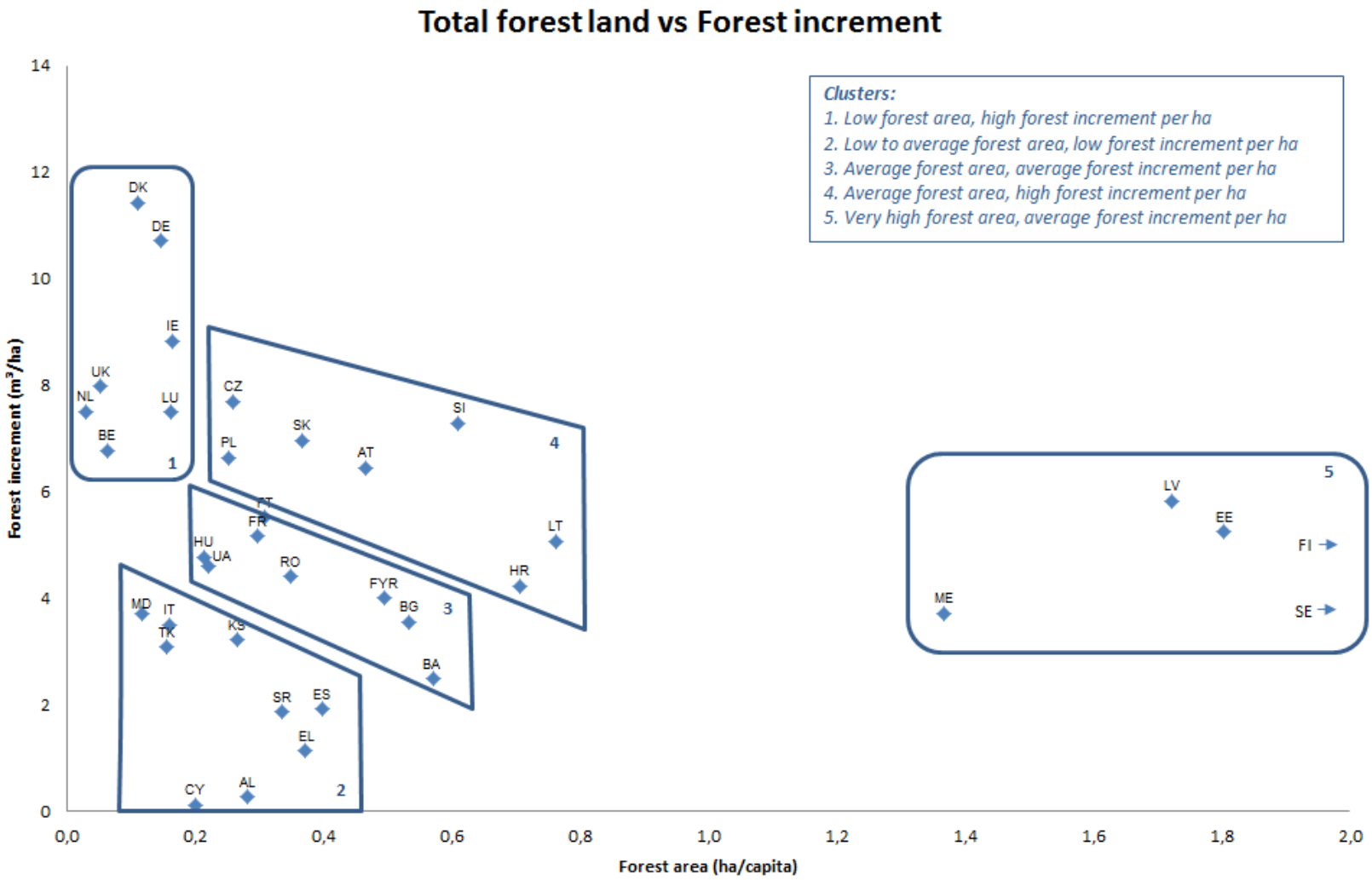

Figure 4: Country clusters – Forest area per capita and Forest increment

2.5 Agriculture

Concerning agriculture, information is collected for the amount of utilized agricultural area, arable land, cereal yield (as a proxy for agricultural productivity), permanent crop area and the amount of livestock units (per ha of agricultural area). An overview of the data concerning agriculture per country is provided in the table below.

Table 5: Agriculture

Country	Arable land	UAA	Cereal yield	Permanent crop area	Livestock units (LSU)
	ha/capita	ha/capita	t/ha	ha/capita	#/ha UAA
Belgium	0.073	0.120	9.21	0.002	2.838
Bulgaria	0.475	0.686	4.56	0.013	0.205
Czech Republic	0.238	0.335	5.32	0.004	0.491
Denmark	0.429	0.469	6.35	0.005	1.872
Germany	0.147	0.207	7.32	0.002	1.102
Estonia	0.476	0.732	3.21	0.003	0.321
Ireland	0.242	0.975	7.76	0.000	1.324
Greece	0.138	0.360	4.48	0.084	0.541
Spain	0.265	0.506	4.00	0.087	0.613
France	0.280	0.442	7.10	0.016	0.755
Croatia	0.205	0.305	5.60	0.017	0.784
Italy	0.114	0.205	4.83	0.034	0.811
Cyprus	0.068	0.103	1.69	0.032	1.961
Latvia	0.597	0.928	3.37	0.003	0.259
Lithuania	0.770	0.973	3.69	0.008	0.290
Luxembourg	0.117	0.244	5.96	0.003	1.262
Hungary	0.437	0.539	4.80	0.014	0.423
Malta	0.021	0.028	5.15	0.003	3.563
Netherlands	0.061	0.110	8.65	0.002	3.573
Austria	0.160	0.339	5.85	0.008	0.852
Poland	0.283	0.379	3.80	0.011	0.636
Portugal	0.115	0.360	4.24	0.068	0.539
Romania	0.437	0.695	3.84	0.015	0.358
Slovenia	0.085	0.233	4.74	0.013	1.019
Slovakia	0.252	0.356	4.67	0.003	0.334
Finland	0.363	0.416	3.74	0.001	0.496
Sweden	0.271	0.317	5.13	0.001	0.565
United Kingdom	0.098	0.270	6.63	0.001	0.771
Albania	0.214	0.411	4.61	0.027	na
Bosnia and Herzegovina	0.135[e]	0.435	4.17	0.028	0.208
Macedonia	0.200	0.611	3.38	0.018	0.902
Kosovo*	0.108	0.162	na	0.004	na
Moldova	0.510	0.702	2.85	0.083	0.076[b]
Montenegro	0.013	0.359	2.84	0.008	0.528**
Serbia	0.357[e]	0.486	4.78	0.026	0.549

Country	Arable land	UAA	Cereal yield	Permanent crop area	Livestock units (LSU)
	ha/capita	ha/capita	t/ha	ha/capita	#/ha UAA
Turkey	0.272	0.508	3.20	0.043	na
Ukraine	0.717	0.942	4.06	0.073	0.205

Source: Eurostat data 2013. *2012, **2010
[a] http://www.stat.gov.mk/Publikacii/PDFSG2015/10-Zemjodelstvo-Agriculture.pdf
[b] Received via partner (University of Zagreb)
[c] Statistical Office of the Republic of Serbia, Livestock number
[d] Received via partner (Renewable Energy Agency Ukraine)
[e] According to data from FAOSTAT (2013) the arable land per capita for Bosnia and Herzegovina and Serbia are respectively 0.266 and 0.458 ha.
UAA = Utilised agricultural area
na = not available

Utilised agricultural area (UAA) means the total area taken up by arable land, permanent pasture and meadow, land used for permanent crops and kitchen gardens. The highest UAA per capita is found in the following countries: Ireland, Lithuania and Ukraine, whereas Malta, Cyprus, the Netherlands and Belgium have the lowest UAA per capita.

Arable land is land cultivated regularly, generally under a system of crop rotation, which includes fallow land and does not contain permanent pastures or permanent crops. The arable land per capita is highest in Lithuania, Ukraine and Latvia. The lowest arable land per capita can be found in Montenegro and Malta. The results are different for UAA.

The cereal yield is a proxy for agricultural productivity in a region and is expressed in tonnes of cereals per hectare (in 2013). The highest cereal yield is reached in Belgium and the Netherlands, followed by Ireland, Germany and France. Countries with the lowest cereal yield per hectare are Cyprus, Moldova and Montenegro.

Permanent crop area is land cultivated with crops that occupy the land for long periods and need not be replanted after each harvest. Permanent crop area per capita is highest in Spain, Greece, Moldova and Portugal and is lowest in Ireland, Finland, Sweden and the United Kingdom.

The amount of livestock units per hectare UAA indicates if there may be excess or shortage of manure for land fertilization. Livestock density is highest for the Netherlands, Malta and Belgium and the lowest livestock density is found in Moldova, Ukraine, Bulgaria, Bosnia-Herzegovina, Latvia and Lithuania.

Based on the set of indicators we made country clusters related to agriculture. We combined three different pairs of indicators to establish the clusters that may later be used for further analysis.

First, we made clusters based on agricultural land vs forest land to indicate if a country is more agriculture or forest oriented. Four different clusters could be identified.

Second, we made clusters based on the arable land per capita and the cereal yield per hectare. In general it might be concluded that the more arable land available per capita, the lower the cereal yield. Apart from climatic conditions and soil types, this might be explained by the drive of countries with a lower availability of arable land to better select crops for higher cereal yields.

Third, the relationship between livestock density (*i.e.* LSU/ha) and UAA per capita is used to make clusters. In general countries with low agricultural area tend to have higher livestock density.

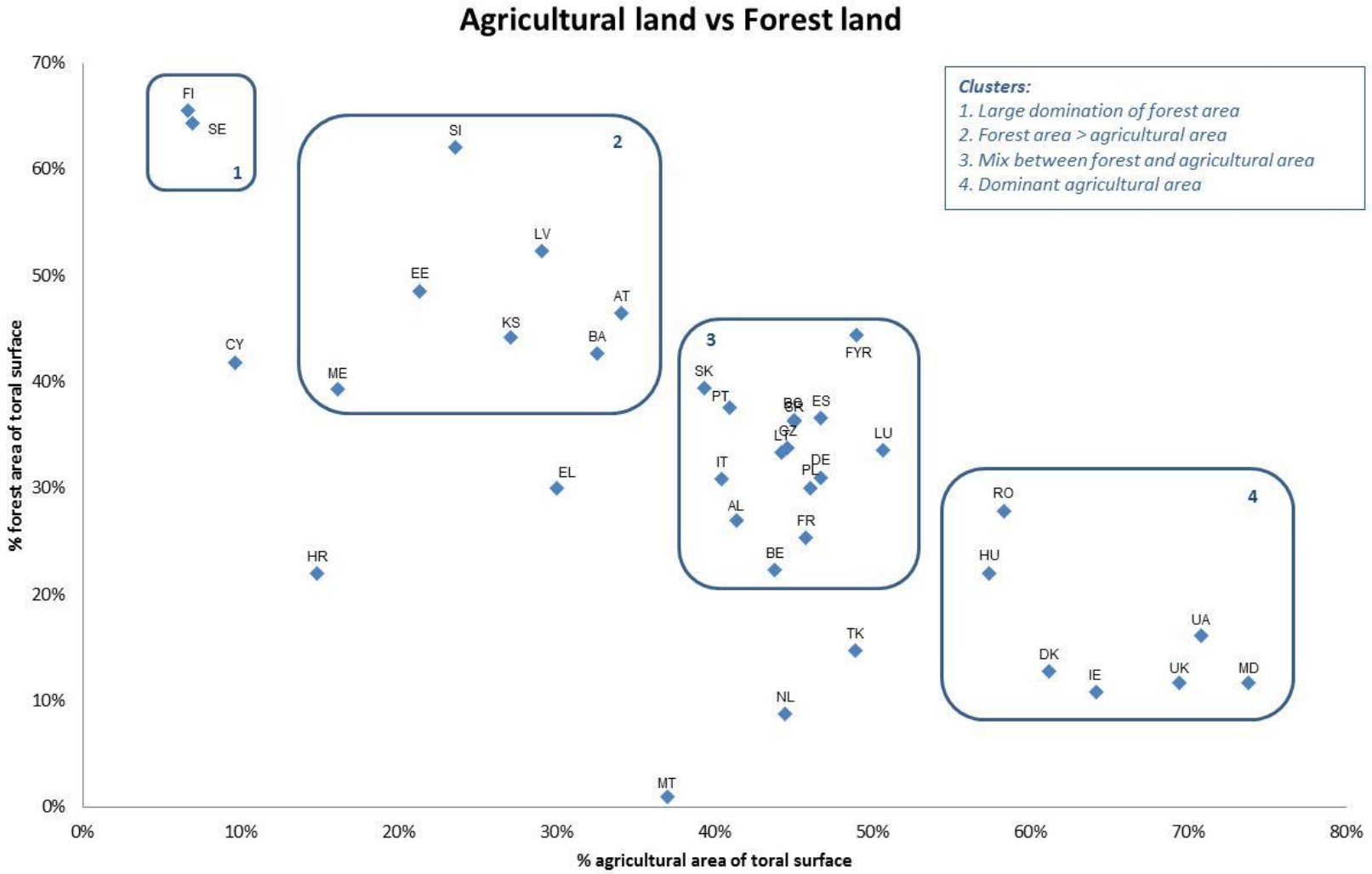

Figure 5: Country clusters – Forest area and Utilised agricultural area

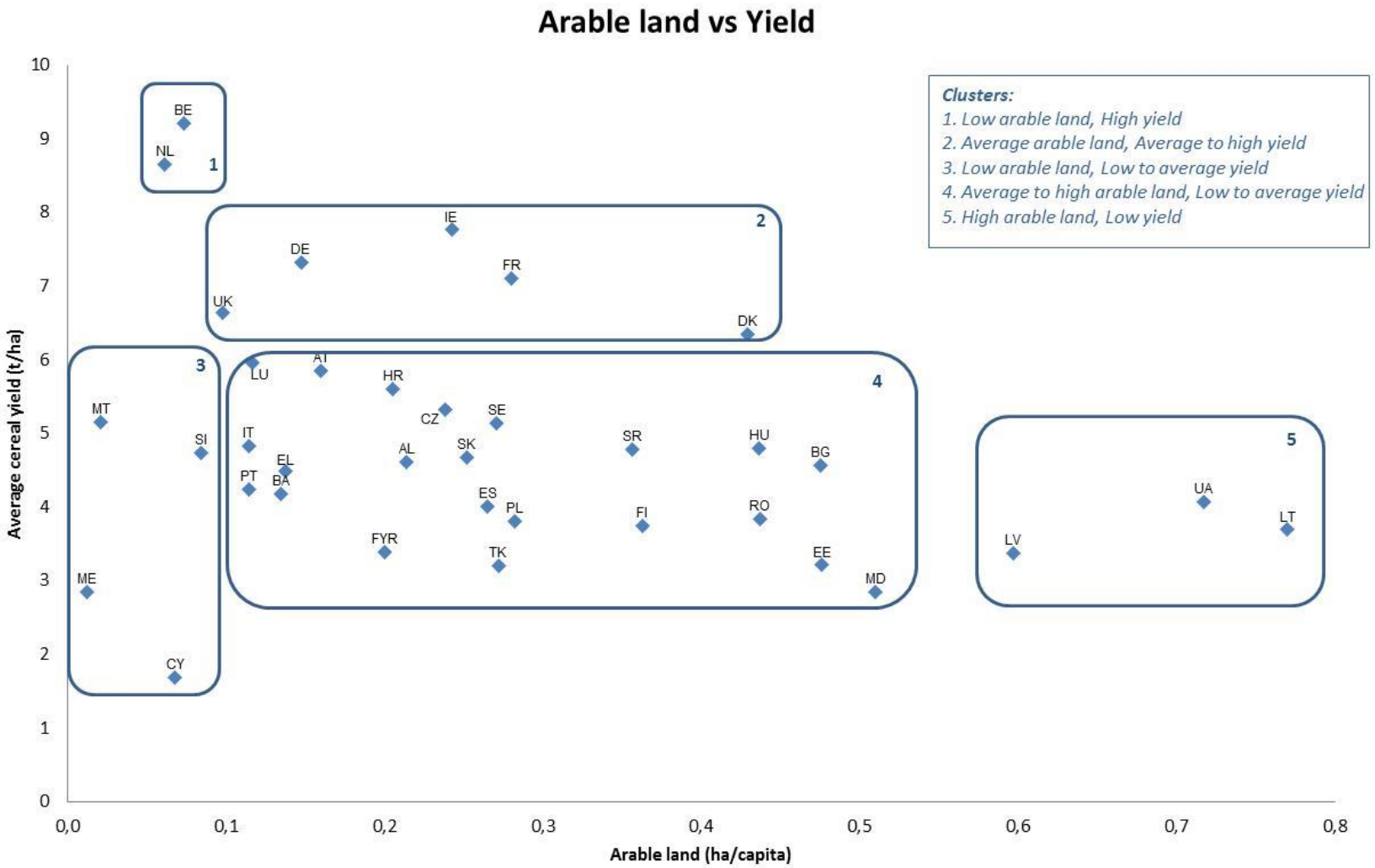

Figure 6: Country clusters – Arable land and Cereal yield (mind that yields not only depend on management practices, but also on climate and soil types)

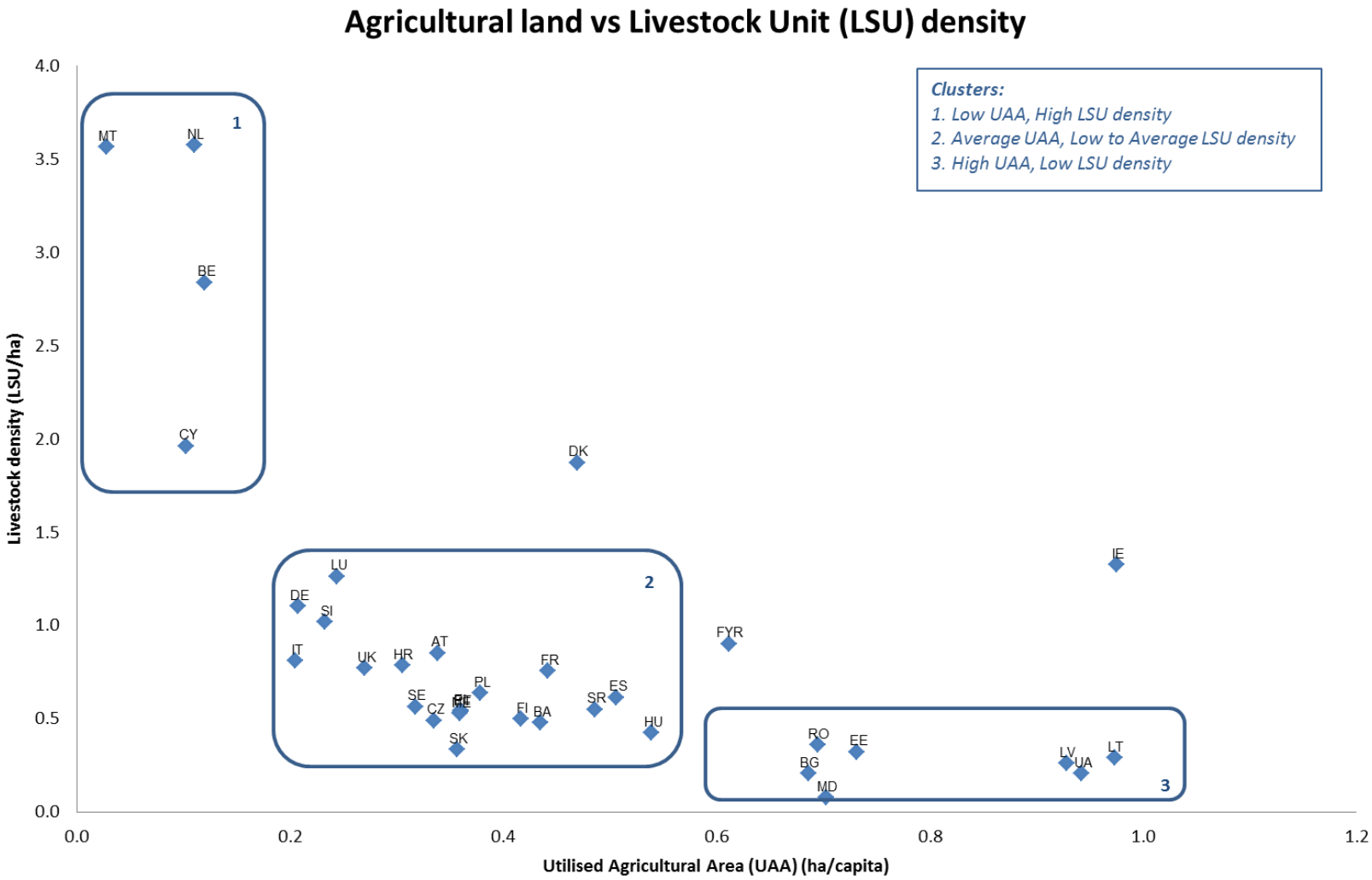

Figure 7: Country clusters – UAA and Livestock density per UAA

3 Defining performance criteria for benchmarking

In this section we will define performance criteria related to specific feedstocks and value chains in order to benchmark the performance of the 37 countries (as far as data is available). Performance criteria will be defined concerning mobilization, sustainable resource management, value chain efficiency, and the balance between different biomass utilizations (*e.g.* energy and materials specifically for wood).

We will first provide an overview of the renewable energy shares and the role of biomass therein for the different countries, as well as the focus on CHP versus electricity only or heat only.

Thereafter, the different performance criteria will be discussed. The performance criteria are grouped according to the different types of bioenergy.

i. Solid biofuels (focus on forestry)
- Sustainable forest management
- Forest increment and harvesting
- Types of energy conversion processes of solid biofuels
- Role of different types of solid biofuels
- Value chain efficiency
- Role of solid biofuels import and export
- Link material-energy sector

ii. Biogas
- Types of energy conversion processes of biogas
- Value chain efficiency

iii. Municipal solid waste (MSW)
- Different treatment types of MSW
- Production of energy from MSW

iv. Liquid biofuels
- Role of different types of liquid biofuels
- Role of liquid biofuels import and export

In the following we discuss in more detail the different performance criteria.

3.1 Renewable energy usage

For 'renewable energy', information is collected concerning (i) the share of renewable energy in transport, electricity and heating and cooling (see Table 6) and (ii) the bioenergy share in the total amount of renewable and total energy consumption (see Table 7).

Table 6: Renewable energy shares in transport, electricity and heating & cooling

Country	Overall RE consumption toe/capita	RE in Transport* %	RE in Electricity %	RE in Heating & Cooling %
Belgium	0.31	4.3	12.3	8.1
Bulgaria	0.25	5.6	18.9	29.2
Czech Republic	0.34	5.7	12.8	15.3
Denmark	0.77	5.7	43.1	34.8
Germany	0.41	6.3	25.6	10.6
Estonia	0.64	0.2	13.0	43.1
Ireland	0.18	5.0	20.9	5.7
Greece	0.24	1.1	21.2	26.5
Spain	0.38	0.4	36.4	14.9
France	0.35	7.2	16.9	18.3
Croatia	0.49	2.1	38.7	18.1
Italy	0.44	5.0	31.3	18.0
Cyprus	0.16	1.1	6.6	21.7
Latvia	0.80	3.1	48.8	49.7
Lithuania	0.41	4.6	13.1	37.7
Luxembourg	0.29	3.9	5.3	5.6
Hungary	0.19	5.3	6.6	13.5
Malta	0.03	3.3	1.6	23.7
Netherlands	0.21	5.0	10.1	3.6
Austria	1.18	7.5	68.1	33.5
Poland	0.22	6.0	10.7	13.9
Portugal	0.51	0.7	49.2	34.5
Romania	0.28	4.6	37.5	26.2
Slovenia	0.57	3.4	32.8	31.7
Slovakia	0.26	5.3	20.8	7.5
Finland	1.83	9.9	31.1	50.9
Sweden	1.79	16.7	61.8	67.2
United Kingdom	0.16	4.4	13.9	2.6
Albania	0.28	0.0[a]	19.2[a]	10.8[a]
Bosnia and Herzegovina	0.21	0.0[b]	8.2[b]	10.9[b]
Macedonia	0.15	0.2[c]	18.4[c]	22.5[c]
Kosovo*	0.14	na	na	na
Moldova	0.08	0.0[a]	1.63[a]	22.3[a]
Montenegro	0.62	0.5[a]	44.4[a]	40.4[a]
Serbia	0.27	0.0[d]	37.8[d]	21.9[d]
Turkey	0.19	na	na	na

Country	Overall RE consumption toe/capita	RE in Transport* %	RE in Electricity %	RE in Heating & Cooling %
Ukraine	0.07	0.4[e]	8.1[e]	5.0[e]

Source: Eurostat data 2013
* including double counting of residues, waste and lignocellulose based biofuels
[a] Received from partner (University of Zagreb)
[b] Agency for Statistics of Bosnia and Herzegovina (BHAS) and estimates of the Energy Community Secretariat, data for 2013
[c] https://www.energy-community.org/portal/page/portal/ENC_HOME/DOCS/3590146/Macedonia_RES_Progress_Report_05.02.2015.pdf
[d] Received from partner (University of Belgrade)
[e] Received from partner (Renewable Energy Agency Ukraine)
RE = Renewable Energy

Overall renewable energy consumption is highest in Finland, Sweden and Austria, followed by Latvia, Denmark, Estonia and Montenegro.

The highest share of renewable energy in *transport* is found in Sweden, Finland and Austria, whereas the lowest share is found in the countries outside the EU. Spain is a special case[6].

For *electricity* the countries with the highest share of renewable energy are Sweden, Austria, Portugal, Latvia and Denmark. Also Montenegro and Serbia have high renewable electricity shares. Malta, Luxembourg, Cyprus, and Hungary have the lowest renewable energy share in electricity.

The highest share of renewable energy in *heating and cooling* is found in Sweden, Finland, and Latvia and the lowest share in the United Kingdom, the Netherlands, Ukraine, Ireland and Luxembourg.

Table 7 provides the data that is collected specifically for bioenergy. The figures are expressed in gross energy consumption.

[6] The Spanish Law 11/2013 enshrines the suspension, for an unspecified period of time, of the application of the RED sustainability criteria in Spain. According to the RED, when assessing the fulfilment of NREAP targets only sustainable biofuels can be taken into account. Although more than 2 Mtoe were consumed in Spain, sustainability was not proved (because the implementation of the RED criteria is suspended) and, therefore, the reported percentage corresponding to biofuels consumption (sustainable biofuels) is zero. The total reported percentage (0.4%) corresponds to renewable electricity in transport (railway).

Table 7: Role of bioenergy in renewable energy

Country	Share in RE %	Share in TE %	Solid biofuels toe/capita	Biogas toe/capita	Renewable share of MSW toe/capita	Liquid biofuels toe/capita
Belgium	83%	6.1%	0.12	0.02	0.03	0.03
Bulgaria	65%	7.3%	0.15	0.00	0.00	0.02
Czech Republic	88%	7.9%	0.22	0.06	0.01	0.03
Denmark	76%	18.6%	0.27	0.02	0.09	0.04
Germany	72%	8.0%	0.14	0.09	0.04	0.04
Estonia	95%	12.4%	0.81	0.01	0.00	0.00
Ireland	47%	2.9%	0.04	0.01	0.01	0.02
Greece	44%	4.9%	0.08	0.01	0.00	0.01
Spain	38%	6.0%	0.12	0.01	0.00	0.02
France	64%	6.0%	0.17	0.01	0.02	0.04
Croatia	62%	17.7%	0.17	0.01	0.00	0.01
Italy	52%	8.9%	0.12	0.03	0.01	0.03
Cyprus	26%	1.6%	0.01	0.01	0.00	0.02
Latvia	85%	31.0%	0.87	0.04	0.00	0.01
Lithuania	92%	19.6%	0.35	0.01	0.00	0.02
Luxembourg	84%	3.1%	0.10	0.03	0.02	0.10
Hungary	89%	7.9%	0.15	0.01	0.01	0.02
Malta	47%	0.7%	0.00	0.00	0.00	0.01
Netherlands	83%	4.4%	0.07	0.02	0.06	0.02
Austria	59%	18.5%	0.56	0.03	0.02	0.06
Poland	91%	8.4%	0.18	0.01	0.00	0.02
Portugal	53%	13.2%	0.26	0.01	0.01	0.03
Romania	69%	12.3%	0.18	0.00	0.00	0.01
Slovenia	61%	10.7%	0.28	0.01	0.00	0.03
Slovakia	69%	6.0%	0.14	0.02	0.00	0.02
Finland	88%	26.7%	1.50	0.02	0.04	0.06
Sweden	64%	23.3%	0.96	0.02	0.09	0.08
United Kingdom	72%	3.9%	0.03	0.03	0.01	0.02
Albania	25%	10.0%	0.07	0.00	0.00	0.00
Bosnia and Herzegovina	22%	2.4%	0.22	0.00	0.00	0.00
Macedonia	51%	5.6%	0.01	0.00	0.00	0.00
Kosovo*	95%	12.3%	0.00	0.00	0.00	0.00
Moldova	92%	6.3%	0.07	0.00	0.00	0.00
Montenegro	44%	15.0%	0.28	0.00	0.00	0.00
Serbia	55%	5.9%	0.15	0.00	0.00	0.00
Turkey	35%	3.8%	0.06	0.00	0.00	0.00
Ukraine	61%	1.7%	0.00	0.00	0.00	0.00

Source: Eurostat data 2013
[a] About 50% of MSW is combusted in 2014.

[b] Agency for Statistics of Bosnia and Herzegovina (BHAS) and estimates of the Energy Community Secretariat, data for 2013
MSW = Municipal Solid Waste; RE = Renewable energy; TE = Total energy

For 12 countries in this list of 37 countries, biomass represents more than 80% of renewable energy. The average in the EU28 is 65%.

Overall solid biofuels are the dominating bioenergy source, on average representing around 70% of bioenergy, while the other bioenergy carriers represent around 10% each.

The discussion on solid biofuels, biogas, municipal solid waste (MSW) and liquid biofuels will be done in the following sections.

3.2 Value chain efficiency

For the value chain efficiency (overall) we collected information concerning electricity production and the amount of district heating (for a common heat provision instead of individual). Eurostat data was collected on combined heat and power electricity generation. For the data about district heating we received information from several partners and made use of the data available from the Euroheat and Power network. The results for the different countries are provided in **Error! Reference source not found.**.

Table 8: CHP and district heating

Country	CHP		District heating[a]	
	% gross electricity generation through CHP	% biomass based	km	m/capita
Belgium	15.2%	9.6%	0	0.0
Bulgaria	8.5%	1.1%	1,566	0.2
Czech Republic	13.7%	9.7%	7,738	0.7
Denmark	50.6%	9.4%	29,000	5.2
Germany	12.4%	13.4%	20,219	0.3
Estonia	9.3%	25.3%	1,450	1.1
Ireland	7.8%	1.0%	0	0.0
Greece	3.4%	1.2%	530[b]	0.1[b]
Spain	8.5%	2.1%	0	0.0
France	2.4%	8.5%	3,725	0.1
Croatia	12.6%	2.3%	410	0.1
Italy	12.7%	4.1%	3,807	0.1
Cyprus	1.4%	42.9%	0	0.0
Latvia	38.3%	7.8%	1,700	0.8
Lithuania	35.0%	6.2%	2,565	0.9
Luxembourg	14.7%	2.0%	0	0.0
Hungary	12.8%	1.6%	2,158	0.2
Malta	0.0%	50.0%	0	0.0

Country	CHP		District heating[a]	
	% gross electricity generation through CHP	% biomass based	km	m/capita
Netherlands	34.5%	4.2%	4,000	0.2
Austria	14.4%	15.0%	4,918	0.6
Poland	15.9%	2.8%	20,139	0.5
Portugal	13.8%	11.2%	0	0.0
Romania	11.2%	0.6%	na	na
Slovenia	7.1%	2.6%	753	0.4
Slovakia	77.0%	3.2%	4,984	0.9
Finland	34.1%	21.6%	13,850	2.6
Sweden	10.2%	37.9%	23,667	2.5
United Kingdom	5.5%	3.9%	361	0.0
Albania	na	0.0%	0	0.0
Bosnia and Herzegovina	1.2%[f]	na	na	na
Macedonia	6.0%[f]	0.0%	185[c]	0.1[c]
Kosovo*	0.0%[f]	0.0%	na	na
Moldova	19.0%[f]	0.1%	755[d]	0.2[d]
Montenegro	na	0.0%	0	0.0
Serbia	36.0%[f]	0.1%	2,085	0.3
Turkey	na	1.7%	0	0.0
Ukraine	na	0.1%	32,429[e]	0.7[e]

Source: Eurostat data 2013
[a] Euroheat
[b] Received from partner (Centre for Research and Technology Hellas (CERTH))
[c] http://weg.ge/wp-content/uploads/2013/05/Macedonia-Energy-Strategy-2010-2030.pdf
[d] Received from partner (University of Zagreb)
[e] http://www.minregion.gov.ua/attachments/content-attachments/2652/Pasport_01_01_2014.pdf
[f] IEA data 2013
na = not available; CHP = combined heat and power

More than 50% of gross electricity generation comes from CHP in Denmark and Slovakia. Whereas in Malta, Greece, France and Cyprus less than 5% of gross electricity generation comes from CHP.

In Denmark, Finland and Sweden a large district heating network is available. In Finland half of the population (i.e. 2.73 million inhabitants) is connected to a district heating network. This is far less common in other countries like the United Kingdom or Mediterranean countries. Differences in European infrastructure development in terms of district heating networks are also related to the differences in seasonal heat and cooling demand.

3.3 Solid biofuels

3.3.1 Sustainable forest management

To have an idea of sustainable forest management in different countries, we collected information concerning the amount of FSC (Forest Stewardship Council) certified forest area per country and the forest area certified by one of the systems endorsed by PEFC (Programme for the Endorsement of Forest Certification). Mind that protected forests as such are not certified, because they are no-go areas (no commercial harvesting) and protected by legislation.

Table 9: FSC and PEFC certified area per country

Country	Forest area*	FSC certified area		PEFC certified area	
	1000 ha	1000 ha	% of forest area	1000 ha	% forest area
Belgium	680	23	3.4%	299	43.9%
Bulgaria	4,037	808	20.0%	0	0.0%
Czech Republic	2,661	50	1.9%	1,754	65.9%
Denmark	548	206	37.5%	258	47.0%
Germany	11,076	1,070	9.7%	7,328	66.2%
Estonia	2,196	1,262	57.5%	1,029	46.8%
Ireland	757	448	59.3%	376,1	49.7%
Greece	3,963	0	0.0%	0	0.0%
Spain	18,525	216	1.2%	1,848	10.0%
France	16,050	29	0.2%	8,035	50.1%
Croatia	1,927	2,039	105.8%	0	0.0%
Italy	9,305	52	0.6%	824	8.9%
Cyprus	387	0	0.0%	0	0.0%
Latvia	3,377	1,702	50.4%	1,684	49.9%
Lithuania	2,176	1,084	49.8%	0	0.0%
Luxembourg	87	22	24.8%	32,5	37.5%
Hungary	2,047	308	15.1%	0	0.0%
Malta	0	0	0.0%	0	0.0%
Netherlands	365	137	37.5%	0	0.0%
Austria	3,897	1	0.0%	2,924	75.0%
Poland	9,392	6,933	73.8%	7,628	81.2%
Portugal	3,464	363	10.5%	253	7.3%
Romania	6,646	2,524	38.0%	0	0.0%
Slovenia	1,257	260	20.7%	31	2.5%
Slovakia	1,933	149	7.7%	1,243	64.3%
Finland	22,157	1,092	4.9%	17,583	79.4%
Sweden	28,203	11,938	42.3%	11,355	40.3%
United Kingdom	2,895	1,594	55.0%	1,352	46.7%
Albania	774	0	0.0%	0	0.0%
Bosnia and Herzegovina	2,185	1,496	68.4%	0	0.0%
Macedonia	1,141	0	0.0%	0	0.0%

Country	Forest area*	FSC certified area		PEFC certified area	
	1000 ha	1000 ha	% of forest area	1000 ha	% forest area
Moldova	395	0	0.0%	0	0.0%
Montenegro	543	0	0.0%	0	0.0%
Serbia	2,808	0	0.0%	0	0.0%
Turkey	11,572	2,360	20.4%	0	0.0%
Ukraine	9,757	2,606	26.7%	0	0.0%

Source:
* Note that total certified forest area is not the sum of FSC and PEFC certified, as some areas are certified for both systems.
[a] https://ic.fsc.org/en/facts-figures 2015
[b] http://www.pefc.org/images/documents/PEFC_Global_Certificates_-_November_2015.pdf

Croatia, Poland, Bosnia & Herzegovina, Ireland, Estonia and the UK have the highest shares of FSC certification in their forests. Highest shares of PEFC certification can be found in Poland, Finland, Austria, Germany and Czech Republic.

There is a low level of certification in Mediterranean countries like Greece, Cyprus, Spain, Italy, as well as in several Balkan states.

Mind that in some cases forests are certified for both systems, so the total amount of certified forest is not always equal to the sum of the two.

3.3.2 Forest increment and harvesting

In order to have an idea about forest biomass mobilization we collected information from Eurostat concerning the forest increment and roundwood removals (under bark[7]) from the forest. This comprises all wood obtained from forest removals.

Data about forest increment is already provided in Chapter 2. In Table 6 the data for total roundwood removal is provided; distinction can be made between fuelwood removal and industrial wood removal.

Table 10: Roundwood removal

Country	Forest increment m³/capita	Roundwood removal m³/capita	Fuelwood[8] removal m³/capita	Industrial wood removal m³/capita
Belgium	0.43	0.60*	0.24*	0.36*
Bulgaria	1.93	0.84	0.38	0.47
Czech Republic	1.96	1.46	0.21	1.25
Denmark	1.13	0.57	0.35	0.22
Germany	1.45	0.66	0.14	0.52

[7] Excluding bark
[8] Fuelwood here means woody biomass extracted from forests for energy

Country	Forest increment m³/capita	Roundwood removal m³/capita	Fuelwood[a] removal m³/capita	Industrial wood removal m³/capita
Estonia	8.64	5.80	1.85	3.95
Ireland	1.47	0.60	0.05	0.56
Greece	0.41	0.09**	0.06**	0.03**
Spain	0.76	0.34	0.07	0.26
France	1.28	0.79	0.42	0.37
Croatia	1.89	1.28	0.33	0.95
Italy	0.55	0.13*	0.09*	0.04*
Cyprus	0.06	0.01	0.01	0.00
Latvia	9.28	6.28	0.62	5.61
Lithuania	3.51	2.37	0.82	1.56
Luxembourg	1.29	0.55**	0.03**	0.51**
Hungary	0.98	0.61	0.29	0.32
Malta	n.a.	0.00	0.00	0.00
Netherlands	0.17	0.07	0.02	0.05
Austria	3.01	2.06	0.59	1.47
Poland	1.64	1.02	0.14	0.89
Portugal	1.81	1.01	0.06	0.96
Romania	1.44	0.76	0.25	0.50
Slovenia	4.48	1.66	0.55	1.11
Slovakia	2.50	1.69	0.10	1.59
Finland	17.45	10.50	1.41	9.09
Sweden	8.49	7.28	0.62	6.67
United Kingdom	0.37	0.17	0.02	0.14
Albania	0.08	0.41[b]	0.38[b]	0.03[b]
Bosnia and Herzegovina	1.43	1.14[b]	0.39[b]	0.75[b]
Macedonia	2.22	0.34	0.28	0.06
Kosovo*	0.87*	na	na	na
Moldova	0.41	0.37[b]	0.36[b]	0.01[b]
Montenegro	3.26	1.47	1.14	0.34
Serbia	0.72	1.07[b]	0.88[b]	0.18[b]
Turkey	0.49	0.30	0.06	0.25
Ukraine	0.98	na	na	na

Source: Eurostat data 2013. *2012, **2010
[a] In Finland and Sweden forest industry is dominating and industrial wood residues and forest residues are used for energy. Share of fuelwood is relatively small.
[b] FAOSTAT data 2013
na = not available

Finland, Sweden, Latvia and Estonia are the countries with the highest roundwood removal per capita (see cluster 5 in Figure 7). In Ireland, Luxembourg, Portugal, Slovakia, and Sweden more than 90% of roundwood removal is for industrial purposes. In Italy, Montenegro, Albania, Moldova, Serbia and Macedonia more than 70% of roundwood removal is for energy purposes.

Harvesting of industrial wood for the wood processing industry is clearly linked to the availability of forestry biomass. The countries achieving relatively high industrial wood removals are the countries in clusters 5 and 4 in figure 7.

The following figure (Figure 8) compares fuelwood removals with industrial wood removal. In most countries roundwood removals are mostly for industrial purposes. Nevertheless there are also countries like France and Denmark which remove more fuelwood than industry wood.

Figure 9 shows how roundwood removal relates to forest increment per capita. For most countries roundwood removals represent around 60% of forest increment. A few countries (Belgium[9], Albania and Serbia) reported removal figures higher than forest increment. Mind that for sustainable harvesting removals (considered at long term) should stay below 100% of forest increment. There can be temporary fluctuations, e.g. in case of storm damage or diseases, leading to over 100% harvesting in a certain year.

[9] Belgium reported a 200% increase of fuelwood removals from 2011 to 2012 (from 0.9 million m³ to 2.6 million m³). This trend is not confirmed yet as no data for 2013 or 2014 were reported yet.

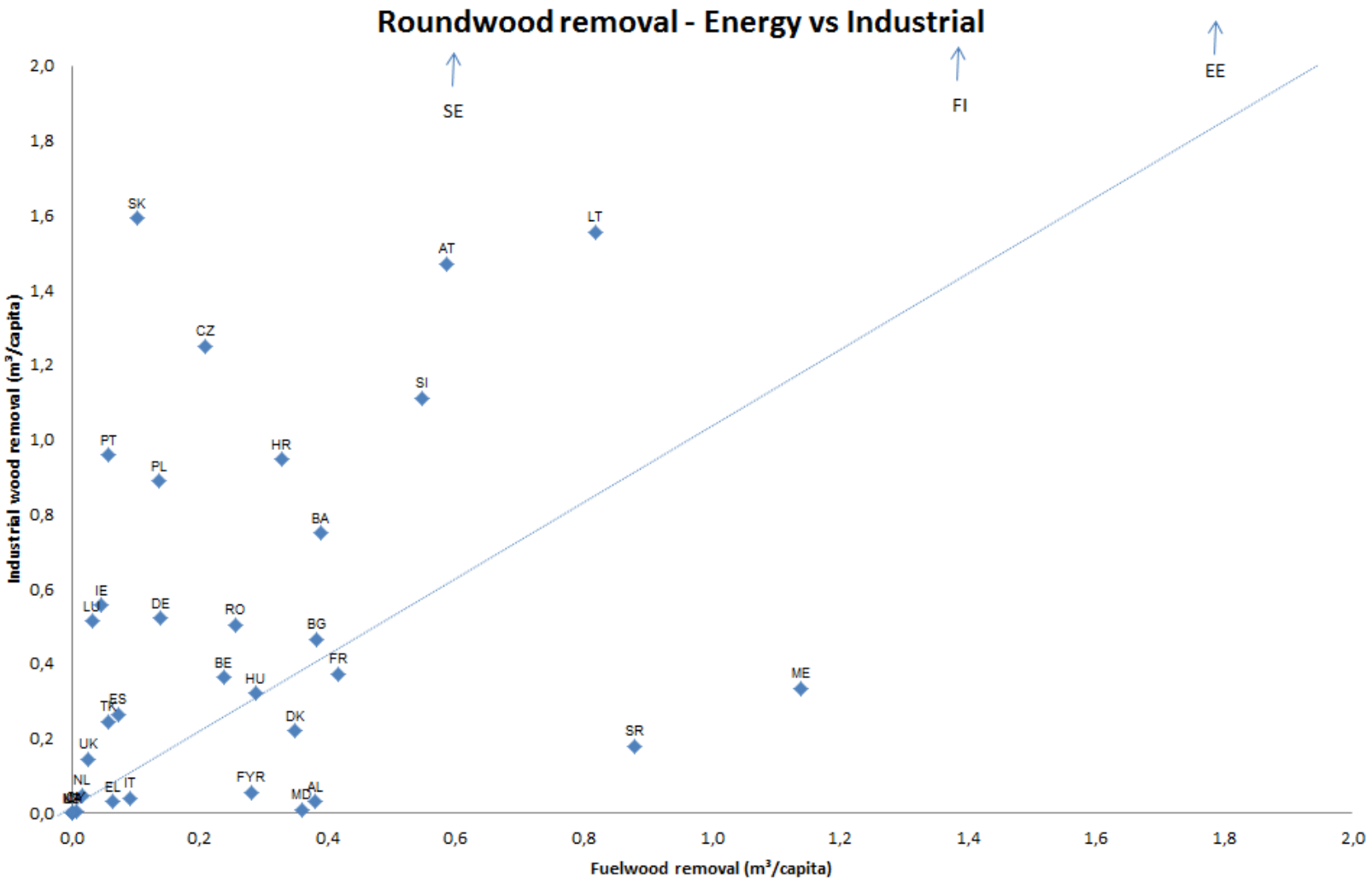

Figure 8: Industrial wood versus fuelwood removal

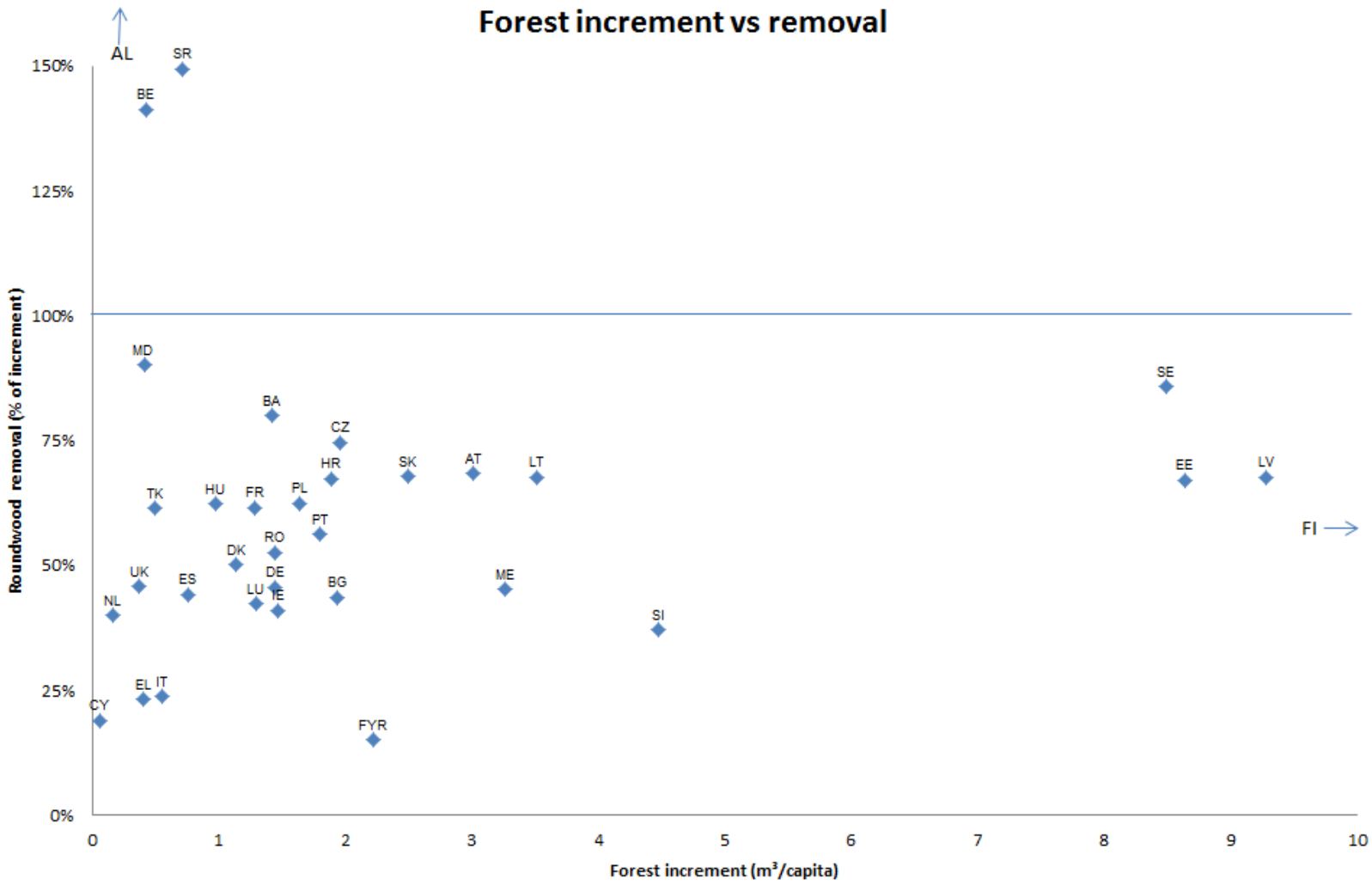

Figure 9: Forest increment vs Roundwood removal

3.3.3 Role of different types of solid biofuels

Next we analyse the role of different types of solid biofuels. We collected information from Eurostat concerning the primary production of different types of solid biofuels. The results are provided in Table 11.

Table 11: Primary production of different types of solid biofuels for energy

Country	Solid biofuels (excl. charcoal) toe/capita	Fuelwood, wood residues and by-products toe/capita	Black liquor toe/capita	Other vegetal materials and residues toe/capita
Belgium	0.18	0.113	0.004	0.007
Bulgaria	0.14	0.134	0.017	0.003
Czech Republic	0.21	0.175	0.032	0.011
Denmark	0.44	0.165	0.000	0.090
Germany	0.14	0.124	0.010	0.002
Estonia	0.60	0.648	0.025	0.135
Ireland	0.05	0.037	0.000	0.000
Greece	0.08	0.064	0.000	0.013
Spain	0.11	0.076	0.010	0.017
France	0.16	0.141	0.013	0.005
Croatia	0.29	0.344	0.000	0.000
Italy	0.15	0.122	0.000	0.003
Cyprus	0.01	0.005	0.000	0.001
Latvia	0.63	0.865	0.000	0.001
Lithuania	0.35	0.348	0.000	0.002
Luxembourg	0.09	0.078	0.000	0.012
Hungary	0.14	0.110	0.000	0.033
Malta	0.00	0.000	0.000	0.000
Netherlands	0.07	0.053	0.000	0.018
Austria	0.58	0.447	0.085	0.024
Poland	0.18	0.133	0.000	0.047
Portugal	0.22	0.099	0.094	0.062
Romania	0.18	0.183	0.000	0.000
Slovenia	0.31	0.302	0.000	0.003
Slovakia	0.14	0.067	0.069	0.006
Finland	1.49	0.859	0.619	0.009
Sweden	0.96	0.569	0.395	0.000
United Kingdom	0.06	0.021	0.000	0.019
Albania	0.07	0.070	0.000	0.000
Bosnia and Herzegovina	0.05	0.047	0.000	0.000
Macedonia	0.07	0.000	0.000	0.000
Kosovo*	0.14	0.137	0.000	0.000
Moldova	0.07	0.075	0.000	0.000
Montenegro	0.27	0.280	0.000	0.000
Serbia	0.15	0.156	0.000	0.000
Turkey	0.06	0.036	0.000	0.021

Country	Solid biofuels (excl. charcoal)	Fuelwood, wood residues and by-products	Black liquor	Other vegetal materials and residues
	toe/capita	toe/capita	toe/capita	toe/capita
Ukraine	0.04	0.037	0.000	0.011

Source: Eurostat data 2013

Depending on the country, other solid biofuels are used. Fuelwood, wood residues and by-products are mainly used in Latvia, Finland, Estonia and Sweden. Finland and Sweden also have a high usage per capita of black liquor as solid biofuels. Whereas Estonia, Denmark, Portugal and Poland have the highest solid biofuels production per capita for other vegetal materials and residues (which includes straw). This can also be concluded from Figure 10.

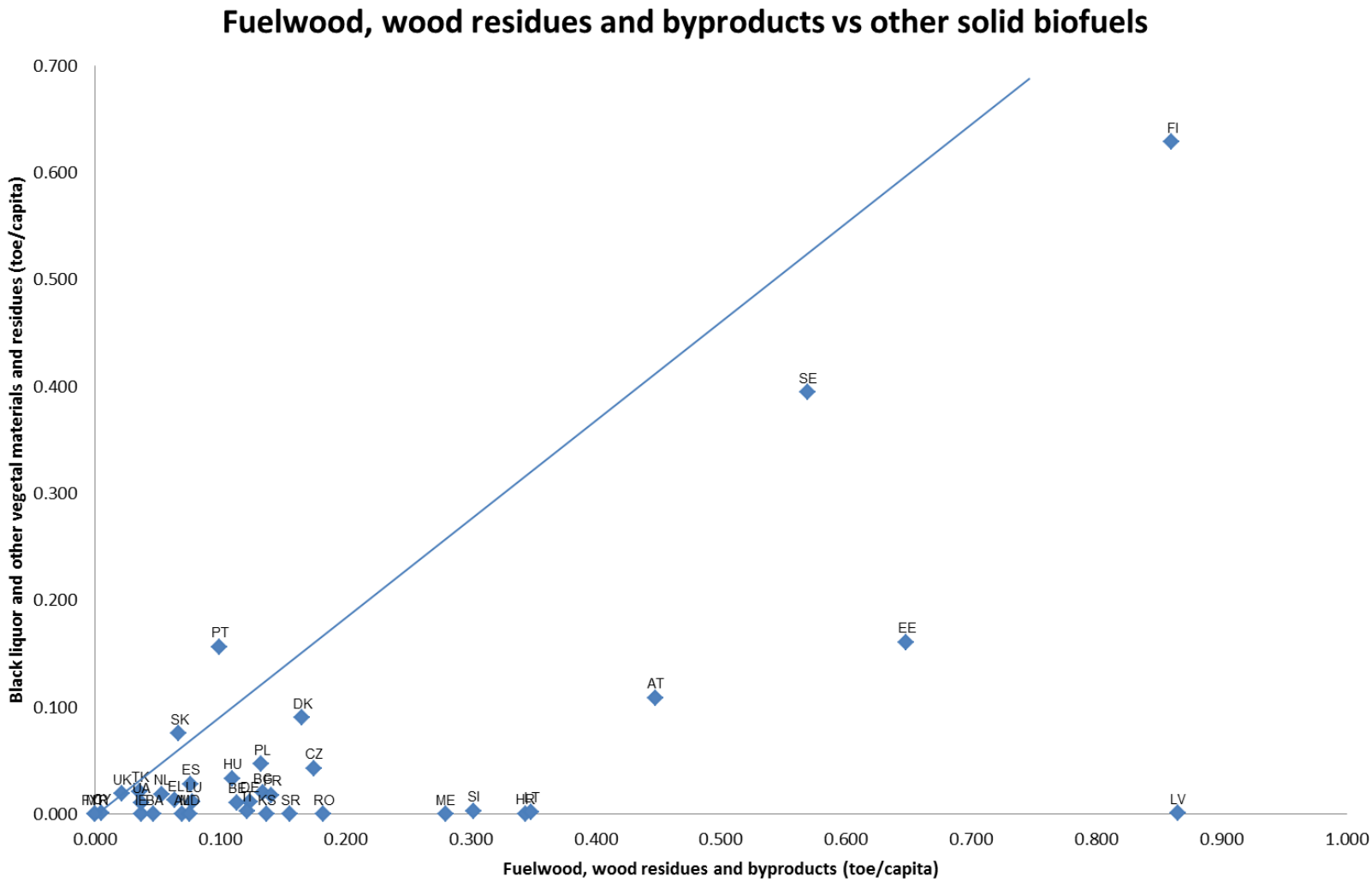

Figure 10: Fuelwood, wood residues and by-products vs other solid biofuels

3.3.4 Types of energy conversion processes for solid biomass

We collected Eurostat information on the transformation input, final energy consumption from solid biomass in the industry and residential and other sectors. For the transformation input we also made an analysis of the share of electricity, CHP and heat-only plants (i.e. district heating). Results are provided in Table 12 and Table 13.

Table 12: Energy conversion processes solid biofuels

Country	Transformation input toe/capita	Final energy consumption – Industry toe/capita	Final energy consumption – Residential and other toe/capita
Belgium	0.07	0.06	0.06
Bulgaria	0.00	0.03	0.11
Czech Republic	0.05	0.04	0.12
Denmark	0.26	0.02	0.16
Germany	0.04	0.02	0.07
Estonia	0.24	0.06	0.29
Ireland	0.01	0.03	0.01
Greece	0.00	0.01	0.07
Spain	0.03	0.02	0.06
France	0.02	0.02	0.12
Croatia	0.01	0.01	0.27
Italy	0.03	0.00	0.11
Cyprus	0.00	0.00	0.00
Latvia	0.14	0.15	0.34
Lithuania	0.12	0.03	0.20
Luxembourg	0.01	0.04	0.04
Hungary	0.05	0.01	0.08
Malta	0.00	0.00	0.00
Netherlands	0.04	0.00	0.03
Austria	0.20	0.15	0.24
Poland	0.06	0.03	0.09
Portugal	0.05	0.10	0.07
Romania	0.00	0.01	0.16
Slovenia	0.02	0.03	0.26
Slovakia	0.09	0.05	0.01
Finland	0.63	0.58	0.28
Sweden	0.41	0.44	0.12
United Kingdom	0.03	0.01	0.02
Albania	0.00	0.00	0.07
Bosnia and Herzegovina	0.00	0.00	0.05
Macedonia	0.00	0.00	0.07
Kosovo*	0.00	0.01	0.13
Moldova	0.00	0.00	0.07

Country	Transformation input toe/capita	Final energy consumption – Industry toe/capita	Final energy consumption – Residential and other toe/capita
Montenegro	0.00	0.01	0.26
Serbia	0.00	0.03	0.12
Turkey	0.00	0.00	0.06
Ukraine	0.02	0.00	0.02

Source: Eurostat data 2013

As expected, Finland, Latvia and Estonia have a large toe/capita for the three energy conversion processes compared to other countries. Also Austria has a high toe/capita for the three types of conversion processes. Other countries like Malta and Cyprus have no energy conversion processes for solid biofuels which we could also conclude from the fact that these countries do not have any solid biofuel production as shown in Table 11. In general it can be concluded that in the majority of the countries, the highest share of solid biofuels conversion processes is found in the residential and other sectors.

The following table details how much of the biomass input for transformation (and to be distributed through electricity and/or heat networks) is converted in CHP, electricity only or heat only.

Table 13: Transformation input solid biofuels

Country	Electricity %	CHP %	Heat only (DH) %
Belgium	71%	29%	0%
Bulgaria	3%	70%	5%
Czech Republic	1%	93%	6%
Denmark	0%	70%	30%
Germany	44%	48%	8%
Estonia	1%	67%	32%
Ireland	92%	8%	0%
Greece	0%	0%	0%
Spain	71%	19%	0%
France	3%	76%	21%
Croatia	0%	74%	0%
Italy	41%	53%	5%
Cyprus	0%	0%	0%
Latvia	1%	43%	51%
Lithuania	0%	41%	59%
Luxembourg	0%	31%	72%
Hungary	72%	19%	10%
Malta	0%	0%	0%

Country	Electricity %	CHP %	Heat only (DH) %
Netherlands	56%	42%	0%
Austria	21%	47%	33%
Poland	0%	98%	2%
Portugal	52%	42%	0%
Romania	9%	44%	47%
Slovenia	0%	80%	20%
Slovakia	1%	84%	15%
Finland	10%	72%	18%
Sweden	0%	78%	22%
United Kingdom	100%	0%	0%
Albania	0%	0%	0%
Bosnia and Herzegovina	0%	0%	100%
Macedonia	0%	0%	0%
Kosovo*	0%	0%	0%
Moldova	0%	0%	89%
Montenegro	0%	0%	0%
Serbia	0%	8%	8%
Turkey	37%	64%	0%
Ukraine	2%	53%	9%

Source: Eurostat data 2013
CHP = combined heat and power; DH = district heating

In the UK, Ireland, Hungary, Spain and Belgium the largest part of the solid biofuels transformation input is used in electricity plants, whereas in Poland, the Czech Republic, Slovenia and Slovakia mainly CHP plants are used. For solid biofuels, heat-only plants are most common in Bosnia and Herzegovina, Moldova and Luxembourg.

3.3.5 Role of imports and exports of solid biofuels

In order to have an insight into the role of imports and exports of solid biofuels we collected Eurostat information on the gross inland consumption of solid biofuels, the primary production, the imports and the exports. Using these data we calculated the imports and exports as a share of gross inland consumption. The net imports were then calculated by subtracting exports from imports. The results are provided in Table 14.

Table 14: imports and exports of solid biofuels

Country	Gross inland consumption	Primary production	Imports	Exports	Net imports
	Mtoe	Mtoe	toe/capita	toe/capita	% gross inland consumption
Belgium	2.02	1.38	0.056	0.000	31%
Bulgaria	1.03	1.12	0.001	0.013	-9%
Czech Republic	2.17	2.29	0.011	0.022	-5%
Denmark	2.45	1.50	0.181	0.000	41%
Germany	10.90	10.90	0.000	0.000	0%
Estonia	0.79	1.07	0.007	0.229	-37%
Ireland	0.22	0.20	0.008	0.000	16%
Greece	0.93	0.85	0.008	0.000	9%
Spain	5.36	5.58	0.007	0.003	3%
France	10.38	10.84	0.000	0.000	0%
Croatia	1.23	0.70	0.001	0.057	-19%
Italy	8.85	7.45	0.024	0.000	16%
Cyprus	0.01	0.01	0.005	0.000	44%
Latvia	1.27	1.75	0.020	0.318	-47%
Lithuania	1.03	1.04	0.040	0.044	-1%
Luxembourg	0.05	0.05	0.014	0.012	2%
Hungary	1.38	1.45	0.002	0.006	-3%
Malta	0.00	0.00	0.002	0.000	100%
Netherlands	1.26	1.11	0.018	0.015	4%
Austria	4.92	4.75	0.057	0.027	5%
Poland	6.84	6.83	0.000	0.000	0%
Portugal	2.35	2.68	0.004	0.035	-14%
Romania	3.59	3.66	0.005	0.008	-2%
Slovenia	0.63	0.57	0.000	0.000	0%
Slovakia	0.76	0.77	0.000	0.002	-1%
Finland	8.11	8.12	0.014	0.008	0%
Sweden	9.21	9.21	0.000	0.000	0%
United Kingdom	3.91	2.15	0.021	0.003	30%
Albania	0.20	0.20	0.000	0.000	0%
Bosnia and Herzegovina	0.18	0.83	0.000	0.000	0%
Macedonia	0.15	0.02	0.004	0.001	4%
Kosovo*	0.25	0.00	0.000	0.001	0%

Country	Gross inland consumption	Primary production	Imports	Exports	Net imports
	Mtoe	Mtoe	toe/capita	toe/capita	% gross inland consumption
Moldova	0.27	0.26	0.000	0.000	0%
Montenegro	0.17	0.17	0.001	0.012	-4%
Serbia	1.06	1.10	0.001	0.008	-5%
Turkey	4.28	4.28	0.000	0.000	0%
Ukraine	1.90	0.00	0.000	0.006	-14%

Source: Eurostat data 2013
Some of the reported 0.000 values may be questionable, e.g. in Germany, France and Sweden

It can be concluded that mainly Denmark, but also Belgium and Austria have a large import amount (expressed per capita) of solid biofuels, whereas about half of the countries mentioned have no or minimal imports. In contrast, Latvia and Estonia have a large amount of exports of solid biofuels per capita. This can also be concluded from the last column of Table 14 indicating the net imports in relation to inland consumption.

Figure 11 shows primary production of solid biofuels per capita versus the net imports (% of consumption). The first cluster consists of countries with a low primary production of solid biofuels and a large import orientation. The second cluster contains countries with a low to high primary production of solid biofuels, but a low trade orientation. However, it can be concluded that with an increasing primary production rate, the low trade orientation that can be noticed switches from import oriented towards export oriented. Austria, Sweden and Finland are the only exceptions in this trend. This can be explained by the high internal consumption of the solid biofuels in these countries. The third and last cluster consists of Latvia and Estonia that are both highly export oriented and both have a large primary production per capita.

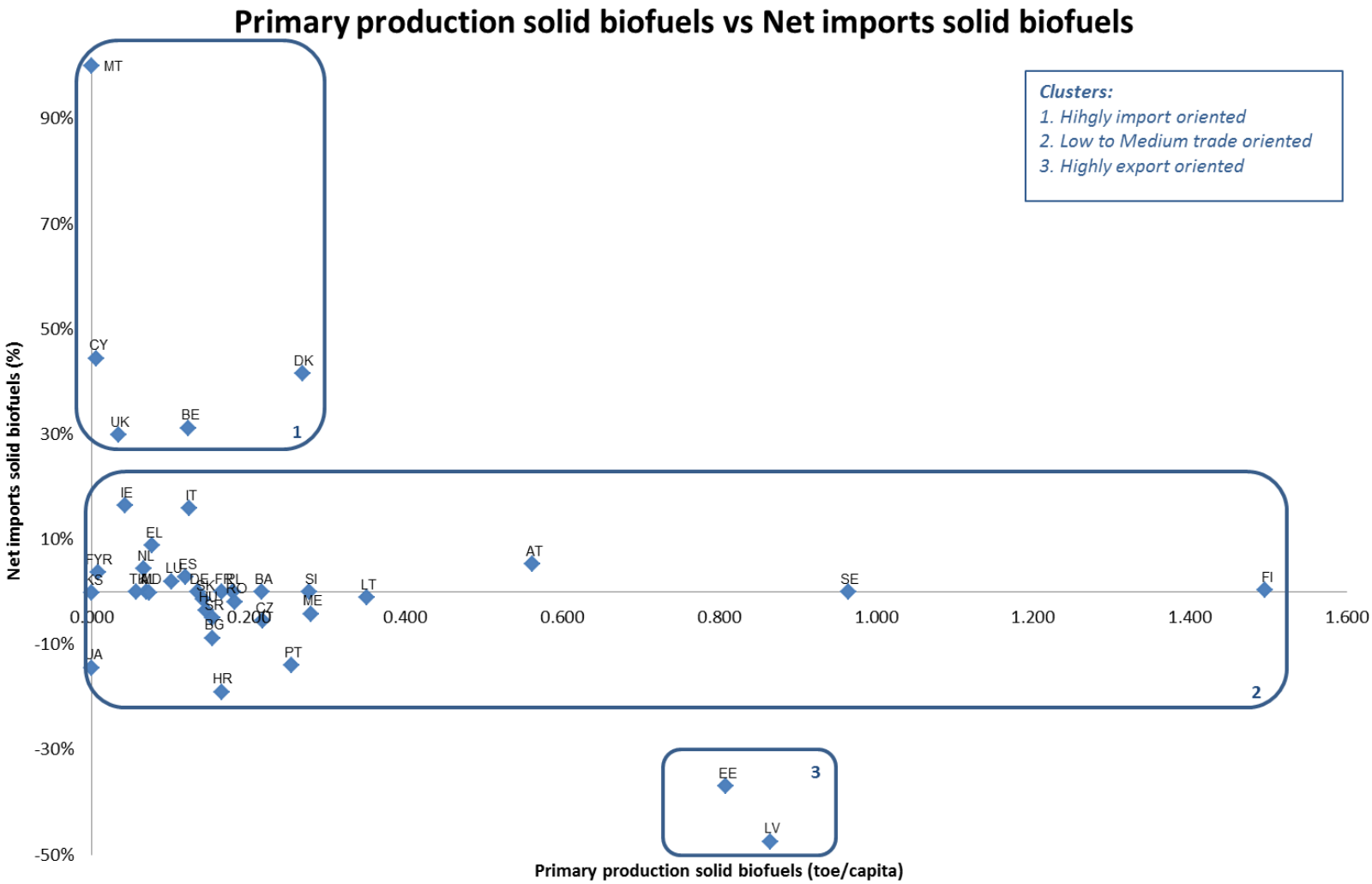

Figure 11: Country clusters - Primary production solid biofuels vs net imports

3.3.6 Link materials-energy sectors

For the category 'industry turnover' information is collected concerning the following sectors, which are available in Eurostat: (i) sawmills & wood planing, (ii) wood products, (iii) pulp & paper products. Figures are expressed per capita to be able to compare countries. Figures for countries outside the EU were difficult to find.

Table 15: Industry turnover

Country	Sawmills & wood planning €/capita	Wood products €/capita	Pulp & paper products €/capita
Belgium	49	282	456
Bulgaria	19	63	67
Czech Republic	87	308	241
Denmark	26	269	233
Germany	79	305	501
Estonia	530	1,238	157
Ireland	42	137	115
Greece	6	30	104
Spain	16	110	272
France	52	175	276
Croatia	76	155	85
Italy	39	227	355
Cyprus	1	104	55
Latvia	457	910	60
Lithuania	105	308	123
Luxembourg	0	359	0
Hungary	19	82	142
Malta	0	22	0
Netherlands	21	142	355
Austria	405	911	715
Poland	45	196	205
Portugal	37	264	344
Romania	51	148	41
Slovenia	89	332	352
Slovakia	91	182	258
Finland	732	1,170	3,564
Sweden	536	948	1,491
United Kingdom	23	132	200
Albania	na	na	na
Bosnia and Herzegovina	na	na	na
Macedonia	5	17	25
Kosovo*	na	na	na
Moldova	0[a]	3[a]	8[a]
Montenegro	na	na	na
Serbia	18[b]	72[b]	43[b]
Turkey	na	na	na
Ukraine	13[c]	19[d]	33[d]

Source: Eurostat data 2013
na = not available

Finland, Sweden and Estonia have the highest turnover per capita for sawmills & wood planing industry. Estonia, Finland, Sweden, Austria and Latvia have the highest turnover for wood products industry per capita. Also for pulp & paper products Finland has the highest turnover per capita, followed by Sweden. Note that Austria, Sweden and Finland have a high industrial turnover over the three sectors. They score high in sawmill & wood planning, wood products and pulp & paper products. Whereas countries like Latvia and Estonia have a high added value in primary processing, but have a lower added value when it comes to creating products like pulp & paper. Other countries may have lower wood processing industry, but an important pulp and paper sector, see e.g. Belgium, Germany, Italy and the Netherlands.

Biomass resources are used for different purposes. For example, forest biomass can be used both for energy and materials.

For forest biomass we look at three different aspects. First, we look at the wood and paper industry turnover and compare this with the forest increment in a country (Figure 12). Second, we look at the forest increment in relation to the solid biofuels consumption in a country (Figure 13). Figure 8 already compared energy wood extraction with industrial wood extraction.

For countries with a high forest increment, it can be concluded that both wood processing and paper industry as well as solid biofuels consumption is higher than in countries with a low forest increment per capita. Therefore the usage of forest biomass for both materials and energy is possible in those countries. Examples of such countries are Sweden and Finland. These countries and the political instruments and measures will be discussed in Chapter 4.

For countries with a low forest increment per capita, there is no relationship between the availability of forests and the size of the wood and paper industry turnover and solid biofuels consumption. For example, a country with a lower forest increment per capita in comparison with another country can still have a larger wood and paper industry turnover, as part may be from imported material.

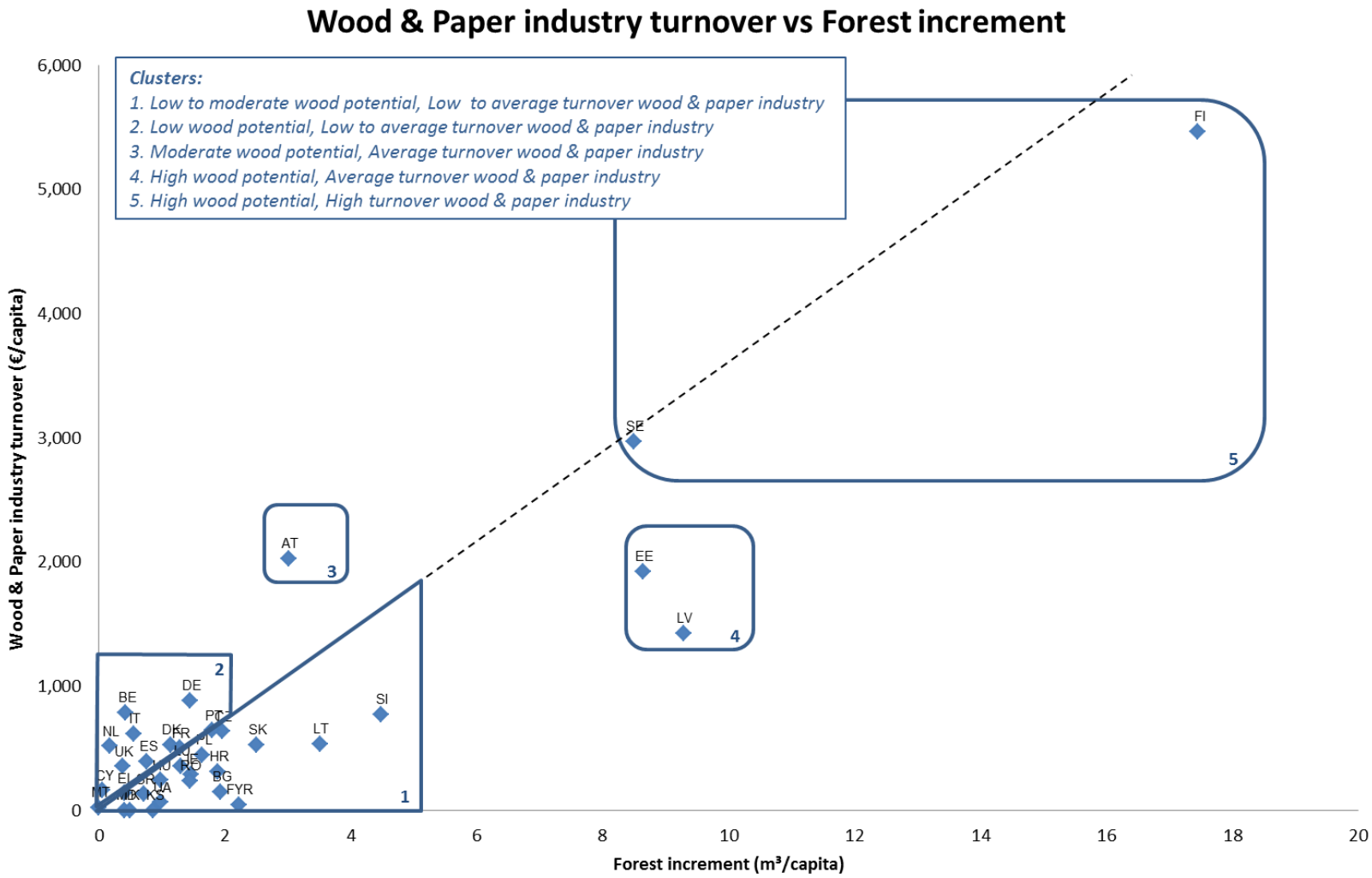

Figure 12: Country clusters - Forest increment vs Wood & paper industry turnover

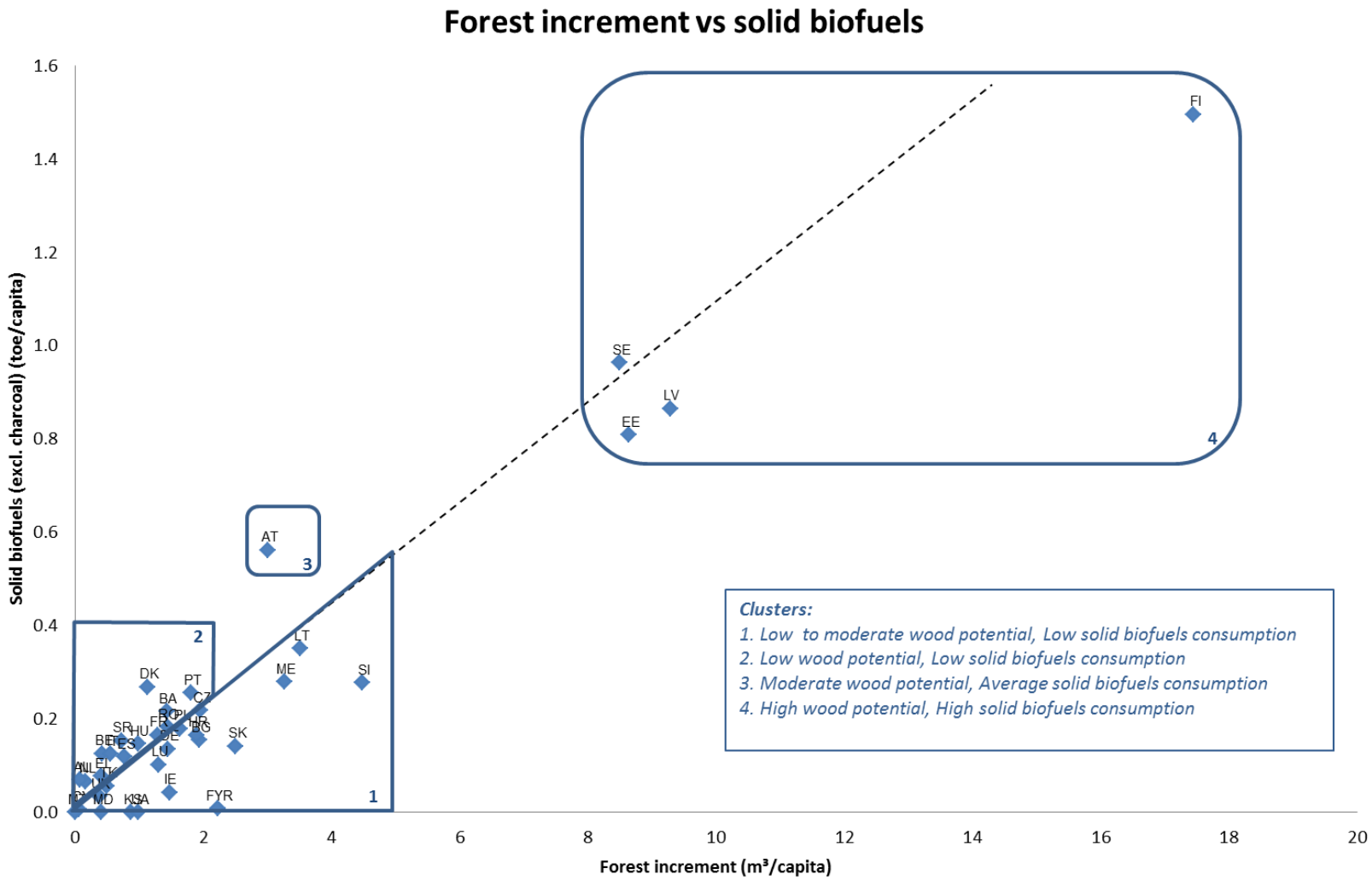

Figure 13: Country clusters - Forest increment vs Solid biofuels consumption

3.4 Biogas

Also for biogas we collected Eurostat information on the gross inland consumption, transformation input and final energy consumption in the industry, transport and services and other sectors. For the transformation input we also made, the same as for solid biofuels, an analysis of the share of electricity, CHP and heat-only plants. Results are provided in Table 16 and Table 17.

Table 16: Energy conversion processes biogas

Country	Gross inland consumption	Transformation input	Final energy consumption		
			Industry	Transport	Services and other sectors
	toe/capita	toe/capita	toe/capita	toe/capita	toe/capita
Belgium	0.02	0.010	0.002	0.000	0.005
Bulgaria	0.00	0.000	0.000	0.000	0.000
Czech Republic	0.05	0.042	0.000	0.000	0.013
Denmark	0.02	0.016	0.001	0.000	0.002
Germany	0.09	0.065	0.001	0.001	0.014
Estonia	0.01	0.004	0.000	0.000	0.002
Ireland	0.01	0.009	0.001	0.000	0.001
Greece	0.01	0.006	0.000	0.000	0.001
Spain	0.01	0.005	0.001	0.000	0.001
France	0.01	0.005	0.000	0.000	0.001
Croatia	0.00	0.004	0.000	0.000	0.000
Italy	0.03	0.030	0.000	0.000	0.000
Cyprus	0.01	0.008	0.000	0.000	0.005
Latvia	0.03	0.028	0.000	0.000	0.004
Lithuania	0.01	0.004	0.001	0.000	0.001
Luxembourg	0.03	0.021	0.000	0.000	0.008
Hungary	0.01	0.005	0.000	0.000	0.001
Malta	0.00	0.002	0.000	0.000	0.001
Netherlands	0.02	0.012	0.002	0.000	0.005
Austria	0.02	0.019	0.004	0.000	0.001
Poland	0.00	0.003	0.000	0.000	0.002
Portugal	0.01	0.006	0.000	0.000	0.000
Romania	0.00	0.001	0.000	0.000	0.000
Slovenia	0.02	0.016	0.000	0.000	0.001
Slovakia	0.01	0.009	0.000	0.000	0.001
Finland	0.01	0.013	0.001	0.000	0.003
Sweden	0.02	0.002	0.000	0.008	0.004
United Kingdom	0.03	0.030	0.000	0.000	0.001
Albania	0.00	0.000	0.000	0.000	0.000
Bosnia and Herzegovina	0.00	0.000	0.000	0.000	0.000
Macedonia	0.00	0.000	0.000	0.000	0.000
Kosovo*	0.00	0.000	0.000	0.000	0.000

Country	Gross inland consumption	Transformation input	Final energy consumption		
			Industry	Transport	Services and other sectors
	toe/capita	toe/capita	toe/capita	toe/capita	toe/capita
Moldova	0.00	0.000	0.000	0.000	0.000
Montenegro	0.00	0.000	0.000	0.000	0.000
Serbia	0.00	0.001	0.000	0.000	0.000
Turkey	0.00	0.003	0.000	0.000	0.000
Ukraine	0.00	0.000	0.000	0.000	0.000

Source: Eurostat data 2013

The table clearly shows that biogas has not really been picked up yet in non-EU countries. Biogas consumption per capita is highest in Germany and the Czech Republic. In many countries there is no or a limited consumption of biogas per capita. Biogas is mainly used as transformation input. In the transport sector, biogas only has a tradition to be used in Sweden. In the German transport sector the usage is very limited. In general it can be concluded that when biogas is available, it is mainly consumed in one specific sector.

In the next table we look in more detail at the use of biogas as transformation input. Only countries with 0.02 toe/capita or more are considered.

Table 17: Transformation input biogas (in case > 0.02 toe/capita)

Country	Electricity %	CHP %	Heat only %
Belgium	71%	29%	0%
Czech Republic	1%	93%	6%
Denmark	0%	70%	30%
Germany	44%	48%	8%
Italy	41%	53%	5%
Latvia	1%	43%	51%
Luxembourg	0%	31%	72%
Netherlands	56%	42%	0%
Austria	21%	47%	33%
Slovenia	0%	80%	20%
Sweden	0%	78%	22%
United Kingdom	100%	0%	0%

Source: Eurostat data 2013

In the UK the available amount of biogas is only used in electricity production plants, whereas countries such as Poland, the Czech Republic, Slovenia and Sweden. The use of biogas in heat-only plants is popular in Luxembourg, Latvia, Austria and Denmark.

3.5 Municipal Solid Waste

3.5.1 Treatment of municipal waste

For the indicator concerning waste, information is collected for the total municipal waste that is collected per capita in a country and the amount that is landfilled, incinerated, recycled and composted or digested. A low share of landfill relates to a high level of waste management.

Table 18: municipal waste collection and treatment

Country	Total municipal waste kg/capita	Landfill kg/capita	Incineration kg/capita	Recycling kg/capita	Composting/ digestion kg/capita
Belgium	437	4	195	151	91
Bulgaria	432	298	7	108	15
Czech Republic	307	173	60	65	9
Denmark	752	12	405	207	124
Germany	609	1	218	290	108
Estonia	293	40	163	36	15
Ireland	586	223	93	180	34
Greece	509	412	0	79	19
Spain	454	270	44	88	46
France	517	150	180	110	89
Croatia	404	332	0	54	7
Italy	491	181	99	122	72
Cyprus	629	491	0	77	57
Latvia	312	259	0	33	20
Lithuania	433	270	31	88	32
Luxembourg	616	114	226	182	131
Hungary	378	244	34	81	19
Malta	582	464	2	32	29
Netherlands	526	8	256	126	137
Austria	578	23	202	142	192
Poland	297	157	20	39	32
Portugal	440	222	104	57	57
Romania	254	213	0	6	1
Slovenia	414	109	2	157	20
Slovakia	304	213	32	10	22
Finland	493	124	209	94	67
Sweden	451	3	228	153	69
United Kingdom	482	165	102	133	77
Albania	359	335[a]	0	144[a]	0
Bosnia and Herzegovina	311	234	0	0	0
Macedonia	384	269	0	0	0
Kosovo*	417	na	na	na	na
Moldova	725	561[a]	0[a]	155[a]	0[a]

Country	Total municipal waste kg/capita	Landfill kg/capita	Incineration kg/capita	Recycling kg/capita	Composting/ digestion kg/capita
Montenegro	508	420	0	4	0
Serbia	336	272	0	0	0
Turkey	406	330	0	na	2
Ukraine	278	209	3.28[b]	7.14[b]	3.92[c]

Source: Eurostat data 2013
[a] Received via partner (university of Zagreb)
[b] http://www.minregion.gov.ua/zhkh/Blahoustri-terytoriy/-stan-sferi-povodzhennya--z-pobutovimi-vidhodami-v-ukrayini-za-2013-rik-694401/
[c] http://www.minregion.gov.ua/zhkh/Blahoustri-terytoriy/informaciya-schodo-vprovadzhennya-suchasnih-metodiv-ta-tehnologiy-u-sferi-povodzhennya-z-pobutovimi-vidhodami-stanom-na-01-10-20-336746/
na = not available

Denmark and Moldova collect more than 720 kg municipal waste per capita each year. In Bosnia and Herzegovina, only 230 kg municipal waste is yearly collected per capita, and also Macedonia, Romania, Serbia and Ukraine collect less than 280 kg per capita each year.

Country clusters are made per type of waste treatment, in terms of landfill (Figure 14), or the balance between incineration and composting/digestion (Figure 15). The choice to make use of landfills is not dependent on the amount of municipal waste that is collected as can be seen in Figure 14, but is dependent on the policy that is in place and the development stage of waste management. From Figure 15 it can be concluded that with an increasing share of MSW incinerated, also more MSW is composted or digested. This is also an indication of the development stage of waste management.

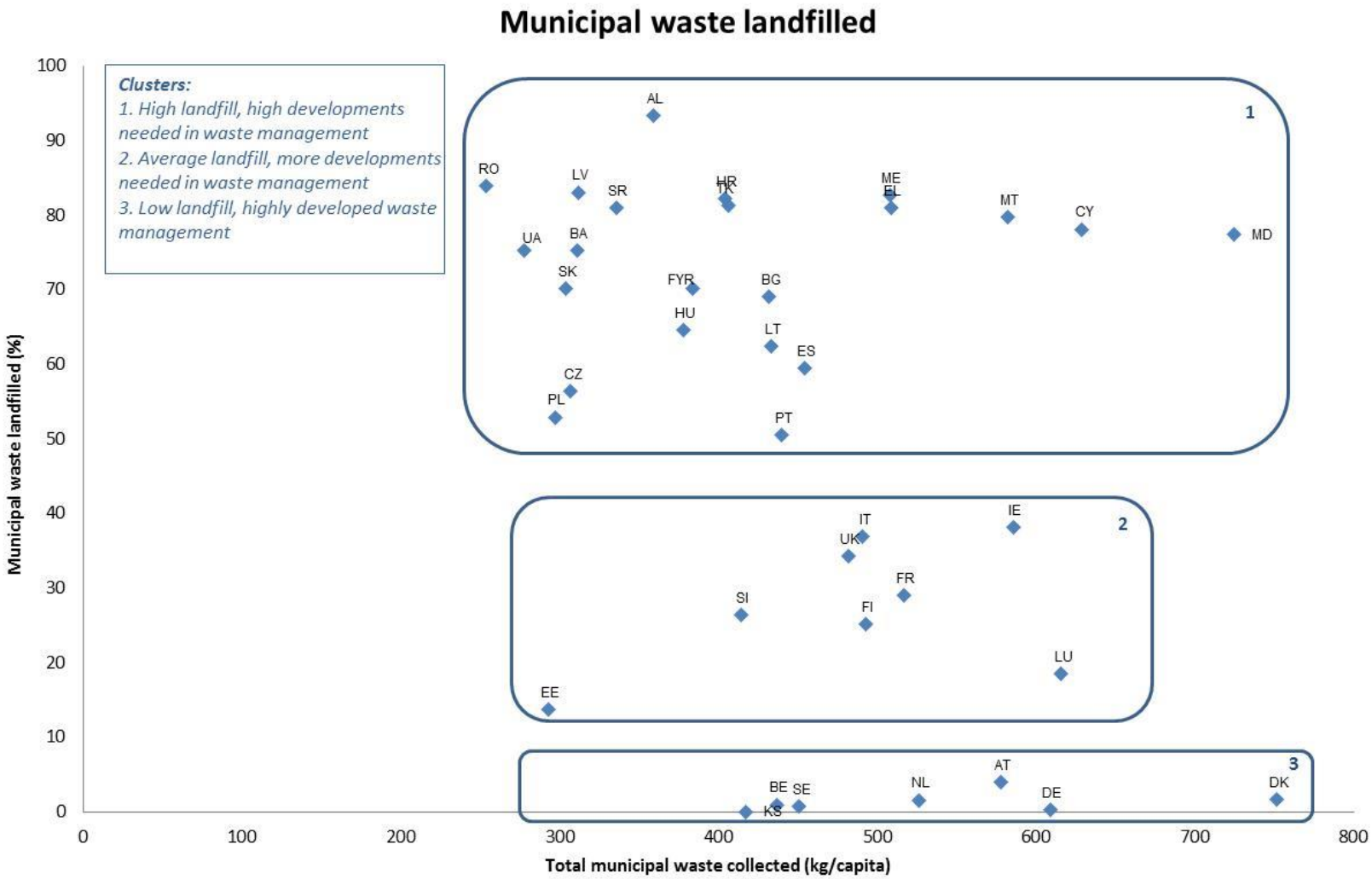

Figure 14: Country clusters – Total municipal waste and Landfill

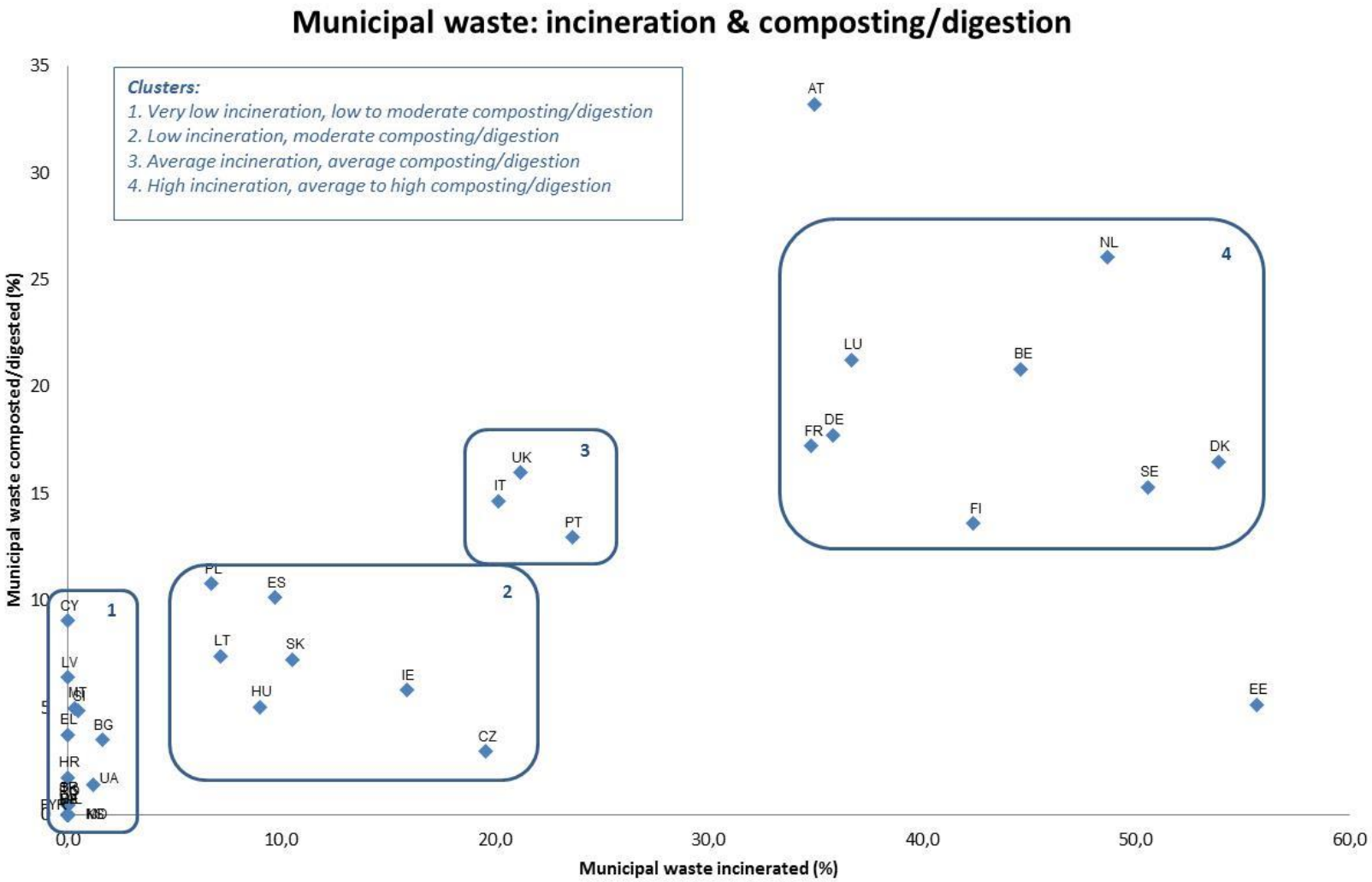

Figure 15: Country clusters – Role of incineration vs composting/digestion of MSW

3.5.2 Production of renewable energy from municipal waste

For MSW we collected information on the primary energy production using the Eurostat database. We collected information for MSW in total and specifically for the renewable part (Table 19). The analysis is limited to countries with substantial amounts of waste incineration and energy recovery.

Table 19: Primary energy production from MSW

Country	Primary production MSW toe/capita	Primary production renewable MSW toe/capita	Share of renewable MSW in total production %
Belgium	0.061	0.026	43%
Czech Republic	0.013	0.008	60%
Denmark	0.160	0.088	55%
Germany	0.073	0.036	50%
Estonia	0.080	na	na
Ireland	0.023	0.011	46%
Spain	0.009	0.004	50%
France	0.036	0.018	50%
Italy	0.028	0.014	50%
Lithuania	0.008	0.004	50%
Luxembourg	0.053	0.020	38%
Hungary	0.008	0.004	51%
Netherlands	0.087	0.048	55%
Austria	0.044	0.018	41%
Portugal	0.018	0.009	50%
Finland	0.070	0.041	58%
Sweden	0.143	0.086	60%
United Kingdom	0.014	0.008	53%

Source: Eurostat data 2013
MSW = municipal solid waste

Countries with the highest primary energy production from MSW are Denmark and Sweden. In most countries the renewable share of MSW is around 50%.

3.6 Liquid biofuels

3.6.1 Role of different types of liquid biofuels

For the liquid biofuels we collected Eurostat information on the total primary production and the production capacity installed in the different countries. We also make a distinction based on the installed production capacity for biogasoline, biodiesel and other liquid biofuels. An overview of the data is provided in Table 20.

Table 20: Production of different liquid biofuels

Country	Primary production	Production capacity			
		Biogasoline	Biodiesel	Other liquid biofuels	Total liquid biofuels
	ton/capita	kton/yr	kton/yr	kton/yr	ton/capita/yr
Belgium	0.050	369	665	72	0.099
Bulgaria	0.008	22	64	0	0.012
Czech Republic	0.027	160	420	0	0.055
Denmark	0.004	0	90	25	0.021
Germany	0.046	737	4,308	1,975	0.087
Estonia	0.000	0	0	0	0.000
Ireland	0.005	0	30	0	0.007
Greece	0.014	0	981	0	0.089
Spain	0.023	464	4,984	0	0.117
France	0.045	1,092	2,760	0	0.059
Croatia	0.008	0	69	0	0.016
Italy	0.010	332	2,212	0	0.043
Cyprus	0.002	0	14	0	0.016
Latvia	0.034	19	173	0	0.095
Lithuania	0.047	60	140	0	0.067
Luxembourg	0.000	0	0	0	0.000
Hungary	0.043	300	150	0	0.045
Malta	0.002	0	1	0	0.002
Netherlands	0.107	503	2,014	0	0.150
Austria	0.033	191	646	0	0.099
Poland	0.022	406	989	0	0.037
Portugal	0.030	0	731	52	0.075
Romania	0.009	89	206	0	0.015
Slovenia	0.001	0	5	0	0.002
Slovakia	0.039	120	142	0	0.048
Finland	0.066	12	380	30	0.078
Sweden	0.058	188	286	139	0.064
United Kingdom	0.011	715	523	0	0.019
Albania	0.000	0	0	0	0.000
Bosnia and Herzegovina	0.000	0	0	0	0.000
Macedonia	0.000	0	20	0	0.010

Country	Primary production	Production capacity			
		Biogasoline	Biodiesel	Other liquid biofuels	Total liquid biofuels
	ton/capita	1000 ton	1000 ton	1000 ton	ton/capita
Kosovo*	0.000	0	0	0	0.000
Moldova	0.000	0	0	0	0.000
Montenegro	0.000	0	0	0	0.000
Serbia	0.000	0	0	0	0.000
Turkey	0.001	0	0	0	0.000
Ukraine	0.001	0	0	0	0.000
Source: Eurostat data 2013					

From the above table it can be concluded that in the countries outside EU28 liquid biofuels production had not really picked up yet in 2013. For the EU countries it is clear that the installed capacity for liquid biofuels is not fully used – in many countries production is even lower than half the production capacity. Countries with the largest production per capita are the Netherlands, Sweden and Finland. Countries with the largest installed capacity per capita are the Netherlands, Spain, Belgium and Austria.

In types of liquid biofuels the largest (absolute) production capacity is available for biodiesel production. Especially Germany, Spain, France and the Netherlands have a large total capacity installed for biodiesel production, able to produce a large share of European biodiesel demand. For biogasoline (ethanol), the largest capacity is installed in France, followed by Germany and the UK.

3.6.2 Role of imports and exports of liquid biofuels

To gain insight in the role of trade of liquid biofuels we collected Eurostat information on the gross inland consumption, the imports and the exports. Using these data we calculated the imports and exports as a share of gross inland consumption and we calculated the net imports by subtracting exports from imports. The results are provided in Table 21.

Table 21: imports and exports of liquid biofuels

Country	Gross inland consumption	Import		Export		Net import
	toe/capita	toe/capita	% [a]	toe/capita	% [a]	% [a]
Belgium	0.03	0.003	9%	0.010	30%	-21%
Bulgaria	0.02	0.012	69%	0.001	4%	65%
Czech Republic	0.03	0.012	43%	0.007	28%	15%
Denmark	0.04	0.047	106%	0.006	14%	92%
Germany	0.04	0.014	39%	0.018	49%	-10%

Country	Gross inland consumption	Import		Export		Net import
	toe/capita	toe/capita	% [a]	toe/capita	% [a]	% [a]
Estonia	0.00	0.002	100%	0.000	0%	100%
Ireland	0.02	0.011	71%	0.000	0%	71%
Greece	0.01	0.001	11%	0.001	9%	1%
Spain	0.02	0.017	85%	0.015	78%	7%
France	0.04	0.007	17%	0.003	8%	10%
Croatia	0.01	0.001	7%	0.000	5%	2%
Italy	0.03	0.026	77%	0.001	2%	75%
Cyprus	0.02	0.015	89%	0.000	0%	89%
Latvia	0.01	0.007	66%	0.027	257%	-191%
Lithuania	0.02	0.013	66%	0.033	171%	-105%
Luxembourg	0.10	0.103	100%	0.000	0%	100%
Hungary	0.02	0.010	61%	0.025	157%	-96%
Malta	0.01	0.005	70%	0.000	0%	70%
Netherlands	0.02	0.000	0%	0.064	281%	-281%
Austria	0.06	0.056	90%	0.022	35%	55%
Poland	0.02	0.005	24%	0.004	19%	4%
Portugal	0.03	0.001	3%	0.002	6%	-4%
Romania	0.01	0.005	47%	0.002	21%	26%
Slovenia	0.03	0.028	97%	0.000	0%	97%
Slovakia	0.02	0.008	44%	0.017	92%	-48%
Finland	0.06	0.046	79%	0.055	93%	-15%
Sweden	0.08	0.038	47%	0.005	6%	41%
United Kingdom	0.02	0.009	57%	0.001	4%	53%
Albania	0.00	0.000	0%	0.000	0%	0%
Bosnia and Herzegovina	0.00	0.000	0%	0.000	0%	0%
Macedonia	0.00	0.000	0%	0.000	0%	0%
Kosovo*	0.00	0.000	0%	0.000	0%	0%
Moldova	0.00	0.000	0%	0.000	0%	0%
Montenegro	0.00	0.000	0%	0.000	0%	0%
Serbia	0.00	0.000	0%	0.000	0%	0%
Turkey	0.00	0.004	88%	0.000	0%	88%
Ukraine	0.00	0.000	7%	0.000	0%	7%

Source: Eurostat data 2013
[a] % of gross inland consumption

In Luxembourg the largest gross inland consumption of liquid biofuels per capita is found. This is related to the high transport fuel consumption in Luxembourg, related to run through traffic. Also in Sweden, Finland and Austria the consumption of biofuel is relatively high. Note that Luxembourg does not have any production capacity itself and Austria only a limited amount; as a consequence, both countries import a high share of their liquid biofuels consumption. Other countries that have a large import amount per capita for liquid biofuels are Finland and Denmark. Exporting countries are the Netherlands, Latvia, Lithuania and Hungary.

3.7 Overview

Table 22 shows a country overview of the key performance criteria as discussed in the sections 3.1 to 3.5. In total 35 criteria are shown. A criterion is highlighted for a country if scores above a certain threshold for that criterion and this from a positive performance viewpoint. E.g. the performance criterion on landfilling is highlighted if the respective country has low landfill statistics.

In terms of **solid biomass**, the Scandinavian countries Finland, Sweden, Denmark, the Baltic States Estonia, Latvia and Lithuania, as well as Austria and to a lesser extend Croatia, Portugal, Slovenia and Montenegro demonstrate rather high scores. Most of these countries also combine this with a strong wood processing or pulp and paper industry. In the case of Denmark, the role of straw is also important to mention.

For **biogas**, Germany and Czech Republic demonstrate highest performance, with Sweden being the leader in terms of biogas for transport. The share of MSW going to composting/digestion is also included here as the flows can be redirected to produce biogas (even if it is currently mainly aimed at composting).

For **MSW**, the stage of waste management is important, and the amount going to landfill is a clear indicator for that. A number of countries (Belgium, Denmark, Germany, Estonia, Netherlands, Austria, Sweden) score high in terms of landfill avoidance, and some of them also produce substantial (renewable) energy from MSW.

For **liquid biofuels**, Austria, Finland, Sweden, Luxembourg, Denmark, Germany and France reach highest consumption amounts per capita. Some of them – in particular Luxembourg, Denmark and Austria - rely heavily on imports to reach that.

With the exception of Montenegro, non-EU countries generally perform at medium or low level for the defined performance criteria. The same can be said for EU member states in East and South Europe

Table 22: Overview table performance criteria

Performance criterion	Threshold	Belgium	Bulgaria	Czech Republic	Denmark	Germany	Estonia	Ireland	Greece	Spain	France	Croatia	Italy	Cyprus	Latvia	Lithuania	Luxembourg	Hungary	Malta	Netherlands	Austria	Poland	Portugal	Romania	Slovenia	Slovakia	Finland	Sweden	United Kingdom	Albania	Bosnia and Herzegovina	Macedonia	Kosovo*	Moldova	Montenegro	Serbia	Turkey	Ukraine
Total RE consumption	> 0.55 toe/capita				*		*								*						*				*		*	*							*			
Share of bioenergy in TE consumption	> 15%				*							*			*	*					*						*	*							*			
RE in transport	> 6%					*					*										*						*	*										
RE in electricity	> 35%				*					*		*			*						*		*	*				*							*	*		
RE in heating & cooling	> 30%				*		*								*	*							*		*		*	*							*			
Share of electricity generation through CHP	> 30%				*										*	*				*						*	*								*		
District heating network	> 2m/capita				*																						*	*										
Solid biofuels - gross energy consumption	> 0.25 toe/capita				*		*								*	*					*		*		*		*	*							*			
Solid biofuels - transformation input	> 0.10 toe/capita				*		*								*	*					*						*	*										
Share of transformation input to CHP	> 60%		*	*	*		*				*	*										*			*	*	*	*									*	
Solid biofuels – industry (final energy cons.)	> 0.10 toe/capita														*						*		*				*	*										
Solid biofuels - residential and other (final energy cons.)	> 0.20 toe/capita						*					*			*	*					*				*		*								*			
Production of solid biofuels for energy - share fuelwood, residues, by-products	> 0.50 toe/capita						*								*						*						*	*										
Production of solid biofuels for energy - share black liquor	> 0.05 toe/capita																				*		*			*	*	*										
Production of solid biofuels for energy - share other vegetal materials & residues	> 0.03 toe/capita				*		*											*				*	*															
Net exports of solid biofuels	> 0.01 toe/capita		*	*			*					*			*								*												*			
Net imports of solid biofuels	> 0.01 toe/capita	*			*								*								*								*									
Certified forest area	> 70%				*	*	*	*				*			*						*	*				*	*	*	*										
Forest increment harvested	> 70%	*		*																									*		*	*			*		*	
Share of forest harvest for industrial wood	> 75%			*		*		*		*		*			*		*				*	*	*			*	*	*	*									*	
Industry turnover sawmills & wood planning	> 250 €/capita						*								*						*						*	*										
Industry turnover wood products	> 250 €/capita	*		*		*	*								*	*	*				*				*		*	*										
Industry turnover pulp & paper products	> 250 €/capita	*				*				*	*		*							*	*		*		*	*	*	*										
Biogas – gross energy consumption	> 0.04 toe/capita			*		*									*																							
Biogas - transformation input	> 0.02 toe/capita			*		*							*		*		*				*								*									
Share of transformation input to CHP	> 60%			*	*																				*			*										
Biogas – transport (final energy cons.)	> 0.005 toe/capita																											*										
Biogas – Services (final energy cons.)	> 0.005 toe/capita	*		*		*								*			*			*																		

Performance criterion	Threshold	Belgium	Bulgaria	Czech Republic	Denmark	Germany	Estonia	Ireland	Greece	Spain	France	Croatia	Italy	Cyprus	Latvia	Lithuania	Luxembourg	Hungary	Malta	Netherlands	Austria	Poland	Portugal	Romania	Slovenia	Slovakia	Finland	Sweden	United Kingdom	Albania	Bosnia and Herzegovina	Macedonia	Kosovo*	Moldova	Montenegro	Serbia	Turkey	Ukraine
MSW to composting/digestion	> 80 kg/capita	*			*	*					*						*			*	*																
Renewable share of MSW incineration – gross energy consumption	> 0.04 toe/capita				*	*														*							*	*									
MSW to landfill	< 50 kg/capita	*			*	*	*													*	*							*										
Liquid biofuels – gross energy consumption	> 0.04 toe/capita				*	*					*						*				*						*	*									
Liquid biofuels - production capacity	> 0.08 ton/capita	*				*			*	*				*						*	*																
Net exports of liquid biofuels	> 0.01 toe/capita														*	*		*		*						*	*										
Net imports of liquid biofuels	> 0.01 toe/capita		*		*			*					*	*			*				*				*			*									

4 Benchmarking performance criteria to policy frameworks

In this section we will link country characteristics and performance criteria to policy frameworks in relation to specific cases either focused at feedstock mobilisation, and/or at the final application. In performing the benchmark analysis the following four key elements are being used:

- The **indicators** discussed in Chapter 2 'Clustering of countries based on indicators' of this report;
- The **performance criteria** as discussed in Chapter 3 'Defining performance criteria for benchmarking' of this report;
- The **policies and policy frameworks** as presented in S2BIOM deliverable 6.1 'policy database'; and available on-line at https://s2biom.vito.be/.
- A number of **cases**. Where possible, the cases have a link with the case studies selected in WP9:
  i) Mobilizing forest based feedstocks for use in energy and materials (*Finland, Sweden*)
  ii) Forest based (district) heating (Sweden)
  iii) Straw based district heating (Denmark)
  iv) Large scale biomass imports (incl. sustainability criteria) (*UK, Belgium, Netherlands, Denmark*)
  v) Lignocellulosic energy crops (*UK, Sweden, Spain*)
  vi) Support for advanced biofuels (*Finland, Sweden, Netherlands, UK*)
  vii) Biomethane (SNG) as transport fuel (*Sweden, Germany*)

In the first step of the benchmarking methodology, the performance criteria are linked to the country profile (indicators). For each indicator group (population and land surface, GDP and trade, energy, forestry, agriculture) the relevance for a performance criterion is indicated through a relative score. Note that not every indicator has an equally strong link with all performance criteria; therefore, the relevance expresses how connected a specific performance criterion with a certain indicator group. In other words, it indicates how relevant an indicator group is to obtain a higher performance for a certain performance criterion. The rationale behind this is the causality between on the one hand the indicator group, expressing the **potential to achieve** a certain performance, and on the other hand the performance criterion, expressing the **actual performance** or deployment of that potential.

To express the relevance of an indicator group for a performance criterion, we used a four-level score, ranging from high relevance (dark green), over medium (orange) to low (light grey) and limited/no relevance (white). The results of this scoring procedure are shown in **Error! Reference source not found.**. For example, the indicators related to 'forestry' such as forest area and forest increment, are considered to have a high relevance for the performance criteria related to 'solid biofuels' such as

sustainable forest management, forest harvesting, solid biofuel production and the role of solid biofuels in imports and exports. Therefore, in **Error! Reference source not found.** the cells are indicated in dark green. Whereas these forestry related indicators are considered to have no impact on the performance criteria concerning MSW and thus these cells are blanc.

In the second step, the performance criteria are scored for their relevance for the case studies using the same scoring method as for the indicators. The results of this scoring are provided in Table 24. Case studies are specific in terms of feedstock, processes and/or product, and also in their focus on certain steps within the value chain. As a consequence not all performance criteria are equally relevant to explain the performance of a specific case study. For example for the case study 'Forest-based (district) heating' the performance criterion 'district heating network' and 'solid biofuels consumption' are provided a high score (*i.e.* dark green colour). In contrast, we provided a low score (*i.e.* Blanc) for the performance criterion 'MSW treatment'.

Mind that the scoring is an expert judgement from our side, and should be interpreted as indicative.

In the third step, the case studies are addressed individually. For every case study we will make use of the data of Chapters 2 and 3. In this step we look at several aspects. First, for every case study we identify the performance criteria that are of high or medium relevance in Table 24. Second, for those performance criteria we search for the indicators in the country profile (Table 23) that got a high or medium score for those performance criteria. The reason is that these indicators will give an idea of the potential a certain country has to attain a high score for a performance criterion. Third, we search for countries that have a high score for the performance criteria that are of relevance for the case study because these countries can be used as an example for other countries with a lower performance score but comparable potential. Finally, we make an analysis of the policy instruments that are implemented in the good performing countries and give advice on how these instruments can be used in countries that have a similar potential, however, a lower performance score.

Table 23: Linking performance criteria with country profiles (indicators)

	PERFORMANCE CRITERIA															
	Renewable Energy	**Value chain efficiency**		**Solid Biofuels**							**Biogas**	**Municipal Solid Waste**		**Liquid biofuels**		
	RE consumption	CHP role in electricity	District heating network	Solid biofuels consumption	Solid biofuels production	Types of solid biofuels	Imports & exports of solid biofuels	Wood processing and pulp & paper industry turnover	Sustainable forest management	Forest increment & harvesting	Biogas production & consumption	Treatment of MSW	Energy from MSW incineration	Liquid biofuels consumption	Liquid biofuels production	imports & exports of liquid biofuels
Population and area (population, area, pop. density, ...)	1	1	2	2		1	2	1	1	2	1	2		2	1	1
GDP & Trade (GDP, cross border trade)	2	1	1				2	3			1	2	2	1	1	2
Energy (consumption, dependency,...)	2	2	2	2	1		3	1			1	1	1	2	1	3
Forestry (area, increment)	2	1	1	2	3	3	3	3	3	3				1	1	
Agriculture (arable land, yield, LSU)	1	1		1	1	2	1				3			1	2	2

Legend: 3 High relevance; 2 Medium relevance; 1 Low relevance; No/limited relevance

Table 24: Linking cases with performance criteria

	PERFORMANCE CRITERIA															
	Renewable Energy	**Value chain efficiency**		**Solid Biofuels**							**Biogas**	**Municipal Solid Waste**		**Liquid biofuels**		
	RE consumption	CHP role in electricity	District heating network	Solid biofuels consumption	Solid biofuels production	Types of solid biofuels	Imports & exports of solid biofuels	Wood processing and pulp & paper industry turnover	Sustainable forest management	Forest increment & harvesting	Biogas production & consumption	Treatment of MSW	Energy from MSW incineration	Liquid biofuels consumption	Liquid biofuels production	imports & exports of liquid biofuels
Forest-biomass for energy and materials	1	3	1	3	2	3	2	3	3	3				1	1	
Forest-based (district) heating	1	3	3	3	3	3	2	2	2	2						
Straw-based district heating	1	3	3	3	3	3	1									
Large scale biomass imports	1	2	1	3	2	2	3	2	1	1						
Energy crops	1			2	2	1	1				1			1	2	1
Advanced biofuels	1					1	2	3	1	1				3	3	3
Biomethane (SNG)	1	2									3	3	2	1		1

Legend: 3 High relevance; 2 Medium relevance; 1 Low relevance; No/limited relevance

4.1 Case 1: Mobilizing forest-based feedstocks for materials and energy (Sweden and Finland)

In the first case study we focus on countries with a strong history in mobilizing forest-based feedstock for products (and energy). We used **Error! Reference source not found.** and Table 24 to identify the most relevant performance criteria and indicators for this case study. According to the Tables, the following performance criteria and indicators are selected as the most relevant.

Highly relevant performance criteria

- **Wood processing and pulp & paper industry turnover**
- Solid biofuel consumption
- Types of solid biofuels, e.g. industry residues
- Value chain efficiency: combined production of electricity and heat through CHP (mainly by industry themselves)
- **Sustainable forest management**
- Forest harvesting in relation to annual increment
- Share of industrial wood in forest harvesting

Highly relevant country indicators

- Forestry:
  - Forest surface area (*also related to population density & land area*)
  - Annual forest increment
- GDP & trade:
  - GDP per capita
  - Cross border movements, related to industrial activity

Based on the scores of the different countries on the performance criteria, we selected **Finland and Sweden** as good examples. Finland and Sweden have many geographical, climatic, and industrial characteristics in common. They both have a large availability of forest resources and they share three general energy policy goals, *i.e.* (1) secure energy supply, (2) low environmental impacts, and (3) economic competitiveness through efficient use and cost-effective supply. In Finland almost three quarters and in Sweden 68% of total land area is covered by forests. Furthermore, the wood-based industry is highly presented. In Finland 60% of forests are privately owned and also in Sweden the majority of the forests are privately owned.

We identified the specific **policy instruments and measures** that are implemented in Sweden and Finland and are of relevance for this case study. These policy instruments and measures can be retained from the S2BIOM policy database (https://s2biom.vito.be/). An overview is provided in Table 25. Next to the short name of the policy instrument or measure, we also indicate the type of the instrument or measure (e.g. regulatory, financial or soft). Furthermore, we give an indication of the impact every policy instrument or measure had in attaining the performance level for the criteria selected for this case study. The score ranges from high (dark green), over medium (orange), to low (light grey).

Table 25: Forestry related policy instruments and measures (Sweden and Finland)

Country	Short name of policy instrument or measure	Type	Impact
Sweden	Environmental code	Regulatory	
Sweden	Forest act	Regulatory	
Sweden	Marketing act	Regulatory	
Sweden	National forest programme	Soft	
Finland	Act on financing of sustainable forestry	Financial	
Finland	Act on forest management associations	Regulatory, soft	
Finland	Act on jointly owned forests	Soft	
Finland	Act on placing timber and wood products to market	Regulatory	
Finland	Act on trade in forest reproductive material	Regulatory	
Finland	Finnish bioeconomy strategy	Soft	
Finland	Forest act	Regulatory	
Finland	Forest damages prevention act	Regulatory	
Finland	Small diameter trees energy subsidy	Financial	
Finland	Sustainable forestry funding for fixed period	Financial	
Finland	Timber measurement act	Regulatory	
Finland	National biodiversity strategy	Soft	

Concerning the Finnish and Swedish forest policy landscape, a lot of information can be gathered from Forest Europe, the Finnish Forest Association[10], the Swedish Forest Agency[11] and Federation of Finnish Forest Industries[12].

Sustainable forest management

Regarding sustainable forest management (SFM), many European countries implement policy objectives concerning land use and forest area or even targets for increasing forest area. However, in Finland and Sweden the government does not have specific targets related to this topic, because current legislation already covers sustainability issues (Table 25). However, governments see the increase of knowledge about forests and their contribution to sustainable development of the society as being important. To put this into practice an e-service[13] exists in Sweden

[10] http://www.smy.fi/en/
[11] http://www.skogsstyrelsen.se/en/
[12] www.forestindustries.fi
[13] http://skogensparagrafer.skogsstyrelsen.se/sp_search.aspx?

for forest owners in which they can plan the management of their forests and submit harvesting notifications to the forest authority or consult the policy that is applicable.

About 100 years ago Sweden introduced forestry legislation that limited the amount of timber that could be harvested, and imposed an obligation on woodlot owners to carry out regeneration after felling, contributing to sustainable management. Sustainable forestry ensures an increase in the stock of growing wood – for each tree that is cut down at least two new ones are planted. Since then forest resources have doubled.[14]

Forest increment and harvesting

In general the forest roundwood removal does not exceed the forest increment in Sweden or Finland (Figure 9). In Sweden the fellings in the past exceeded the net annual increment. Sweden experienced catastrophic storms in the past decade, which resulted in high natural losses and consequently the removal of downed timber and a reduction of the net annual increment. This implies that a utilization rate above 100% can still be sustainable if it is on temporary basis.

From Figure 8 it can also be concluded that mainly industrial wood is removed in Sweden and Finland and to a lesser extent fuelwood is harvested.

In both countries there is a large availability of forest resources and a considerable part of the biomass that is available from these forests is used for energy purposes. To a large extent the forest or pulp and paper industry themselves use these resources for bioenergy for process heat and electricity through combustion of internal by-products such as black liquor and bark. A major advantage of integrating the production of biofuels with the forestry industry itself is the opportunity to use existing skills and infrastructure. For example, the harvesting of forest residues can be coordinated together with normal forestry operations costs, the costs of machinery and forest road can be shared between users[19,15].

Link materials and energy

According to a report concerning the state of Europe's forests (2015), the contribution of the forest sector to GDP is declining from 1.2% in 2000 to 0.8% in 2010. In general the value added in the pulp and paper industry in Europe is decreasing due to the digitalization and changes on the worldwide market. Sweden and Finland are, together with Germany, the largest paper and paperboard producing Member States. In Finland only paperboard production remains stable in 2015 at 720,000 tonnes

[14] http://www.svenskttra.se/siteassets/6-om-oss/publikationer/pdfer/swedish-forestry.pdf
[15] Roos et al. (1999)

compared with 2014. Whereas pulp and paper production in 2015 fell by respectively 3% and 4% compared to the year 2014. An overview of the production volumes in Finland since 1960 is provided in Figure 16.

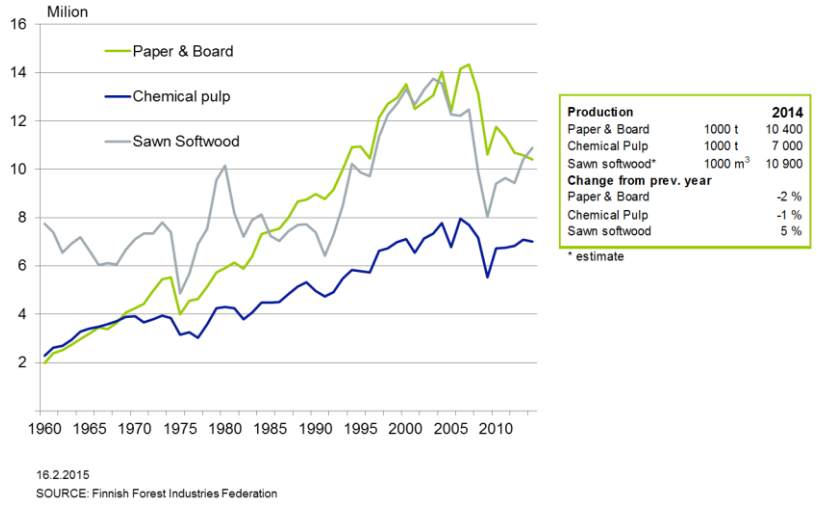

Figure 16: Finland forest industries' production volumes since 1960

Taking into account these trends and the strategic importance of forestry, the Ministry of Agriculture and Forestry in Finland organized a stakeholder consulting to prepare a government report on forest policy 2050 and to identify new ideas and prioritize objectives. The forest policy report 2050 serves as the basis for a revised **Finnish national forest programme** (i.e. National Forest Strategy 2025[16]) which is adopted in February 2015. Important background documents for the strategy are for example the Finnish Bioeconomy Strategy and the National Biodiversity Strategy. Eleven different strategic projects are formulated in the National Forest Strategy, for example new incentive schemes and resource-efficient forest management and transport infrastructure in support of the forest-based business and activities. Also in Sweden the government established a **Swedish National Forest Programme** process in June 2014.

Through their existing industries, Sweden and Finland aim to pioneer the bioeconomy, with an important role for advanced biofuels in decarbonising the transport sector. There are interesting evolutions in Finnish pulp and paper industries picking up an important role producing advanced biofuels from their by-products. An example case of this is UPM's advanced biofuels production in the UPM Lappeenranta Biorefinery in Finland. Finland has put a target of 30% biofuels by 2030, most from forest biomass.

[16] http://mmm.fi/documents/1410837/1504826/National+Forest+Strategy+2025/197e0aa4-2b6c-426c-b0d0-f8b0f277f332

Biomass and renewable energy

Concerning renewable energy, various types of support are known in both Sweden and Finland since respectively 1975 and 1979. Ericsson et al. (2004) provide a clear overview of bioenergy policy and market development in both Sweden and Finland at that time. Finland and Sweden joined the EU in 1995, but European targets have not been the driver for policies supporting bioenergy. **Policies included research and development support, investment grants and energy and environmental taxes.** On top of these policies, both countries have a strong **monitoring system,** as already mentioned in the section concerning sustainable forest management.

Both Finland and Sweden have installed **taxes** on fossil fuels ('carbon taxes'). In Sweden biomass is the least costly fuel for heat production in district heating systems due to the high level of taxes on fossil fuels.

Next to taxes, both countries used **investment grants** for biomass-fired plants. In Finland, biomass-based electricity production receives a sliding premium per kWh produced by forest chips (not suitable for forest industry) on top of the investment grant. If roundwood is used (BDH > 16 cm) support is 60% of the full feed-in premium. In Sweden investment grants are replaced by a quota system with certificate trading.

Conclusion

It is clear that both Finland and Sweden have a long forestry policy history. Finland's first sustainable policy legislation was in force in 1905. Forestry management and the conversion of forestry products to both bioenergy and materials is an integrated part of their market. Despite this long history, in both countries governments recognize the need for additional actions to safeguard the forest industries and moving towards an intensified bioeconomy. Although there is a large interest in forest-based biorefineries, the investment climate is still uncertain and unstable, long-term policy with a clear ambition is needed to boost the bioeconomy. Also, it is a challenge to integrate biorefinery processes into existing plants. Note that policy measures and instruments used in Finland and Sweden cannot be directly copied to other European countries. The non-policy context that can influence the success of certain legislation needs to be taken into account. Of course lessons can be learned and some of the actions taken in Finland and Sweden can be used in other countries whether or not in a modified form. Principles of sustainable forest management and advising private forest owners can be promoted in other countries. Important lessons are the fact that support for biomass has remained relatively stable over time in both countries, despite changing political forces. Supporting bioenergy through a tax on fossil fuels (carbon tax) has shown quite successful. Nevertheless it should be considered how this impacts the competitiveness of biorefineries aiming at non-energy products.

Support for biomass has remained relatively stable over time in Sweden and Finland, despite changing political forces.

In both countries a National Forest Programme is formulated which can provide a stable, long-term policy with a clear ambition to boost the bioeconomy (incl. industry);

Principles of sustainable forest management and advising private forest owners can be an example for other countries

4.2 Case 2: Forest-based (district) heating (Sweden)

The second case study is about forest-based (district) heating. This is complementary to the previous case. We used Table 23 and Table 24**Error! Reference source not found.** to identify the most relevant performance criteria and indicators for this case study. According to the Tables, the following performance criteria and indicators are selected as the most relevant.

Highly relevant performance criteria

- **Size of district heating network**
- Solid biofuels consumption
- Solid biofuels production
- **Types of solid biofuels, e.g. forest residues, industry residues**
- Wood processing and pulp & paper industry turnover
- Value chain efficiency: combined production of electricity and heat CHP

Highly relevant country indicators

- Forestry:
  - Forest surface area (*also related to population density & land area*)
  - Annual forest increment
- Energy:
  - Energy consumption
  - Energy dependency

In terms of district heating network, the Scandinavian countries Sweden, Finland and Denmark jump out. Denmark's bioenergy system is more directed towards

agricultural residues (straw) and will be treated in the next case. For this case we will focus on Sweden.

Sweden has a large availability of forest biomass and mainly uses CHP installations to convert their available solid biofuels. From the data it can also be concluded that Sweden already has a large district heating network available. In Sweden, the building of district heating networks started in 1948 and nowadays it represents around 60% of heating. Of all multi-dwelling houses and all public buildings, 85% is connected to the district heating network. This number is much smaller for one- and two-dwelling buildings as heat pumps are more popular for these types of buildings[17]. The main input source is biomass, which accounts for 40% of the production[18].

Using the S2BIOM policy database (https://s2biom.vito.be/) and a literature review we identified the most relevant policy instruments and measures for this case study. The policy instruments and measures are summarized in Table 26. The last column the relevance of a certain instrument/measure on the development of the forest-based district heating system in Sweden. The score ranges from high (dark green), over medium (orange), to low (light grey).

Table 26: District heating policy instruments and measures (Sweden)

Country	Short name of policy instrument or measure	Type	Impact
Sweden	Forest act	Regulatory	
Sweden	Electricity certificates Act	Financial	
Sweden	Energy tax	Financial	
Sweden	Local authority act (SFS 1991:100)*	Regulatory	
Sweden	Swedish electricity act	Regulatory	
Sweden	District heating law (SFS 2016:120)	Regulatory	
Sweden	Municipal energy plans (SFS 2016:961)	Soft	
Sweden	Planning and building act (SFS 1987:10)*	Regulatory	
Sweden	Grants for Residential Heating Conversion*	Financial	
Sweden	Local investment programmes (LIP)*	Financial	
Sweden	Climate investment programmes (KLIMP)*	Financial	

* Ended

Concerning the lessons learned from the Swedish system, a report is available by Ericsson and Svenningsson (2009)[19].

District heating and the role of bioenergy

Especially in countries where a large fraction of the electricity production comes from power plants, implementing district heating systems can be an important solution for using the residual heat from these plants and thereby reducing primary energy demand for heating. One of the main competing energy sources that can pose a

[17] http://www.youris.com/Energy/Ecocities/District-Heating-Sweden-Is-Leading-The-Way-Out-Of-Fossil-Fuels.kl
[18] http://www.svenskfjarrvarme.se/
[19] Ericsson, K, and Svenningsson, P (2009).

barrier for the introduction of district heating systems in other European countries is natural gas. In some countries an extensive natural gas grid is available that supplies gas to buildings. Natural gas was only introduced after 1985 in Sweden and its grid is only developed in specific regions. As a consequence, natural gas only played a negligible role in the heating of buildings[19].

Policy has played an important role in Sweden in the reform of their energy system. Although district heating systems were introduced in the 1950s, a slowdown was noticed in Sweden due to nuclear power plants and low electricity prices, in favour of electric heating. Only in recent years, district heating gained new interest thanks to the introduction of renewable electricity certificates and the increasing electricity prices. Policy also influenced the type of energy sources used in the district heating network. First by introducing the oil tax and later by introducing the energy tax, the competitiveness of fossil fuels has been greatly reduced. This made the use of biomass increasingly attractive, especially because biomass is exempt from the energy and environmental taxes**Error! Bookmark not defined.**.

District heating systems are especially popular for multi-dwelling houses and public buildings and to a lesser extent for one- and two-dwelling buildings. In one- and two-dwelling buildings in Sweden heat pumps are more attractive. For these also other aspects are important such as the availability of space, the availability of information about new heating systems, and having positive experience with current systems. Furthermore, another aspect that influences especially the residential sector is the convenience of a system, which is a disadvantage for biomass (wood pellets) when compared to heat pumps[19].

After the introduction of the carbon tax, the share of biomass in district heating input sources increased rapidly. The tax made fossil-energy sources more expensive and biomass became the most competitive resource. The biomass that is used consists mainly of wood fuels such as forestry residues, waste wood and wood pellets. The remaining biomass is for a large part tall oil (*i.e.* by-product from pulp production)[19]. An overview of the input sources in the district heating system in Sweden is provided in Figure 17.

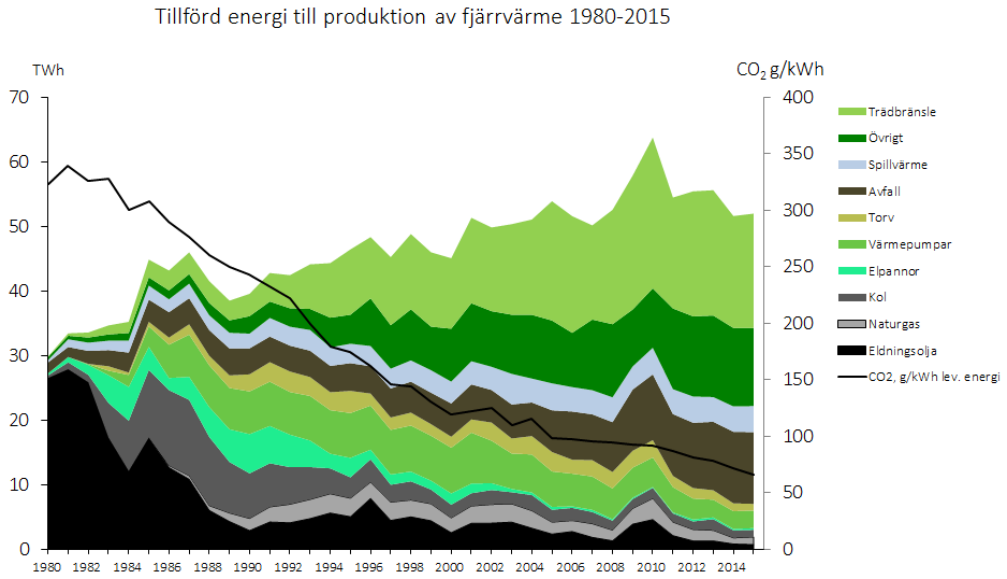

Figure 17: Input sources Swedish district heating system since 1980[18]

Value chain efficiency

The interest in CHP installations has picked up with increased electricity prices and renewable electricity certificates[19]. If we look at the numbers of 2013 the majority, *i.e.* over 70%, of the solid biofuels converted in energy plants are used in CHP installations.

In order to develop district heating networks, two aspects are important: (1) an actor is needed that invests in the system and that operates the system, and (2) public perception to accept collective infrastructure technologies. For the first aspect, in Sweden the municipalities took the first initiative and later the systems were transformed into **municipality-owned companies**. Only in late 1990s some of the systems were sold to national or international utilities companies. That municipalities took the first initiative is logic considering they own themselves several buildings that need heating. Furthermore, local governments traditionally have (some) power in Sweden and they have financial resources from tax incomes[17].

Concerning the second aspect, there always has been a high acceptance towards community-wide technical solutions in Sweden. Furthermore, thanks to reliable supplies and competitive prices compared to other heat options, district heating networks have a good reputation in Sweden. The importance of these non-technical barriers may not be underestimated. In order to maintain confidence in district heating in Sweden, the sector is constantly monitored by the Energy Market Inspectorate[17 above].

Solid biofuels import and export

Although Sweden has a large availability of forest resources, they still imported a large part of the biomass used in biomass-fired CHP installations. Up to 30 - 40% percent of the biomass was imported (e.g. wood fuels from Baltic countries, wood pellets from Canada, and waste wood from Germany and the Netherlands)[20]. The import of biomass is due to the high demand and the high price Sweden is willing to pay for biomass when compared to other countries. Another reason for the high import is the greater acceptance of waste wood in incineration plants in Sweden. On top, Sweden has some interesting coastal locations to facilitate biomass import[19].

Conclusions

The introduction of district heating systems in Sweden already started in the 1950s and the energy market looks much different today. Investments in biomass-fired CHP installations in Sweden increased thanks to increasing electricity prices and the renewable electricity certificates. Another reason is the introduction of the energy tax which was part of a reform of the entire taxation system in Sweden. To a lesser extent the subsidies that were provided had an influence on the district heating system in Sweden. Biomass is an important input in Swedish energy provision and this is mainly due to the large availability of forest resources. Nevertheless, there is also some reliance on imported biomass, which is related to accessibility of some coastal regions. Very important to take into account is the fact that no natural gas grid was available in Sweden when introducing the district heating system. In Sweden the main competitor of the system are heat pumps, especially for one- and two-dwelling buildings. Finally, municipalities play a key role in the development of district heating systems.

Link with the natural gas network: in Sweden, district heating grids were developed before the introduction of a natural gas grid.

Municipalities are key in developing district heating networks.

Introduction of a fossil fuel tax boosted the use of renewable energy.

[20] Ericsson, K., and Nilsson, L.J. (2004)

4.3 Case 3: Straw-based district heating (Denmark)

For the third case study we also analyse district heating in more detail, however, this time we focus on the use of agricultural residues ('other vegetal materials & residues'). Agricultural residues originating directly from the fields (e.g., straw, leaves, stover, stalks, husks, cobs) provide a potentially attractive source of biomass in that they do not directly require additional land to produce and can be harvested alongside more high-value agricultural products (e.g. food and fodder grains). Harvesting residues for bioenergy or biobased applications can provide additional income to agricultural operations, by giving these residues financial value.

We used Table 23 and Table 24**Error! Reference source not found.** to identify the most relevant performance criteria and indicators for this case study. According to the Tables, the following performance criteria and indicators are selected as the most relevant.

Highly relevant performance criteria

- **Size of district heating network**
- Solid biofuels consumption
- Solid biofuels production
- **Types of solid biofuels: other vegetal materials and residues**
- Value chain efficiency: combined production of electricity and heat CHP

Highly relevant country indicators

- Agriculture:
  - Arable land
  - Yields
- Energy:
  - Energy consumption
  - Energy dependency

In this case, Denmark comes out as an interesting example. Denmark has a large district heating network available (the largest in Europe, expressed per capita) and is dominated by agricultural area when compared to forest area. In Denmark the first district heating network was developed in the 1920s. Nowadays, the district heating system is the most important heating source for households. Of all private houses, 63% is connected to the system. Approximately 70% of all district heating is produced in CHP installations[21].

In Denmark straw is being used for district heating systems. The straw is combusted in heating and in combined heat and power installations. The installations are used

[21] Danish Energy Agency (2015)

during the heating season and are maintained during summer times. To be able to use straw for energy systems a considerable amount of straw is necessary. The amount of straw is related to the used arable land.

Also for the case study on straw-based district heating we searched the S2BIOM policy database (https://s2biom.vito.be/) for relevant policy instruments and measures. We searched specifically for instruments and measures that influenced the development of the district heating system in Denmark. Additionally, we searched in literature to complete the list. The relevant policy instruments and measures for this case study are summarized in Table 27.

Table 27: District heating policy instruments and measures (Denmark)

Country	Short name of policy instrument or measure	Type	Impact
Denmark	Heat supply act	Regulatory	
Denmark	Danish technology catalogue	Soft	
Denmark	Co-generation agreement	Regulatory	
Denmark	The electricity supply act	Regulatory	
Denmark	Energy policy	Regulatory	
Denmark	The carbon tax legislation	Financial	
Denmark	Biomass agreement	Regulatory	

Role of bioenergy

In Denmark, the main rationale to initiate energy production from agricultural residues was energy security. Renewables, nuclear power and natural gas became priorities for the nation during the oil crisis in 1973-74, to increase national energy security (Nygård 2011). In the 1986 “Electricity Agreement” instalment of 80-100 MW, combined heat and power (CHP) production based on domestic fuels such as straw, natural gas, woodchips or biogas was stipulated. In 1993, the “Biomass Agreement” mandated the use of 1.2 million tonnes of straw and 0.2 million tonnes of wood chips by 2000, with revisions in 1997 and 2000 to increase flexibility and attainability. In the late 2000s, the focus shifted from energy security to creating a fossil free future (Nygård 2011), and feed-in tariffs for renewables increased. Denmark wants to be fossil-fuel independent by 2050 and biomass combustion is expected to play an increasingly important role. In 2014, the share of biomass in the total fuel use of district heating was over 40%[21].
Danish goals for the use of straw over the past 20 years have led to a well-developed supply chain supported by mandated use and/or financial incentives throughout.[22]

Next to the oil crisis, also political support was provided to the use of biomass. Important in the development was the first heating supply law of 1979 in which the Danish government regulated the form and content of heat planning in Denmark (see

[22] http://www.ieabioenergy.com/wp-content/uploads/2015/11/IEA-Bioenergy-inter-task-project-synthesis-report-mobilizing-sustainable-bioenergy-supply-chains-28ot2015.pdf

further). Grants, taxes on fossil fuels and tax exemptions for biomass and biogas and quotas were introduced.
Given the exemption from CO_2 taxes (as other biomass fuels), straw is historically the cheapest form of biomass available in Denmark, making it competitive with oil and natural gas.

Decentralized CHP installations receive a fixed annual subsidy until the end of 2018. Originally a feed in tariff was used. After 2018, only power and CHP plants using renewable energy sources keep on receiving this add-on price. Electricity produced from biomass for example receives an add-on price of 20 euro per MWh to the market price[21].

Types of solid biofuels

In 1993 the Danish government prioritized the use of biomass through its Biomass Agreement. The biomass agreement first focused on the use of mainly straw and some wood chips. In a later phase they left more room in the choice of biomass. The focus on straw instead of forestry biomass as is the case in Sweden (see previous case study) is logical considering the higher share of agriculture and yield in Denmark. Denmark is characterized by the large availability of agricultural area compared to forest area (Figure 5).

Figure 18 shows the evolution of straw use for energy in Denmark, in comparison to other applications and the amount left on the field. The amount used for energy is a rather stable market, around 1.5 million tonnes per year. In future a shift to straw based ethanol might be expected.

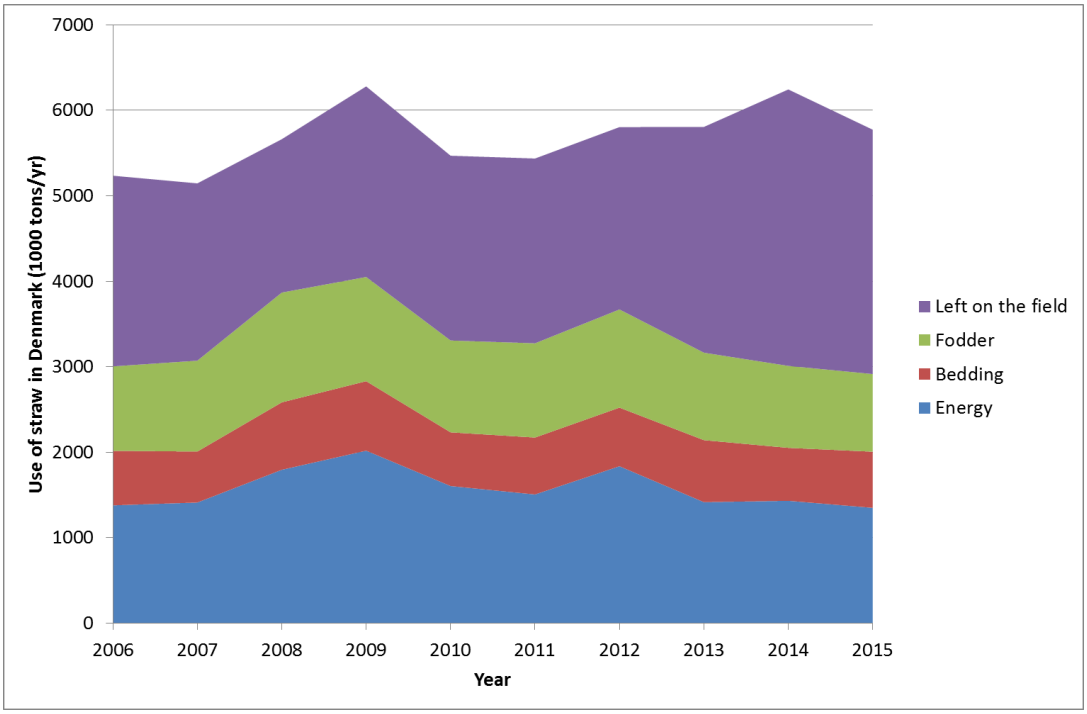

Figure 18: Evolution of annual production and use of straw in Denmark (Statistics Denmark 2016)

Taking into account the increased use of biomass in large CHP installations the Danish energy industry associations agreed on the inclusion of sustainability aspects for wood pellets and wood chips in plants with a capacity over 20 MW. The aspects include reforestation and biodiversity, protection of ecosystems and global carbon cycle[21].

Energy production from solid biofuels

In Denmark the district heating production from small-scale CHP installations and surplus heat from industry increased during several years, however, decreased in recent years. The heat only boilers (*i.e.* district heating units) increased in recent years because of lower electricity prices[21].

Large scale CHP installations are typically placed in large urban areas and heat is produced using different sources, e.g. large generation plants, municipal waste plants, industrial surplus heat, and peak load boilers. Whereas small-scale CHP installations are located in smaller cities or villages and normally consist of a base load installation (mostly biomass boiler (straw or wood chips) or natural gas boiler) and a peak load boiler (mostly natural gas or oil)[21].

For CHP installations the owners can chose the fuel type, but for heat-only production the choice is limited by law. In case natural gas supply is available, natural

gas has to be used. Some exceptions were made in 2013 and 2015 where they used biomass[21].

District heating

In contrast to the situation in Sweden (*i.e.* case study 2), in Denmark the majority of the district heating infrastructure is owned by large energy companies. Only the smaller plants are owned by municipalities. Some of the smaller networks are owned by consumer cooperatives. The district heating company has to follow the non-profit principles to protect consumers from the monopoly position the district heating owner has[21].

One of the important political actions is the introduction of the heating supply law. The municipalities define the heating planning in accordance to the heating supply law. For this planning, four steps are followed:

1. Mapping by municipalities of existing heat demand, supply and amount of energy used (both current and future);
2. Identify options for future heating by municipalities and for regions this identification is performed by counties;
3. Counties prepare regional heating plans with priority of heating supply options and locations for supply and network;
4. Preparation of municipal heating plans with local authorities.

Despite the different role compared to municipalities in Sweden, they are still key in the development of the district heating systems.

Next to the heating planning, the heating supply law also contained another important aspect. The goal was to secure the investments in the district heating infrastructure by requiring a connection to the network for new buildings. Furthermore, in Denmark a ban on electric heating was introduced.

Local authorities can make use of the Danish technology catalogue that helped them assessing heating supply options. The catalogues provides information on heating supply plants, calculating the distribution of heating demand over a year, forecasts of fuel prices and assessing investments in gas networks and district heating networks.

One of the important aspects of the Danish system is that the district heating network is equipped with a short-term (*i.e.* 12 hours) heat storage system. This increases the flexibility of the system and improves the economic feasibility[21].

Conclusion

Important to note is that, as in case study 2, the development of the district heating network in Denmark started decades ago and policy played an active role in the development of it. Both in the second and third case study, one of the important aspects in determining the success of the district heating system is the cost for the consumer. In both cases the price for heating was lower when customers used the district heating network compared to having their individual heat supply.

Important in Denmark were some political steps taken to ensure a secure income for energy companies like the obliged connection to the network and the ban of electric heating systems. Although the municipalities had a different role in comparison with municipalities in Sweden, also in Denmark they were key in the development of the system.

Interesting to note is that in Denmark an increase in both the natural gas share and the district heating network is realised. This indicates that although the availability of an extensive gas grid infrastructure, it is still possible to establish a district heating network.

The long term commitment to move away from fossil fuels, the political prioritization of biomass use and the introduction of a fossil fuel tax was key in the development of (largely biomass based) district heating systems in Denmark.

Danish goals for the use of straw over the past 20 years have led to a well-developed supply chain.

Lessons can be learned from the heat supply law with clear steps to follow when developing a district heating network, and an important role of municipalities in the process.

The cost and reliability of the system is key in convincing the general public and is secured by policy actions (e.g. non-profit law).

4.4 Case 4: Large scale biomass imports (UK, Belgium, the Netherlands, Denmark)

In this case, the focus lies on countries with a relatively low domestic potential of woody biomass, but large scale power plants producing electricity (and heat) from imported biomass. We used Table 23 and Table 24**Error! Reference source not found.** to identify the most relevant performance criteria and indicators for this case study. According to the Tables, the following performance criteria and indicators are selected as the most relevant.

Highly relevant performance criteria

- **Imports and exports of solid biofuels**
- Solid biofuels consumption
- Share of bioenergy in overall renewable energy
- Value chain efficiency: combined production of electricity and heat (CHP)

Highly relevant country indicators

- Population and area: high population density
- GDP and trade: GDP per capita & Cross border trade
- Energy: Energy consumption per capita & Energy dependency

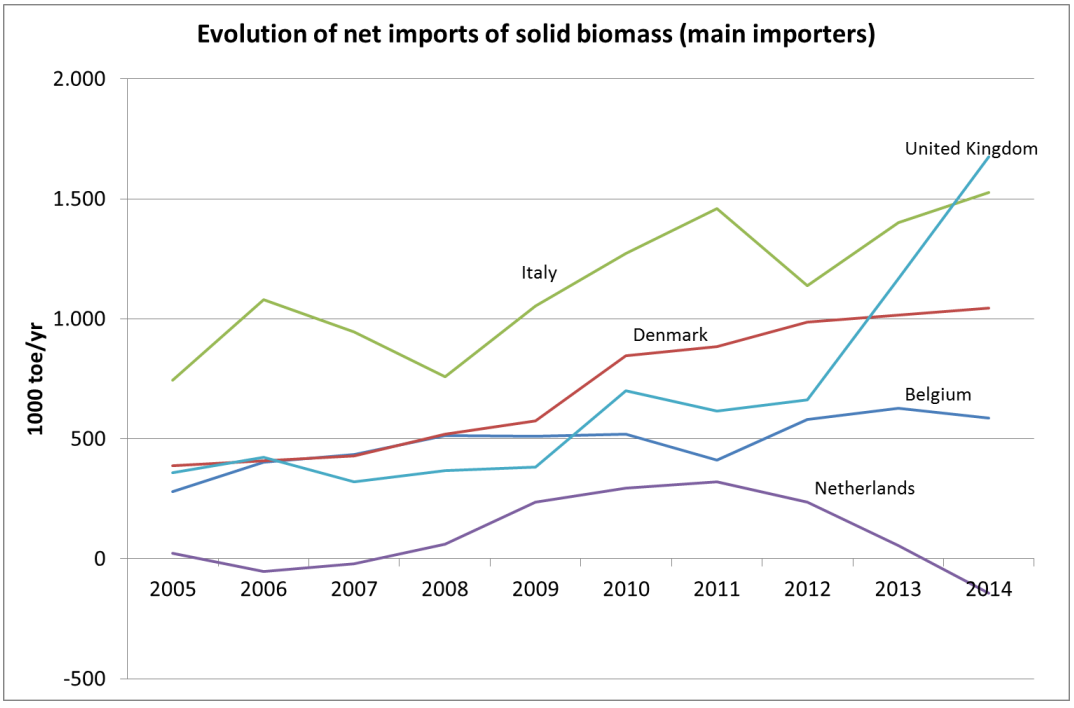

Figure 19: evolution of net imports of solid biomass for the main importing countries (data derived from Eurostat)

For this case, we selected UK, Belgium, the Netherlands and Denmark as examples. All these countries represent a combination of an important volume of solid biofuels being imported (most from outside Europe) and a dominant role of bioenergy in overall renewable energy production. They are generally alike in terms climate condition, industrial and economic characteristics and have availability of (deep) sea harbour infrastructure able to except large transatlantic sea-liners.

The drivers for biomass imports in these countries are specifically support systems for renewable electricity and/or heat, particularly when picked up by large firing installations. These **policy instruments and measures** can be retained from the policy database that is developed in the course of the S2BIOM project (https://s2biom.vito.be/). We identified the specific **policy instruments and measures** that are implemented that are of relevance for this case. An overview of the most relevant policies in the UK, Belgium and the Netherlands for this case is provided in Table 28. Next to the short name of the policy instrument or measure, we also indicate the type of the instrument or measure (e.g. regulatory, financial or soft). Furthermore, we give an indication of the impact every policy instrument or measure had in attaining the performance level for the criteria selected for this case. The score ranges from high (dark green), over medium (orange), to low (light grey).

Table 28: Renewable electricity related policy instruments and measures (UK, Belgium, the Netherlands, Denmark)

Country	Short name of policy instrument or measure	Type	Impact
BE (FL)	Energy Decree & green power certificates	Regulatory (substitution obligation) & financial (tradable certificates)	
BE (FL)	Grid injection of renewable electricity	Regulatory	
BE (WAL)	Green certificates	Regulatory (substitution obligation) & financial (tradable certificates)	
BE (BCD)	Brussels green certificates	Substitution Obligation	
NL	Renewable energy production incentive scheme (SDE+)	Financial (auction, feed-in premium)	
NL	Energy Agreement	Regulatory	
NL	Vision Biomass 2030	Soft	
UK	Renewables obligation for England and Wales (and similar for Scotland and Northern Ireland)	Regulatory (substitution obligation) & financial (tradable certificates)	
UK	Feed-in Tariffs Order	Financial	
UK	Renewable Heat Incentive	Financial	
UK	Finance Act - Climate Change Levy	Financial	
Denmark	Heat supply act	Regulatory	
Denmark	Law on the Promotion of Renewable Energy	Financial (feed-in premium)	

Country	Short name of policy instrument or measure	Type	Impact
Denmark	Co-generation agreement	Regulatory	
Denmark	Carbon tax legislation	Financial	
Denmark	Biomass agreement	Regulatory	

In all these countries there is a clear renewable electricity and/or heat support system in place, being it via a system of premiums, feed-in tariffs or substitution obligations, combined with green certificates. In Belgium support of renewable energy is a regional responsibility, hence leading to three separate policy initiatives in Flanders (FL), Wallonia (WAL) and Brussels Capital District (BCD). The same is true for the UK with England & Wales, Northern Ireland and Scotland, although the basis for these systems is very similar. In the Netherlands, the basis for renewable energy support is the SDE+ system, which is basically an auction system providing premiums. In the period 2013-2015 there has been unclarity about the outcomes of the energy agreement (particularly in terms of requirements for biomass, see further). This has caused a (temporary decrease in imports), but the expectation is that it will pick up again now requirements have been clarified and in the new SDE+ call, indeed a number of biomass installations have been awarded SDE+ support. Denmark has a consistent promotion of renewable energy, with an important role for biomass, as mentioned in the previous case study.

Sustainability requirements[23]

A common finding is that in these countries, particularly in NL, UK and BE, for some time discussions have emerged about biomass and bioenergy sustainability. This can be related to the concern that the national government does not have control over how imported biomass is produced. These countries have therefore developed their own system to ensure that imported biomass is sustainably produced and actual GHG reductions are achieved.

In contrast to liquid biofuels, which have to fulfil EU-wide sustainability criteria imposed through the Renewable Energy Directive, for solid and gaseous biomass used in the heating and cooling sector and for electricity generation, the Commission decided not to introduce EU binding criteria but to adopt non-binding recommendations to Member States, given that biomass was largely produced domestically and therefore subject to sustainable forest policies and regulations at national level. The Belgian regions had already introduced sustainability criteria into their supporting scheme since 2006, which also entailed auditing of biomass supply chains. The UK and the Netherlands developed their own mandatory systems. Meanwhile, the Sustainable Biomass Partnership (SBP), combining large European energy producers, developed a common certification scheme designed for woody

[23] BioSustain Final Report (not published on-line yet)

biomass used in industrial, large-scale energy production, which would also fulfil national requirements of the countries concerned. In Denmark, the energy utilities reached a voluntary agreement.

In 2015, the **UK** Renewables Obligation Order was consolidated and the requirement for solid biomass and biogas stations to meet sustainability criteria in order to receive support under the scheme was introduced. The legislation requires operators of generating stations using bioliquids, and operators of generating stations with a total installed capacity ≥1MW using solid biomass and biogas, to report against, and meet, the sustainability criteria to get support under the scheme. The sustainability requirements are described into four categories: Fuel classification, mass balance, GHG reduction and land criteria. The land criteria make a distinction between land criteria for bioliquids (based on the Renewable Energy Directive), for woody biomass and for other fuels. The GHG account to the life cycle of the biomass.

Green Power Certificates Systems in **Belgium**: Stationary energy (including bioliquids, but also solid and gaseous biomass) falls under responsibility of the regions (Flanders, Walloon Region, Brussel Capital District) in Belgium. The three regions introduced sustainability criteria directly into their supporting scheme. All calculations must be proven by an audit of an independent body.

In Flanders the fossil energy used for transporting and pre-treatment of the biomass, is deducted from the green power certificates. In the Brussels and the Walloon region a greenhouse gas balance and reduction compared to a best available natural gas system is calculated to determine the amount of green certificates.

To reduce the risk of competition, in the Flemish region certain biomass streams are not entitled to receive green power certificates as a resource for the production of renewable electricity, e.g. wood (waste) streams that are still suitable for recycling in board or pulp and paper industry. In the Walloon and Brussels Region, this competition prevention measure does not exist.

In the **Netherlands**, an agreement has been made between government, energy utilities and NGOs to apply sustainability criteria for the co-firing of biomass. Under this agreement, energy companies will only receive a subsidy for co-firing of biomass when these sustainability criteria are met. The sustainability criteria are defined for different biomass categories, including woody biomass (distinguished to large and small Forest Units), residues, and waste streams. The sustainability criteria include requirements on GHG emission reduction, carbon and land use change and sustainable forest management. The legal criteria are directly linked to subsidies. In addition, some of the (social) criteria are laid down in a covenant and have no legal or policy basis.

In **Denmark**, the Danish District Heating Association and the Danish Energy Association have established an industry-initiated voluntary framework (without

regulation from the Danish government) for the sustainable use of solid biomass in CHP plants (wood pellets and wood chips) in Denmark. Companies must demonstrate compliance with the biomass sustainability criteria through annual reporting (to be made publicly available) on compliance with the requirements. This is to be verified by a third party. The documentation requirements enter into force from August 2016.

Meanwhile, on 30 November 2016, the **European Commission** published its proposal for a revised Renewable Energy Directive[24], for their post-2020 policy on this topic. This proposal also includes sustainability criteria for forest biomass and GHG saving requirements for (large) biomass electricity and heat plants.

Value chain efficiency

Considering that many of the large scale installations relying on imported biomass are converted coal power plants, the reliance on 'electricity-only' plants is still high. In the UK, 100% of solid biofuels going to the energy transformation sector are converted to electricity only (situation 2013); in Belgium, this share is 71%, in the Netherlands 56%, and in Denmark 0%. The Danish performance is linked to specific cogeneration requirements, and the deployment of district heating, so even large plants feed into district heating grids.

The proposed revised Renewable Energy Directive (see before) also includes a requirement that electricity from biomass is produced using highly efficient combined heat and power technology (*including a grandfathering of existing installations).*

Conclusions

The countries discussed above have high population density and limited forest area, so have limited local woody resource supply options in relation to their energy requirements. The presence of main harbours is/was a main infrastructural benefit in setting up import supply systems of solid biomass. Biomass import streams are generally linked to large scale installations, often co-firing biomass in existing coal power plants, or converted coal power plants.

The main policy frameworks aiding the use of biomass in large scale power plant are support frameworks for renewable energy, with biomass co-firing providing a relatively easy and cheap renewable energy solution. In countries with large imports of woody resources, sustainability is an important policy thematic. The sustainability topic is regularly (constantly) debated in legislative and society circles, and in the discussed countries sustainability requirements have been / are being implemented

[24] https://ec.europa.eu/energy/sites/ener/files/documents/1_en_act_part1_v7_1.pdf

in their renewable energy support systems. As the European Commission did not impose EU-wide sustainability requirements for solid biomass, Member States have mostly developed their own system. Large players have joined in a common partnership (SBP) to obtain a common certification system, to overcome trade barriers. The proposed post-2020 legislation from the side of the European Commission indicates that EU-wide sustainability requirements may be introduced for forest biomass, at least for large installations.

Many of the converted (large) coal power systems operating on imported biomass are focused on electricity-only production, with exception of Denmark, which has long experience in cogeneration and district heating, also for large power plants (including fossil). Other countries could move in that direction; however, it would be recommended that countries already put requirements on (existing) fossil power plants to use residual heat, e.g. through building district heating networks, so the burden is not fully placed on the conversion process to biomass (which would make it very expensive).

For more thorough analysis of trade in the European bioenergy system, we refer to the project BioTrade2020+[25].

Countries with high population density, low domestic resources and high trade orientation logically include biomass imports for renewable energy.

Sustainability requirements have emerged in these countries – it would be most efficient to have common requirements at EU level to avoid trade barriers.

Trade is mostly linked to larger scale installations (co-firing or dedicated biomass plants). Large scale installations often produce electricity only. Countries should move towards higher use of residual heat, but should already start this process for fossil power plants.

4.5 Case 5: Energy crops (UK, Sweden, Spain)

We did not find specific data in Eurostat on the amount of land used for energy crops. Therefore data has been searched in literature to draw general conclusions.

Highly relevant performance criteria

[25] http://www.biotrade2020plus.eu/

- **Area destined for energy crops**
- Production of solid biofuels for energy
- Solid biofuels consumption
- (Advanced) biofuels production capacity

Highly relevant country indicators

- Agriculture:
  - Arable land
  - Yields

Energy crop support up to 2007

With the reform of the CAP in 1992, set-aside regulations were introduced. To reduce overproduction in agriculture, a certain percentage of land (amounting to maximum 10%) was to be set aside, and farmers received a set-aside premium. Non-food crops could be grown on 'set-aside land', and the set-aside premium would be kept - crops used to produce biofuels also qualified. Out of 6.4 million hectare set aside in 1995, nearly 1 million hectares were used for non-food crops, most of that rapeseed and sunflower.

In the 2003 Common Agricultural Policy reform, an energy crop aid scheme was introduced (on land without set-aside support). This included a 45 euro per hectare aid to provide an incentive for farmers to grow the raw materials for bioenergy. The maximum support area was limited at 1.5 million hectares (later increased to 2.0 million ha) at EU level.

The CAP Health Check of 2008 ended this support scheme. 2007 was also the last year when compulsory set-aside was applicable in the EU.

The following table shows the evolution of the agricultural area in the EU used for energy crops, split up in areas with energy crop premium, set-aside support and no support.

Table 29: overview of energy crops in the EU from 2003 to 2007[26]

Million hectares	2003	2004	2005	2006	2007
Energy crops on set-aside area	0.9	0.6	1.0	1.0	1.0
Cropland with energy crop premium		0.3	0.7	1.3	1.9
Energy crop land without support	0.3	0.5	0.7	1.4	1.7
Total	1.2	1.4	2.4	3.7	4.6

[26] http://www.cepi.org/system/files/public/epw-presentations/2007/Summa_Slides.pdf

In absolute terms, Germany (884 kha) and France (904 kha) accounted for more than 60% of the total area devoted to renewable energy under the two support schemes in the EU-27 (in 2007).

Since 2008 (i.e. after these schemes were abolished), there are no reliable statistical data available. DG AGRI estimated that in 2011, 6.1 million ha of agricultural land was used for biomass and energy crops in the EU27[27].

High growth levels were obtained in the 5 year period from 2003 to 2007. Mind that the main driver was demand side policy, with tax incentives and blending obligations for biofuels; the agricultural support were flanking measures to facilitate sufficient supply of feedstocks to fulfil the demand.

Most energy crop area was used to produce rapeseed (for biodiesel); in recent years the amount of maize used for biogas has grown, particularly in Germany.

Lignocellulosic crops

It is difficult to find statistics for lignocellulosic crops, i.e. energy grasses (such as miscanthus) or short rotation coppice (such as willow or poplar) and there is a lot of variation in reported figures.

In 2007, Aebiom reported that there were 50 to 60.000 hectare of solid biomass energy crops in Europe, of which most in Finland (reed canary grass), Sweden (willow), Italy (miscanthus) and the UK (miscanthus and willow).[28]

The Aebiom 2015 Statistical Report reported the following numbers. Mind that there were strong incongruences between figures collected by Eurostat and those provided by the experts and stakeholders consulted by Aebiom[29].

Table 30: overview of lignocellulosic crops (in ha) in different EU Members States (Aebiom, 2015)

ha (2014)	Switchgrass	Reed Canary	Willow	Poplar	Miscanthus	EUROSTAT
AT	200	20	280	1069	1014	1200 (2014)
BE			70		120	
BG						1400 (2013)
CZ						2300 (2014)
DE			4000	5000	15000	3100 (2014)
GR						1000 (2012)
FI		18700	<100			6600 (2014)

[27] http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_renewable_energy_production
[28] http://www.aile.asso.fr/wp-content/uploads/2007/11/14h15-contexte-europeen.pdf
[29] http://www.aebiom.org/wp-content/uploads/2016/11/WG-Draft.pdf

ha (2014)	Switchgrass	Reed Canary	Willow	Poplar	Miscanthus	EUROSTAT
FR			2300		3500	
HR						100 (2010)
HU						6100 (2014)
IE			930		2200	1600 (2014)
IT			670	5490	50-100	
LT			550			300 (2014)
LU						200 (2014)
NL					90	
PL			5000-9000	300		2300 (2014)
RO	50000					
SE		780	11000	550	450	600 (2014)
UK			1500-2300		17000	7000 (2014)

According to Aebiom, the situation concerning lignocellulosic energy crops could be described as 'stagnating' - at best. In the majority of cases the total used surface has remained unchanged compared to previous years. In others, SRC are reported to have decreased, with only Miscanthus increasing slightly. On a larger scale, these types of energy crops still play a marginal role compared to most other biomass feedstocks available. Aebiom presents the following possible reasons:

1. Abundance of woody biomass on the market which is driving prices down;
2. Low fossil fuel prices;
3. Market uncertainties for energy crops.

It is a challenge to convince farmers and the processing industries to grow completely new crops, when quality performance, yield and price remain uncertain.[30]

In the following paragraphs, we will shortly discuss some cases in Europe, particularly in the UK, Sweden and Spain.

United Kingdom

In England there were three concurrent support schemes with relevance for energy crops:

- Energy Crops Scheme (ECS), providing establishment grants for approved energy crops (short rotation coppice £1,000 per hectare; miscanthus £800 per hectare)

[30] C. Mangan, J. Coombs (2004) Renewable raw materials and European Union Research Policy. In Biomass and Agriculture – Sustainability, markets and policies. OECD, 2004.

- Bio-energy Infrastructure Scheme, helping to develop the supply chains required to harvest, store, process and supply energy crops and wood fuel to energy end-users
- Bio-energy Capital Grants Scheme, supporting the installation of biomass fuelled heat and combined heat and power projects in the industrial, commercial and community sectors in England.

The reporting on the impact of the Energy Crop Scheme by DEFRA[31] makes distinction between two phases: from 2000 to 2007 (ECS1) and a second phase from 2008 to 2015 (ECS2).

For *miscanthus*, in ECS1, 6376 ha of new miscanthus plantings were supported; in ECS2 the supported amount was 3675 kha. Total planted area of miscanthus was 8657 ha in 2010 and 7012 ha in 2014. Volumes of miscanthus use in UK power stations dropped from 47 ktonnes in 2012/13 down to 22 ktonnes in 2013/14. This decline can be connected to a wider trend of a declining usage of energy crops and policy changes, e.g. the Renewables Obligation Amendment Order in 2013 reduced the incentive for power stations to use energy crops. Other outlets for using miscanthus include horse and livestock bedding, small scale CHP plants directly on farms for heating buildings and domestic uses such as wood burners and open fires.

For *short rotation coppice* (SRC), in ECS1 1815 ha of new SRC plantings were supported; in ECS2 the supported amount was only 674 ha. Total planted area of short rotation coppice reached 2850 kha in 2014. The vast majority of SRC is grown within the subsidy payment scheme. Approximately 6.7 ktonnes of SRC were used in UK power stations for electricity in 2013/14, less than half compared to 2010/11 when around 15 ktonnes of SRC was consumed in power stations. Reasons for this decline are similar as for miscanthus (see previous paragraph).

Overall, success of lignocellulosic energy crops has been limited, particularly in the second phase of the ECS, and farmers have been hesitant to pick this up. There are different reasons: (1) lack of experience with these crops, (2) hesitation to make a long term commitment for 20 year crops, as opposed to annual crops, (3) uncertainty of prices and end use markets.

Sweden[32]

In the first half of the 1990s, willow plantations increased in Sweden, powered by subsidies and positive market prospects. Nearly 1200 Swedish farmers established willow plantations, covering some 15000 hectares. A specific set-aside hectare subsidy was introduced for willow planting in 1991 when the income from cereals was low; at the same time, the infrastructure was developed. Also new or improved

[31] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/483812/nonfood-statsnotice2014-10dec15.pdf
[32] Derived from http://stud.epsilon.slu.se/2914/1/ariasnavarro_c_110623.pdf

machinery for planting and harvesting became accessible. In 1996, as a result of the inclusion of Sweden in the EU, the Common Agricultural Policy (CAP) program reduced the compulsory “set aside” area and the planting subsidy was reduced to a third of its previous amount. It signalled a turning point in the development of willow. The annual planting rate dropped from 2000 hectares to 200 hectares in only one year. Many farmers and small contractors lost interest in willow crops.

After that year, the subsidy for the establishment of willow plantations was raised again. The total area planted in Sweden was more or less constant because several plantations that were poorly established in the 1990s were removed at the same rate that new plantations were established. The price for willow wood chips in Sweden has increased but some farmers keep their negative view of willow.

About 16000 hectares of SRC willow are being cultivated in Sweden; around 500 hectares are added every year in the form of new plantations (Swedish Board of Agriculture’s statistics, 2009). The crop is commercially grown, for the most part on agricultural land, and the biomass created is used in district heating plants for combined heat and power production. Every winter SRC willow is harvested from approx. 2500 hectares for delivery to around 25 heating / power plants in central and southern Sweden.

Today the majority of willow plantations in Sweden are established on private farms, but administrated by the Federation of the Swedish Farmers Coops, and managed by Lantmännen Agroenergi AB who is located in central Sweden. Lantmännen Agroenergi has contracts with 1250 willow growers, and liaises with processors and utilities to guarantee a proper handling of the crop. The organization takes care of the harvest and delivery of wood chips to nearby district heating plants.

The expansion of willow can be promoted by the establishment of long-term contracts between district-heating companies and farmers. It can contribute to the decrease of the risks taken by the farmer. This has been followed in Enköping, in central Sweden. The model is based on agreements between the main actors involved in the biomass supply and demand. The agreements include the obligation of the CHP plant to buy the harvested willow at the current market price, and the farmer has to sell their willow chips to the plant. Furthermore, the CHP is encouraged to recycle the wood ash back to the plantation.

Spain

Lignocellulosic crops were supported through higher subsidies for the power sector for this source compared to biomass residues. The main crops are triticale as herbaceous material and poplar as woody. In 2014, once the Spanish government abolished the difference in subsidies, the main companies who were purchasing these crops changed their strategy since the cost of biomass residues is lower (at the

same subsidy level). Therefore, poplar plantations for energy use are being removed and the triticale cultivation decreased.[33]

Conclusions

So far, the introduction of lignocellulosic crops has been limited, and there is even a downward – or at best stagnating - trend in the past years. Some countries have had active support measures, mostly covering different parts of the chain, both on supply and demand side, i.e. subsidies for growing energy crops, setting up supply chains, and support for energy production facilities.

Various reasons can be indicated:

- Compared to other biomass types, particularly residues, energy crops are much more expensive.
- In general, support systems for bioenergy are under pressure, particularly with current low fuel prices, and dropping prices for other renewable energy types (PV, wind).
- This creates market uncertainties for farmers to grow these types of crops, particularly because they commit to a long period as these crops are planted for 20 years or more, and because farmers experience with these crops is still limited.

The Swedish example shows that at least attention should be given to organizing the supply chains. A central organization or cooperation to manage the interests of all farmers helps in their negotiation position. Moreover, long-term off-take agreements are needed to reduce the risks for farmers.

Uptake of lignocellulosic crops in Europe is limited and even declining (or stagnating at most).

Support measures should be applied at supply (push) and demand side (pull), and through setting up collection systems.

A central organization or cooperation to manage the interests of all farmers helps in their negotiation position.

Growers have to make long commitments (>20 year crops), and therefore need certainty. Risks should be reduced, e.g. through long term off-take agreements. Changing policies are detrimental for the sectors confidence.

[33] Personal communication from CIRCE

4.6 Case 6: Advanced biofuels

The Renewable Energy Directive (2009/28/EC) defines that *biofuels made from wastes, residues, non-food cellulosic material, and ligno-cellulosic material* can be counted double towards the target of renewable energy in transport. These biofuels are generally called '**advanced biofuels**'. There are no specific data in Eurostat on advanced biofuels in relation to other transport biofuels. Therefore data has been searched in progress reports of the European Member States[34] to draw general conclusions.

Highly relevant performance criteria

- Liquid biofuels consumption
  - **Share of advanced biofuels**
- (Advanced) biofuels production capacity
- Wood processing and pulp & paper industry turnover (residues)

Based on the latest progress reports, the amount of conventional biofuels in 2014 in EU28 is estimated at 14 Mtoe, while advanced biofuels reached 2.6 Mtoe. However, only 10 countries reported substantial volumes of advanced biofuels in 2014:

Table 31: amounts of advanced biofuels reported by European member states

kTOE	2010	2012	2014	total biofuels (in 2014)	Share of advanced biofuels in total
United Kingdom	298	441	616	1179	52%
Germany	-	392	518	3041	17%
Finland	-	105	417[35]	517	80%
Sweden	55	183	413	1120	37%
Netherlands	85	194	213	586	36%
Italy	38	340	185	1310	14%
France	63	125	134	3340	4%
Ireland	25	56	77	117	66%
Luxembourg	-	-	41	71	58%
Greece	12	24	30	37	81%

The difference in amounts of biofuels per country depends on how the double counting mechanism for advanced biofuels, as foreseen in the Renewable Energy Directive of 2009, was implemented in the different countries.

[34] https://ec.europa.eu/energy/en/topics/renewable-energy/progress-reports
[35] Finland did not report figures of advanced biofuels in its latest progress report. Figures are estimated from http://www.biofuelstp.eu/factsheets/CountryFactsheets/EBTP_Factsheet_Finland_250416.pdf

Countries like the UK, the Netherlands, Finland, Ireland and Luxembourg put a clear focus on double counting biofuels, filling more than one third of their biofuels target with these types of biofuels. Some are clearly relying on EU and international markets for acquiring the necessary feedstock. Other countries generally produce from domestic feedstocks.

While the double counting mechanism was intended to promote advanced and technically challenging biofuels, it has merely incentivised the use of biodiesel from used cooking oil and animal fats, a relatively mature and inexpensive biofuel in relation to other biofuels. The majority of double counted biofuels in the EU are produced from **used cooking oil or animal fat**. These can be fed into normal biodiesel facilities with existing pre-treatment technology which does not incur significant cost compared to virgin oil. For market parties this was a very cost-effective way to reach their obligations or take advantage of extra incentives, but it hardly contributed to technological advances.[36] Moreover it actually led to lower volumes of biofuel, as mandates could be fulfilled with lower amounts of biofuel, so less fossil fuel was displaced. It should also be considered that UCO and AF potential is limited; a rough estimate is that around 1% of transport fuel consumption could be produced through these sources if based on domestic resources. So countries going above this, clearly rely on EU and international markets for acquiring their feedstock, while other countries (which may less favourable policies) may be deprived from an interesting feedstock option for their own market. Harmonized measures in biofuel policies and consistent definitions across Member States are needed to avoid market distortions and trade inefficiencies.

More specific promotion mechanisms will be needed to achieve advancement in real advanced biofuels. In particular Finland and Sweden reached significant amounts of (non-UCO) advanced biofuels. Finland even increased its target of renewable energy in transport to 20% (instead of 10%, of course taking into account that most of its biofuels will be double counted), with a prospective target of 40% in 2030.

Following the adoption of amendments in the Renewable Energy Directive and Fuel Quality Directive (through the 2015 iLUC Directive), Member States will have to set non-binding national targets for advanced biofuels (excluding used cooking oils and fats).

Production facilities

Despite the important and continuous progress during the past 5 years, including the opening of commercial production facilities, the development of large-scale production capacity for advanced biofuels in the EU is still slow. It was hampered by technological challenges, feedstock availability, financing and political uncertainty. The most viable business model will in most cases be based on an integrated

[36] http://task40.ieabioenergy.com/wp-content/uploads/2013/09/t40-low-iluc-UCO-august-2014.pdf

biorefinery approach that produces both biofuels and a range of other bio-based products.[37] A number of EU production facilities have already been producing advanced biofuels since 2009, often in conjunction with other bio-based products.

Hydrogenated vegetable oils (HVO) can supply specific fuel markets such as aviation, and produce drop-in biofuels for diesel vehicles, but are not necessarily produced from non-food feedstocks, or also depend on the (limited) basket of used cooking oils and animal fats. The production of HVO fuels has taken off in Finland, the Netherlands, Spain and Italy, with further installations expected to come on-line in Italy and France in 2017.

Other advanced biofuel production plants/initiatives[38] are biodiesel from tall oil in Finland (UPM), methanol from glycerine in the Netherlands (BioMCN), ethanol from straw in Denmark (Inbicon), ethanol from straw and energy crops in Italy (Beta Renewables), ethanol from sawdust in Finland (St1 Biofuels), bio-DME in Sweden (Chemrec), … Some of these may already have halted or paused their initiatives.

When looking at the location of these projects, they are mostly connected to feedstock availability, which are mostly industrial residues, and in some cases also agricultural residues and crops. For now, production is focused to be used in national markets, but considering the companies that have invested in these first commercial plants, many are international players which look further than national markets. Support is mostly European based, possibly connected with some national support.

Some EU countries have actively implemented the double counting mechanism for advanced biofuels, but this has merely incentivised the use of biodiesel from used cooking oil and animal fats, a relatively mature and inexpensive biofuel in relation to other advanced biofuels.

Specific targets and incentives for advanced biofuels are needed.

Advanced biofuel projects are mostly connected to feedstock availability - mostly industrial residues, and in some cases also agricultural residues and crops.

The most viable business model for advanced biofuels will in most cases be based on an integrated biorefinery approach that produces both biofuels and a range of other bio-based products.

Companies investing in these technologies generally look further than national markets.

[37] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52015SC0117&rid=2
[38] http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biofuels%20Annual_The%20Hague_EU-28_6-29-2016.pdf

In the next section we will look into bio-methane, which can also be considered as advanced biofuel when produced from waste and residues.

4.7 Case 7: Biomethane as transport fuel (Germany, Sweden, Italy)

In this case we focus on biomethane as transport fuel. The traditional way to produce biomethane is from biogas, which is produced by anaerobic digestion of organic resources (e.g. organic waste, manure, sewage sludge …). Biogas contains roughly 65-70% methane (CH_4) and 30-35% carbon dioxide (CO_2) and a small amount of other gaseous impurities. After removal of the CO_2, and other impurities, biomethane is left over and has the same properties as natural gas. It can be used as a transport fuel in the form of Compressed Natural Gas (CNG) or Liquid Natural Gas (LNG).

In terms of lignocellulosic biomass, the roll-out of biomethane can be extended to the deployment of SNG, i.e. synthetic natural gas, obtained after biomass gasification and subsequent methane synthesis.

We used **Error! Reference source not found.** and Table 24 to identify the most relevant performance criteria and indicators for this case study. According to the Tables, the following performance criteria and indicators are selected as the most relevant.

Highly relevant performance criteria

- **Biogas production**
- Biomethane production (biogas upgrading)
- MSW treatment: composting/digestion
- Biogas consumption
- **Share of natural gas in transport**
- Number of natural gas refilling stations
- Types of solid biofuels (for gasification projects in future)

Highly relevant country indicators

- Agriculture:
  - Arable land
  - Livestock density (LSU)
  - Yields (for agricultural residues)
- GDP & trade:
  - GDP per capita
- Energy:
  - Energy consumption
  - Energy dependency

According to EBA 'The number of biomethane filling stations doubled in 2013 with 10% of the total produced biomethane in Europe now used in transport'. Their statistics show that Germany and Sweden are frontrunner when it comes to biomethane production plants.

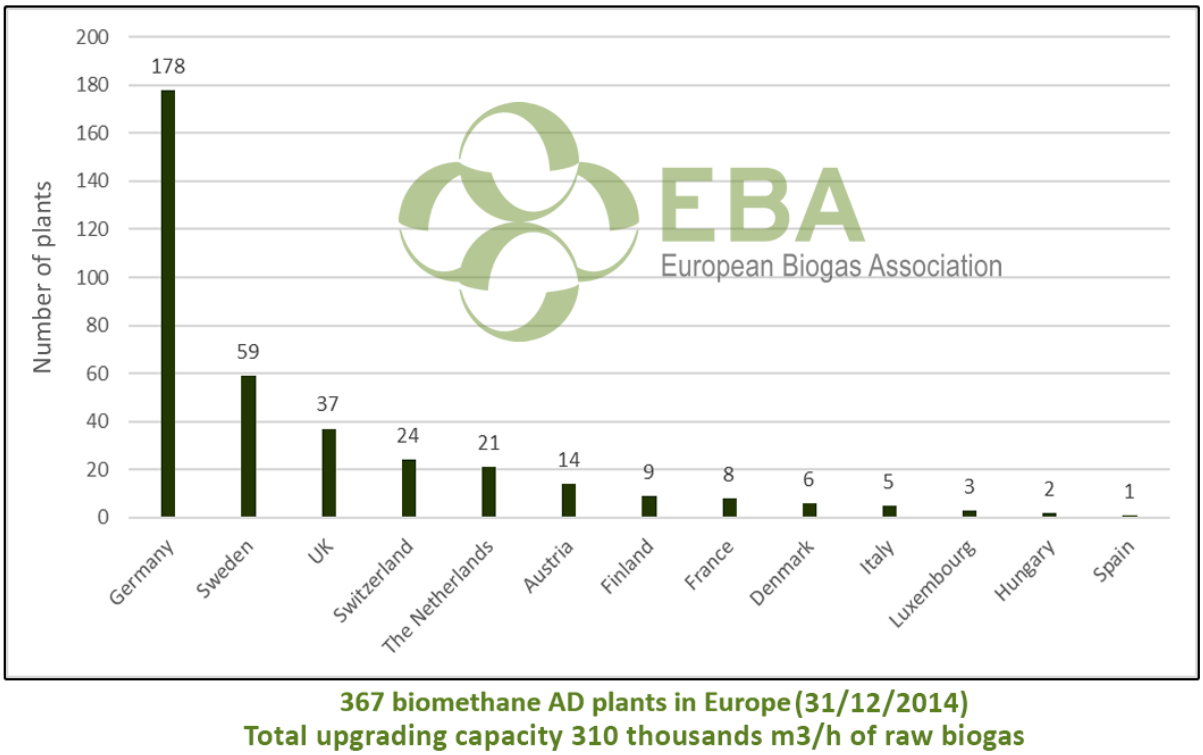

Figure 20: Number of biomethane production plants (source: EBA 2015)

The forerunner in biomethane, with 75% of biomethane production in Europe, is **Germany** where ambitious targets and implementation of legal frameworks, like the Renewable Energy Act (EEG), have spurred production. In 2014 there were 178 biomethane plants in Germany. Most is injected into the grid and mixed with natural gas for electricity generation and heating purposes. There are currently 165 fuelling stations that offer biomethane for vehicles in the country (EBA, 2015). Since the 2014 EEG reform removed bonuses for biomethane used for electricity generation, it is likely that the growth in the transport sector will continue.[39]

Despite its small size in terms of gas consumption, **Sweden** has placed itself as the European front runner in biomethane production and especially the use of biomethane in transport: the country dedicated 78% of its production to fuel almost 50,000 vehicles. Sweden counts 218 refuelling stations offering biomethane. The country uses exclusively waste for biomethane production, 52% coming from organic residues and 48% from sewage sludge. The country has rapidly increased the use of biomethane in transport through exemptions from CO_2 and energy taxes. (EBA 2016)

[39] http://european-biogas.eu/wp-content/uploads/2016/05/BiomethInTransport.pdf

Italy so far had limited deployment of biomethane plants (5 up to 2014), but potential of biomethane in transport is very high. Italy is the 2nd biggest biogas producer in Europe and is by far the European leader of natural gas-powered transport with almost 900,000 vehicles (77% of the natural gas fleet in Europe) and more than 1100 natural gas filling stations[40]. The amount of natural gas fuel stations will grow with the implementation of the European Directive on Alternative Fuel Infrastructure (Dir. 2014/94/EU). In the past, the country had generous tariffs for biogas fuelled power plants; however, since December 2013 biomethane incentives have become more attractive. Italy is developing an obligation scheme for biomethane in transport consistent and complimentary with the blending scheme for liquid biofuels. Biomethane (from waste and residues) will be part of the Italian subtarget in advanced biofuels. The Italian use of biomethane in transport is expected to grow to 650 million m³ by 2020.

The use of biomethane for transport was in the focus of numerous EU supported projects[41] with a focus on demonstration and market introduction. Additionally the **Green Gas Initiative** (GGI)[42] is a partnership of seven independent gas infrastructure operators; Energinet.dk (Denmark), Fluxys Belgium, Gasunie (the Netherlands), Gaznat (Switzerland), GRT gaz (France), ONTRAS (Germany) and Swedegas (Sweden), committing themselves in supporting 100% carbon-neutral gas supply by 2050. One of the specific ambitions of the initiative is boosting biomethane as biofuel for road transport.

The Swedish gas operator Swedegas has benefited from the cooperation possibilities within the GGI. The experiences gained have been fed into prioritized projects for Swedegas, such as the development of a **national strategy for biogas and power to gas**. As a result of years of work together with different stakeholders, biomethane use is steadily increasing in Sweden. In 2015, injection of biomethane in the grids of transmission system operators (TSO) and distribution system operators (DSO) in south-west Sweden increased 60% compared to 2014 (to 497 GWh in 2015, up from 306 GWh in 2014, upper heating value). This development of increased injection into the grid will continue and shows that cooperation with several partners, both nationally and on a European level, is crucial.

While so far most evolutions in transport have been on CNG (compressed natural gas), supply in liquid form (LNG), particularly for heavy duty vehicles is gaining momentum.

[40] http://www.ieabioenergy.com/wp-content/uploads/2016/05/P14-The-potential-role-of-biomethane-in-Italian-transport-Perella.pdf
[41] BIOMASTER, MADEGASCAR, GasHighWay, BioGas Max, Urban Biogas, Green Gas Grids and Baltic Biogas Bus (Source: EBA).
[42] http://www.greengasinitiative.eu/

Lessons and conclusions

Next to biodiesel (for diesel vehicles) and bio-ethanol (for gasoline vehicles), biomethane (for natural gas vehicles) has reached substantial implementation levels as biofuel in some countries, in particular Sweden and Germany. Nevertheless many countries have hardly considered this biofuel option up to now. Most biomethane is produced from waste and residues, so it can be considered an 'advanced biofuel', as part of the specific subtarget suggested by the European iLUC Directive.

The further deployment of biomethane in transport clearly depends on the further deployment of natural gas vehicles and natural gas refuelling infrastructure. In fact, deployment of natural gas refuelling infrastructure is one of the aims of the European Alternative Fuels Infrastructure Directive[43].

Using the natural gas grid as a buffer creates flexibility, as the physical connection between biomethane production and use is decoupled, so a chicken and egg situation can be avoided. Mind that production cost of biomethane is higher than natural gas, so specific incentives like mandates or CO2/energy tax exemptions are needed. When using the grid, this also implies the use of certificates of origin, or specific 'green gas certificates', which can be similar to the way green electricity is treated in electricity markets.

Mind that the final use of biomethane (towards electricity, heat, transport fuel or even as raw material for the chemical industry) depends on the paying capacity in those markets, which is influenced by specific incentives. We have seen in the past years that changes in incentives (e.g. lower support for renewable electricity) have a clear impact on the final use of biomethane. So it should be considered which applications provide most added value for society.

The deployment of upgraded biogas (from anaerobic digestion) is paving the way for future use of SNG (gasification and methanation of lignocellulose material) or power to gas.

[43] Directive 2014/94/EU on the deployment of alternative fuels infrastructure.

Biomethane is mostly produced from waste and residues, so can be considered an advanced biofuel for transport. However, so far only few countries have considered it as transport biofuel.

The potential for biomethane in transport depends on the outroll of natural gas vehicles and refueling infrastructure.

Using the natural gas grid creates flexibility between production and use. A system of 'green gas certificates' would aid biomethane deployment through the natural gas grid.

Incentives (like carbon tax exemption) are necessary as (fossil) natural gas remains cheap. However, incentives also steer the final use of biomethane. It should be considered which applications of biogas/biomethane provide most added value for society.

5 General conclusions

All 37 different countries considered in S2Biom (*i.e.* EU28, Western Balkans, Moldova, Turkey and Ukraine) have been covered in this benchmark analysis.

Countries/regions have different specific backgrounds and certain policy approaches may only be successful in a specific context. We therefore clustered countries in groups with comparable background. Mind that countries are not uniform, regions within a country can have different characteristics. So lessons from e.g. forest based countries may also be applicable for forest based regions, even if the country as a whole is less forestry based. In order to cluster the countries, indicators were selected and data was gathered, mostly from Eurostat. Further, the indicators were scored based on a reference value (*i.e.* EU28 average), and similarities between countries were defined. Clustering was done according to population density and land surface, GDP and importance of trade and agriculture vs forest oriented countries. Specific further clustering, e.g. according to yields, or livestock density could also be done.

To benchmark the performance and impact of national policies we different performance criteria. These performance criteria are mainly linked to the usage of specific types of biomass and the mobilization of the biomass (*i.e.* the amount of biomass used in relation to its potential and sustainable resource management) and to the structure of the value chain (*i.e.* resource efficiency and the link between material and energy use).

For a number of representative cases the performance criteria are linked to the policy frameworks. The cases were: mobilizing forest based feedstocks for use in energy and materials, forest biomass based (district) heating, straw based district heating, large scale biomass imports (incl. sustainability criteria), support for energy crops, mechanisms for supporting advanced biofuels, and introducing bio-methane as transport fuel. For each of the cases, some of the best performing countries were discussed, together with their policy framework. The following conclusions were drawn for the different cases:

Mobilizing forest-based feedstocks for materials and energy (FI, SE):

- Support for biomass has remained relatively stable over time in Sweden and Finland, despite changing political forces.
- In both countries a National Forest Programme is formulated which can provide a stable, long-term policy with a clear ambition to boost the bioeconomy (incl. industry);
- Principles of sustainable forest management and advising private forest owners can be an example for other countries.

Forest-based (district) heating (SE)

- Link with the natural gas network: in Sweden, district heating grids were developed before the introduction of a natural gas grid.
- Municipalities are key in developing district heating networks.
- Introduction of a fossil fuel tax boosted the use of renewable energy.

Straw-based district heating (DK):

- The long term commitment to move away from fossil fuels, the political prioritization of biomass use and the introduction of a fossil fuel tax was key in the development of (largely biomass based) district heating systems in Denmark.
- Danish goals for the use of straw over the past 20 years have led to a well-developed supply chain.
- Lessons can be learned from the heat supply law with clear steps to follow when developing a district heating network, and an important role of municipalities in the process.
- The cost and reliability of the system is key in convincing the general public and is secured by policy actions (e.g. non-profit law).

Large scale biomass imports (UK, BE, NL, DK):

- Countries with high population density, low domestic resources and high trade orientation logically include biomass imports for renewable energy.
- Sustainability requirements have emerged in these countries – it would be most efficient to have common requirements at EU level to avoid trade barriers.
- Trade is mostly linked to larger scale installations (co-firing or dedicated biomass plants). Large scale installations often produce electricity only. Countries should move towards higher use of residual heat, but should already start this process for fossil power plants.

Energy crops (UK, SE, ES):

- Uptake of lignocellulosic crops in Europe is limited and even declining (or stagnating at most).
- Support measures should be applied at supply (push) and demand side (pull), and through setting up collection systems.
- A central organization or cooperation to manage the interests of all farmers helps in their negotiation position.
- Growers have to make long commitments (>20 year crops), and therefore need certainty. Risks should be reduced, e.g. through long term off-take agreements. Changing policies are detrimental for the sectors confidence.

Advanced biofuels:

- Some EU countries have actively implemented the double counting mechanism for advanced biofuels, but this has merely incentivised the use of biodiesel from

used cooking oil and animal fats, a relatively mature and inexpensive biofuel in relation to other advanced biofuels.
- Specific targets and incentives for advanced biofuels are needed.
- Advanced biofuel projects are mostly connected to feedstock availability - mostly industrial residues, and in some cases also agricultural residues and crops.
- The most viable business model for advanced biofuels will in most cases be based on an integrated biorefinery approach that produces both biofuels and a range of other bio-based products.
- Companies investing in these technologies generally look further than national markets.

Biomethane in transport (SE, DE):

- Biomethane is mostly produced from waste and residues so can be considered an advanced biofuel for transport. However, so far only few countries have considered it as transport biofuel.
- The potential for biomethane in transport depends on the deployment of natural gas vehicles and refuelling infrastructure.
- Using the natural gas grid creates flexibility between production and use. A system of 'green gas certificates' would aid biomethane deployment through the natural gas grid.
- Incentives like carbon tax exemption are necessary as (fossil) natural gas remains cheap. However, incentives also steer the final use of biomethane. It should be considered which applications of biogas/biomethane provide most added value for society.

The outcomes of this report will be further used to derive policy conclusions and recommendations in Deliverables D6.3 and D8.2.

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Annex : country factsheets

Albania

Category	Albania	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	2.898.782	18.040.258	n° 2013		ES, FR, TK, CY, SI, MD, SR, AT, HU
Area	28.750	160.518	km²		
Population density	101	168	n°/km²	Medium	
Land area	0,99	1,42	ha/capita	Medium	
2. GDP and trade					
GDP/capita	3	25	€ 1.000	Low	KS, BA, FYR
	28	100	PPS	Low	
Cross-border movements	0,60	6,87	€1000/capita	Low	
3. Energy					
Primary energy consumption	0,70	3,22	toe/capita (2012)	Low	ME
Energy dependence	25,1	55,4	%	Low	
Renewable energy share	28,4	17,9	%	High	
GHG emissions	2,76	9,47	ton CO_2-eq/capita	Low	
4. Agriculture					
UAA	0,411	0,415	ha/capita	Medium	BA, UA
Cereal yield	4,61	5,20	t/ha	Medium	
Livestock density	na	1,020	LSU/ha UAA		
5. Forestry					
Forest area	0,280	0,650	ha/capita	Medium	CY
Forest increment	0,29	5,47	m³/ha	Low	
	0,08	2,80	m³/capita (2010)	Low	
6. Waste					
Total municipal waste	359	464	kg/capita/year	Low	LV
Landfill	335	185	kg/capita/year	High	
Incineration	0	104	kg/capita/year	Low	
Recycling	144	104	kg/capita/year	High	
Composting/digestion	0	57	kg/capita/year	Low	
7. Industry (turnover)					
Wood and paper products	na	854	€/capita		/
Food products	na	1.684	€/capita		
Chemical products	na	883	€/capita		
8. Renewable energy (RE)					
Bioenergy in RE	25%	69%	%	Low	ES
Bioenergy in total energy	10,0%	10,6%	%	Medium	
9. Energy infrastructure					
Biofuels prod. capacity	0,000	0,051	ton/capita	Low	
CHP	na	17,3%	% gross electricity generation		
District heating	0	7.404	km		
	0,0	0,3	m/capita	Low	

Austria

Category	Austria	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	8.451.860	18.040.258	n° 2013		ES, FR, TK, CY, SI, AL, MD, SR, HU
Area	83.879	160.518	km²		
Population density	101	168	n°/km²	Medium	
Land area	0,99	1,42	ha/capita	Medium	
2. GDP and trade					
GDP/capita	37	25	€ 1.000	High	FI, DE, IE
	128	100	PPS	High	
Cross-border movements	8,49	6,87	€1000/capita	Medium	
3. Energy					
Primary energy consumption	3,77	3,22	toe/capita (2012)	High	DE, FI
Energy dependence	62,3	55,4	%	Medium	
Renewable energy share	32,6	17,9	%	High	
GHG emissions	9,52	9,47	ton CO_2-eq/capita	Medium	
4. Agriculture					
UAA	0,339	0,415	ha/capita	Medium	CZ, HR, UK
Cereal yield	5,85	5,20	t/ha	Medium	
Livestock density	0,852	1,020	LSU/ha UAA	Medium	
5. Forestry					
Forest area	0,465	0,650	ha/capita	Medium	SK
Forest increment	6,45	5,47	m³/ha	Medium	
	3,01	2,80	m³/capita (2010)	Medium	
6. Waste					
Total municipal waste	578	464	kg/capita/year	High	NL
Landfill	23	185	kg/capita/year	Low	
Incineration	202	104	kg/capita/year	High	
Recycling	142	104	kg/capita/year	High	
Composting/digestion	192	57	kg/capita/year	High	
7. Industry (turnover)					
Wood and paper products	2.030	854	€/capita	High	ES, FI, SE
Food products	1.940	1.684	€/capita	Medium	
Chemical products	1.690	883	€/capita	High	
8. Renewable energy (RE)					
Bioenergy in RE	59%	69%	%	Medium	DK, SE
Bioenergy in total energy	18,5%	10,6%	%	High	
9. Energy infrastructure					
Biofuels prod. Capacity	0,099	0,051	ton/capita	High	
CHP	14,4%	17,3%	% gross electricity generation	Medium	
District heating	4.918	7.404	km		
	0,6	0,3	m/capita	High	

Belgium

Category	Belgium	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	11.161.642	18.040.258	n° 2013		NL
Area	30.528	160.518	km²		
Population density	366	168	n°/km²	High	
Land area	0,27	1,42	ha/capita	Low	
2. GDP and trade					
GDP/capita	34	25	€ 1.000	High	NL
	119	100	PPS	High	
Cross-border movements	19,67	6,87	€1000/capita	High	
3. Energy					
Primary energy consumption	4,25	3,22	toe/capita (2012)	High	LU
Energy dependence	77,5	55,4	%	High	
Renewable energy share	7,9	17,9	%	Low	
GHG emissions	10,50	9,47	ton CO_2-eq/capita	Medium	
4. Agriculture					
UAA	0,120	0,415	ha/capita	Low	NL
Cereal yield	9,21	5,20	t/ha	High	
Livestock density	2,838	1,020	LSU/ha UAA	High	
5. Forestry					
Forest area	0,062	0,650	ha/capita	Low	NL, UK
Forest increment	6,78	5,47	m³/ha	Medium	
	0,43	2,80	m³/capita (2010)	Low	
6. Waste					
Total municipal waste	437	464	kg/capita/year	Medium	DE, NL, SE
Landfill	4	185	kg/capita/year	Low	
Incineration	195	104	kg/capita/year	High	
Recycling	151	104	kg/capita/year	High	
Composting/digestion	91	57	kg/capita/year	High	
7. Industry (turnover)					
Wood and paper products	787	854	€/capita	Medium	DE, NL
Food products	3.680	1.684	€/capita	High	
Chemical products	3.366	883	€/capita	High	
8. Renewable energy (RE)					
Bioenergy in RE	83%	69%	%	High	DE, HU, NL, SK
Bioenergy in total energy	6,1%	10,6%	%	Medium	
9. Energy infrastructure					
Biofuels prod. Capacity	0,099	0,051	ton/capita	High	
CHP	15,2%	17,3%	% gross electricity generation	Medium	
District heating	na	7.404	km		
	0,0	0,3	m/capita	Low	

Bosnia & Herzegovina

Category	Bosnia and Herzegovina	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	3.835.645	18.040.258	n° 2013		RO, UA, FYR, IE, BG, EL
Area	51.209	160.518	km²		
Population density	75	168	n°/km²	Medium	
Land area	1,34	1,42	ha/capita	Medium	
2. GDP and trade					
GDP/capita	4	25	€ 1.000	Low	FYR, KS, AL, SR, UA, MD
	29	100	PPS	Low	
Cross-border movements	1,11	6,87	€1000/capita	Low	
3. Energy					
Primary energy consumption	1,98	3,22	toe/capita (2012)	Low	RO
Energy dependence	29,8	55,4	%	Low	
Renewable energy share	19,1	17,9	%	Medium	
GHG emissions	5,62	9,47	ton CO_2-eq/capita	Low	
4. Agriculture					
UAA	0,435	0,415	ha/capita	Medium	AL, UA
Cereal yield	4,17	5,20	t/ha	Medium	
Livestock density	0,479	1,020	LSU/ha UAA	Low	
5. Forestry					
Forest area	0,570	0,650	ha/capita	Medium	BG
Forest increment	2,51	5,47	m³/ha	Low	
	1,43	2,80	m³/capita (2010)	Low	
6. Waste					
Total municipal waste	311	464	kg/capita/year	Low	FYR, SR, UA
Landfill	234	185	kg/capita/year	Medium	
Incineration	0	104	kg/capita/year	Low	
Recycling	0	104	kg/capita/year	Low	
Composting/digestion	0	57	kg/capita/year	Low	
7. Industry (turnover)					
Wood and paper products	0	854	€/capita		/
Food products	na	1.684	€/capita		
Chemical products	na	883	€/capita		
8. Renewable energy (RE)					
Bioenergy in RE	22%	69%	%	Low	CY
Bioenergy in total energy	2,4%	10,6%	%	Low	
9. Energy infrastructure					
Biofuels prod. Capacity	0,000	0,051	ton/capita	Low	
CHP	1,2%	17,3%	% gross electricity generation	Low	
District heating	0	7.404	km		
	0,0	0,2	m/capita	Low	

Bulgaria

Category	Bulgaria	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	7.284.552	18.040.258	n° 2013		RO, UA, FYR, BA, IE, EL
Area	110.900	160.518	km²		
Population density	66	168	n°/km²	Low	
Land area	1,52	1,42	ha/capita	Medium	
2. GDP and trade					
GDP/capita	5	25	€ 1.000	Low	ME, SR
	45	100	PPS	Low	
Cross-border movements	2,65	6,87	€1000/capita	Low	
3. Energy					
Primary energy consumption	2,24	3,22	toe/capita (2012)	Medium	ES, FR, PL, SI, SK, ME
Energy dependence	37,8	55,4	%	Medium	
Renewable energy share	19	17,9	%	Medium	
GHG emissions	8,33	9,47	ton CO_2-eq/capita	Medium	
4. Agriculture					
UAA	0,686	0,415	ha/capita	High	EE, HU, RO, UA
Cereal yield	4,56	5,20	t/ha	Medium	
Livestock density	0,205	1,020	LSU/ha UAA	Low	
5. Forestry					
Forest area	0,531	0,650	ha/capita	Medium	BA, FYR
Forest increment	3,56	5,47	m³/ha	Low	
	1,93	2,80	m³/capita (2010)	Medium	
6. Waste					
Total municipal waste	432	464	kg/capita/year	Medium	CZ, ES, PL
Landfill	298	185	kg/capita/year	High	
Incineration	7	104	kg/capita/year	Low	
Recycling	108	104	kg/capita/year	Medium	
Composting/digestion	15	57	kg/capita/year	Low	
7. Industry (turnover)					
Wood and paper products	150	854	€/capita	Low	HU, RO
Food products	548	1.684	€/capita	Low	
Chemical products	177	883	€/capita	Low	
8. Renewable energy (RE)					
Bioenergy in RE	65%	69%	%	Medium	FR, SI
Bioenergy in total energy	7,3%	10,6%	%	Medium	
9. Energy infrastructure					
Biofuels prod. Capacity	0,012	0,051	ton/capita	Low	
CHP	8,5%	17,3%	% gross electricity generation	Low	
District heating	1.566	7.404	km		
	0,2	0,3	m/capita	medium	

Croatia

Category	Croatia	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	4.262.140	18.040.258	n° 2013		ME, LT, EE, LV
Area	87.661	160.518	km²		
Population density	49	168	n°/km²	Low	
Land area	2,06	1,42	ha/capita	High	
2. GDP and trade					
GDP/capita	10	25	€ 1.000	Low	PT, TK, HU, LV, (RO)
	61	100	PPS	Low	
Cross-border movements	2,14	6,87	€1000/capita	Low	
3. Energy					
Primary energy consumption	1,71	3,22	toe/capita (2012)	Low	EL, HU, FYR
Energy dependence	52,3	55,4	%	Medium	
Renewable energy share	18	17,9	%	Medium	
GHG emissions	6,18	9,47	ton CO_2-eq/capita	Low	
4. Agriculture					
UAA	0,305	0,415	ha/capita	Medium	CZ, AT, SE, UK
Cereal yield	5,60	5,20	t/ha	Medium	
Livestock density	0,784	1,020	LSU/ha UAA	Medium	
5. Forestry					
Forest area	0,706	0,650	ha/capita	High	PT, RO
Forest increment	4,23	5,47	m³/ha	Medium	
	1,89	2,80	m³/capita (2010)	Medium	
6. Waste					
Total municipal waste	404	464	kg/capita/year	Medium	EL
Landfill	332	185	kg/capita/year	High	
Incineration	0	104	kg/capita/year	Low	
Recycling	54	104	kg/capita/year	Low	
Composting/digestion	7	57	kg/capita/year	Low	
7. Industry (turnover)					
Wood and paper products	316	854	€/capita	Medium	EL
Food products	1.039	1.684	€/capita	Medium	
Chemical products	185	883	€/capita	Low	
8. Renewable energy (RE)					
Bioenergy in RE	62%	69%	%	Medium	DK
Bioenergy in total energy	17,7%	10,6%	%	High	
9. Energy infrastructure					
Biofuels prod. Capacity	0,016	0,051	ton/capita	Low	
CHP	12,6%	17,3%	% gross electricity generation	Medium	
District heating	410	7.404	km		
	0,1	0,3	m/capita	Low	

Cyprus

Category	Cyprus	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	865.878	18.040.258	n° 2013		ES, FR, TK, SI, AL, MD, SR, AT, HU
Area	9.251	160.518	km²		
Population density	94	168	n°/km²	Medium	
Land area	1,07	1,42	ha/capita	Medium	
2. GDP and trade					
GDP/capita	19	25	€ 1.000	Medium	EL, PT, (ES)
	89	100	PPS	Medium	
Cross-border movements	2,36	6,87	€1000/capita	Low	
3. Energy					
Primary energy consumption	2,54	3,22	toe/capita (2012)	Medium	IE, IT
Energy dependence	96,4	55,4	%	High	
Renewable energy share	8,1	17,9	%	Low	
GHG emissions	10,74	9,47	ton CO_2-eq/capita	Medium	
4. Agriculture					
UAA	0,103	0,415	ha/capita	Low	/
Cereal yield	1,69	5,20	t/ha	Low	
Livestock density	1,961	1,020	LSU/ha UAA	High	
5. Forestry					
Forest area	0,200	0,650	ha/capita	Medium	AL
Forest increment	0,12	5,47	m³/ha	Low	
	0,06	2,80	m³/capita (2010)	Low	
6. Waste					
Total municipal waste	629	464	kg/capita/year	High	EL, MT
Landfill	491	185	kg/capita/year	High	
Incineration	0	104	kg/capita/year	Low	
Recycling	77	104	kg/capita/year	Medium	
Composting/digestion	57	57	kg/capita/year	Medium	
7. Industry (turnover)					
Wood and paper products	160	854	€/capita	Low	EL
Food products	1.376	1.684	€/capita	Medium	
Chemical products	87	883	€/capita	Low	
8. Renewable energy (RE)					
Bioenergy in RE	26%	69%	%	Low	BA
Bioenergy in total energy	1,6%	10,6%	%	Low	
9. Energy infrastructure					
Biofuels prod. Capacity	0,016	0,051	ton/capita	Low	
CHP	1,4%	17,3%	% gross electricity generation	Low	
District heating	na	7.404	km		
	0,0	0,3	m/capita	Low	

Czech Republic

Category	Czech Republic	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	10.516.125	18.040.258	n° 2013		PL, SK, DK, PT
Area	78.866	160.518	km²		
Population density	133	168	n°/km²	Medium	
Land area	0,75	1,42	ha/capita	Medium	
2. GDP and trade					
GDP/capita	14	25	€ 1.000	Medium	EE, SK
	82	100	PPS	Medium	
Cross-border movements	4,59	6,87	€1000/capita	Medium	
3. Energy					
Primary energy consumption	3,77	3,22	toe/capita (2012)	High	DE, NL, PL
Energy dependence	27,9	55,4	%	Low	
Renewable energy share	12,4	17,9	%	Medium	
GHG emissions	12,51	9,47	ton CO_2-eq/capita	High	
4. Agriculture					
UAA	0,335	0,415	ha/capita	Medium	EL, HR, AT, PT, SR
Cereal yield	5,32	5,20	t/ha	Medium	
Livestock density	0,491	1,020	LSU/ha UAA	Medium	
5. Forestry					
Forest area	0,259	0,650	ha/capita	Medium	IE, LU, PL, SK
Forest increment	7,69	5,47	m³/ha	High	
	1,96	2,80	m³/capita (2010)	Medium	
6. Waste					
Total municipal waste	307	464	kg/capita/year	Low	BG, ES, HU, PL
Landfill	173	185	kg/capita/year	Medium	
Incineration	60	104	kg/capita/year	Medium	
Recycling	65	104	kg/capita/year	Medium	
Composting/digestion	9	57	kg/capita/year	Low	
7. Industry (turnover)					
Wood and paper products	637	854	€/capita	Medium	LT, PT
Food products	1.086	1.684	€/capita	Medium	
Chemical products	628	883	€/capita	Medium	
8. Renewable energy (RE)					
Bioenergy in RE	88%	69%	%	High	EE, PL
Bioenergy in total energy	7,9%	10,6%	%	Medium	
9. Energy infrastructure					
Biofuels prod. Capacity	0,055	0,051	ton/capita	Medium	
CHP	13,7%	17,3%	% gross electricity generation	Medium	
District heating	7.738	7.404	km		
	0,7	0,3	m/capita	High	

Denmark

Category	Denmark	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	5.602.628	18.040.258	n° 2013		CZ, PL, SK, PT
Area	42.916	160.518	km²		
Population density	131	168	n°/km²	Medium	
Land area	0,77	1,42	ha/capita	Medium	
2. GDP and trade					
GDP/capita	44	25	€ 1.000	High	SE
	124	100	PPS	High	
Cross-border movements	9,31	6,87	€1000/capita	High	
3. Energy					
Primary energy consumption	3,18	3,22	toe/capita (2012)	Medium	EE, IE, UK
Energy dependence	12,3	55,4	%	Low	
Renewable energy share	27,2	17,9	%	High	
GHG emissions	9,25	9,47	ton CO_2-eq/capita	Medium	
4. Agriculture					
UAA	0,469	0,415	ha/capita	Medium	LU
Cereal yield	6,35	5,20	t/ha	High	
Livestock density	1,872	1,020	LSU/ha UAA	High	
5. Forestry					
Forest area	0,109	0,650	ha/capita	Low	DE
Forest increment	11,43	5,47	m³/ha	High	
	1,13	2,80	m³/capita (2010)	Medium	
6. Waste					
Total municipal waste	752	464	kg/capita/year	High	DE, LU
Landfill	12	185	kg/capita/year	Low	
Incineration	405	104	kg/capita/year	High	
Recycling	207	104	kg/capita/year	High	
Composting/digestion	124	57	kg/capita/year	High	
7. Industry (turnover)					
Wood and paper products	528	854	€/capita	Medium	IT
Food products	4.337	1.684	€/capita	High	
Chemical products	826	883	€/capita	Medium	
8. Renewable energy (RE)					
Bioenergy in RE	76%	69%	%	Medium	HR, AT
Bioenergy in total energy	18,6%	10,6%	%	High	
9. Energy infrastructure					
Biofuels prod. Capacity	0,021	0,051	ton/capita	Medium	
CHP	50,6%	17,3%	% gross electricity generation	High	
District heating	29.000	7.404	km		
	5,2	0,3	m/capita	high	

Estonia

Category	Estonia	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	1.320.174	18.040.258	n° 2013		ME, LT, EE, LV, HR
Area	45.227	160.518	km²		
Population density	29	168	n°/km²	Low	
Land area	3,43	1,42	ha/capita	High	
2. GDP and trade					
GDP/capita	14	25	€ 1.000	Medium	SK, CZ
	73	100	PPS	Medium	
Cross-border movements	4,59	6,87	€1000/capita	Medium	
3. Energy					
Primary energy consumption	4,92	3,22	toe/capita (2012)	High	DK, SI, SK
Energy dependence	11,9	55,4	%	Low	
Renewable energy share	25,6	17,9	%	High	
GHG emissions	14,48	9,47	ton CO_2-eq/capita	High	
4. Agriculture					
UAA	0,732	0,415	ha/capita	High	BG, LU, LT, RO, UA
Cereal yield	3,21	5,20	t/ha	Low	
Livestock density	0,321	1,020	LSU/ha UAA	Low	
5. Forestry					
Forest area	1,804	0,650	ha/capita	High	LV
Forest increment	5,24	5,47	m³/ha	Medium	
	8,64	2,80	m³/capita (2010)	High	
6. Waste					
Total municipal waste	293	464	kg/capita/year	Low	/
Landfill	40	185	kg/capita/year	Low	
Incineration	163	104	kg/capita/year	Medium	
Recycling	36	104	kg/capita/year	Low	
Composting/digestion	15	57	kg/capita/year	Low	
7. Industry (turnover)					
Wood and paper products	1.925	854	€/capita	High	LT
Food products	1.151	1.684	€/capita	Medium	
Chemical products	458	883	€/capita	Medium	
8. Renewable energy (RE)					
Bioenergy in RE	95%	69%	%	High	CZ, PL, KS
Bioenergy in total energy	12,4%	10,6%	%	Medium	
9. Energy infrastructure					
Biofuels	0,000	0,051	ton/capita	Low	
CHP	9,3%	17,3%	% gross electricity generation	Medium	
District heating	1.450	7.404	km		
	1,1	0,3	m/capita	High	

Finland

Category	Finland	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	5.426.674	18.040.258	n° 2013		SE
Area	338.435	160.518	km²		
Population density	16	168	n°/km²	Low	
Land area	6,24	1,42	ha/capita	High	
2. GDP and trade					
GDP/capita	36	25	€ 1.000	High	AT, DE, IE
	113	100	PPS	High	
Cross-border movements	8,25	6,87	€1000/capita	Medium	
3. Energy					
Primary energy consumption	6,04	3,22	toe/capita (2012)	High	AT, SE
Energy dependence	48,7	55,4	%	Medium	
Renewable energy share	36,8	17,9	%	High	
GHG emissions	11,29	9,47	ton CO_2-eq/capita	High	
4. Agriculture					
UAA	0,416	0,415	ha/capita	Medium	SE, ME, SR
Cereal yield	3,74	5,20	t/ha	Low	
Livestock density	0,496	1,020	LSU/ha UAA	Medium	
5. Forestry					
Forest area	4,560	0,650	ha/capita	High	SE
Forest increment	4,21	5,47	m³/ha	Medium	
	17,45	2,80	m³/capita (2010)	High	
6. Waste					
Total municipal waste	493	464	kg/capita/year	Medium	FR, UK
Landfill	124	185	kg/capita/year	Medium	
Incineration	209	104	kg/capita/year	High	
Recycling	94	104	kg/capita/year	Medium	
Composting/digestion	67	57	kg/capita/year	Medium	
7. Industry (turnover)					
Wood and paper products	5.466	854	€/capita	High	AT, SE
Food products	1.845	1.684	€/capita	Medium	
Chemical products	1.467	883	€/capita	High	
8. Renewable energy (RE)					
Bioenergy in RE	88%	69%	%	High	LV, LT
Bioenergy in total energy	26,7%	10,6%	%	High	
9. Energy infrastructure					
Biofuels prod. Capacity	0,078	0,051	ton/capita	Medium	
CHP	34,1%	17,3%	% gross electricity generation	High	
District heating	13.850	7.404	km		
	2,6	0,3	m/capita	high	

France

Category	France	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	65.560.721	18.040.258	n° 2013		ES, TK, CY, SI, AL, MD, SR, AT, HU
Area	632.834	160.518	km²		
Population density	104	168	n°/km²	Medium	
Land area	0,97	1,42	ha/capita	Medium	
2. GDP and trade					
GDP/capita	31	25	€ 1.000	Medium	UK, IT
	107	100	PPS	Medium	
Cross-border movements	5,23	6,87	€1000/capita	Medium	
3. Energy					
Primary energy consumption	3,75	3,22	toe/capita (2012)	High	BG, ES, SI, SK, UK
Energy dependence	47,9	55,4	%	Medium	
Renewable energy share	14,2	17,9	%	Medium	
GHG emissions	7,51	9,47	ton CO_2-eq/capita	Medium	
4. Agriculture					
UAA	0,442	0,415	ha/capita	Medium	UK
Cereal yield	7,10	5,20	t/ha	High	
Livestock density	0,755	1,020	LSU/ha UAA	Medium	
5. Forestry					
Forest area	0,296	0,650	ha/capita	Medium	HU, PL, UA
Forest increment	5,16	5,47	m³/ha	Medium	
	1,28	2,80	m³/capita (2010)	Medium	
6. Waste					
Total municipal waste	517	464	kg/capita/year	Medium	IT, FI, UK
Landfill	150	185	kg/capita/year	Medium	
Incineration	180	104	kg/capita/year	Medium	
Recycling	110	104	kg/capita/year	Medium	
Composting/digestion	89	57	kg/capita/year	High	
7. Industry (turnover)					
Wood and paper products	502	854	€/capita	Medium	DE
Food products	2.360	1.684	€/capita	High	
Chemical products	1.169	883	€/capita	High	
8. Renewable energy (RE)					
Bioenergy in RE	64%	69%	%	Medium	BG, IT, SI
Bioenergy in total energy	6,0%	10,6%	%	Medium	
9. Energy infrastructure					
Biofuels prod. Capacity	0,059	0,051	ton/capita	Medium	
CHP	2,4%	17,3%	% gross electricity generation	Low	
District heating	3.725	7.404	km		
	0,1	0,3	m/capita	Low	

Germany

Category	Germany	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	80.523.746	18.040.258	n° 2013		UK, IT, LU, KS
Area	357.168	160.518	km²		
Population density	225	168	n°/km²	High	
Land area	0,44	1,42	ha/capita	Low	
2. GDP and trade					
GDP/capita	34	25	€ 1.000	High	IE, FI, AT
	122	100	PPS	High	
Cross-border movements	9,78	6,87	€1000/capita	High	
3. Energy					
Primary energy consumption	3,76	3,22	toe/capita (2012)	High	CZ, FR, AT
Energy dependence	62,7	55,4	%	Medium	
Renewable energy share	12,4	17,9	%	Medium	
GHG emissions	11,47	9,47	ton CO_2-eq/capita	High	
4. Agriculture					
UAA	0,207	0,415	ha/capita	Low	LU
Cereal yield	7,32	5,20	t/ha	High	
Livestock density	1,102	1,020	LSU/ha UAA	Medium	
5. Forestry					
Forest area	0,145	0,650	ha/capita	Low	DK, IE
Forest increment	10,71	5,47	m³/ha	High	
	1,45	2,80	m³/capita (2010)	Medium	
6. Waste					
Total municipal waste	609	464	kg/capita/year	High	BE, DK
Landfill	1	185	kg/capita/year	Low	
Incineration	218	104	kg/capita/year	High	
Recycling	290	104	kg/capita/year	High	
Composting/digestion	108	57	kg/capita/year	High	
7. Industry (turnover)					
Wood and paper products	885	854	€/capita	Medium	BE, FR, NL
Food products	2.147	1.684	€/capita	High	
Chemical products	2.045	883	€/capita	High	
8. Renewable energy (RE)					
Bioenergy in RE	72%	69%	%	Medium	BE, HU, SK
Bioenergy in total energy	8,0%	10,6%	%	Medium	
9. Energy infrastructure					
Biofuels	0,087	0,051	ton/capita	High	
CHP	12,4%	17,3%	% gross electricity generation	Medium	
District heating	20.219	7.404	km		
	0,3	0,3	m/capita	Medium	

Greece

Category	Greece	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	11.003.615	18.040.258	n° 2013		RO, UA, FYR, BA, BG, IE
Area	131.957	160.518	km²		
Population density	83	168	n°/km²	Medium	
Land area	1,20	1,42	ha/capita	Medium	
2. GDP and trade					
GDP/capita	17	25	€ 1.000	Medium	PT, CY, ES
	73	100	PPS	Medium	
Cross-border movements	3,58	6,87	€1000/capita	Medium	
3. Energy					
Primary energy consumption	2,15	3,22	toe/capita (2012)	Medium	HR, HU
Energy dependence	62,1	55,4	%	Medium	
Renewable energy share	15	17,9	%	Medium	
GHG emissions	9,98	9,47	ton CO_2-eq/capita	Medium	
4. Agriculture					
UAA	0,360	0,415	ha/capita	Medium	CZ, ES, HR, PT, SE, SR
Cereal yield	4,48	5,20	t/ha	Medium	
Livestock density	0,541	1,020	LSU/ha UAA	Medium	
5. Forestry					
Forest area	0,372	0,650	ha/capita	Medium	ES, SR
Forest increment	1,14	5,47	m³/ha	Low	
	0,41	2,80	m³/capita (2010)	Low	
6. Waste					
Total municipal waste	509	464	kg/capita/year	Medium	HR, CY, MT
Landfill	412	185	kg/capita/year	High	
Incineration	0	104	kg/capita/year	Low	
Recycling	79	104	kg/capita/year	Medium	
Composting/digestion	19	57	kg/capita/year	Low	
7. Industry (turnover)					
Wood and paper products	140	854	€/capita	Low	HR, CY
Food products	1.059	1.684	€/capita	Medium	
Chemical products	204	883	€/capita	Low	
8. Renewable energy (RE)					
Bioenergy in RE	44%	69%	%	Low	IE, MT
Bioenergy in total energy	4,9%	10,6%	%	Low	
9. Energy infrastructure					
Biofuels prod. Capacity	0,089	0,051	ton/capita	High	
CHP	3,4%	17,3%	% gross electricity generation	Low	
District heating	1.060	7.404	km		
	0,1	0,3	m/capita	Low	

Hungary

Category	Hungary	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	9.908.798	18.040.258	n° 2013		ES, FR, TK, CY, SI, AL, MD, SR, AT
Area	93.024	160.518	km²		
Population density	107	168	n°/km²	Medium	
Land area	0,94	1,42	ha/capita	Medium	
2. GDP and trade					
GDP/capita	10	25	€ 1.000	Low	TK, PL, LV, HR
	66	100	PPS	Low	
Cross-border movements	3,96	6,87	€1000/capita	Medium	
3. Energy					
Primary energy consumption	2,12	3,22	toe/capita (2012)	Medium	EL, HR
Energy dependence	52,3	55,4	%	Medium	
Renewable energy share	9,8	17,9	%	Medium	
GHG emissions	6,24	9,47	ton CO_2-eq/capita	Low	
4. Agriculture					
UAA	0,539	0,415	ha/capita	High	BG, RO, SR
Cereal yield	4,80	5,20	t/ha	Medium	
Livestock density	0,423	1,020	LSU/ha UAA	Low	
5. Forestry					
Forest area	0,214	0,650	ha/capita	Medium	FR, RO, KS, UA
Forest increment	4,77	5,47	m³/ha	Medium	
	0,98	2,80	m³/capita (2010)	Medium	
6. Waste					
Total municipal waste	378	464	kg/capita/year	Low	CZ, PL
Landfill	244	185	kg/capita/year	Medium	
Incineration	34	104	kg/capita/year	Low	
Recycling	81	104	kg/capita/year	Medium	
Composting/digestion	19	57	kg/capita/year	Low	
7. Industry (turnover)					
Wood and paper products	242	854	€/capita	Low	BG, RO
Food products	967	1.684	€/capita	Low	
Chemical products	585	883	€/capita	Medium	
8. Renewable energy (RE)					
Bioenergy in RE	89%	69%	%	High	BE, DE, NL
Bioenergy in total energy	7,9%	10,6%	%	Medium	
9. Energy infrastructure					
Biofuels prod. Capacity	0,045	0,051	ton/capita	Medium	
CHP	12,8%	17,3%	% gross electricity generation	Medium	
District heating	2.158	7.404	km		
	0,2	0,3	m/capita	Medium	

Ireland

Category	Ireland	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	4.591.087	18.040.258	n° 2013		RO, UA, FYR, BA, BG, EL
Area	69.797	160.518	km²		
Population density	66	168	n°/km²	Medium	
Land area	1,52	1,42	ha/capita	Medium	
2. GDP and trade					
GDP/capita	36	25	€ 1.000	High	DE, FI, AT
	130	100	PPS	High	
Cross-border movements	11,26	6,87	€1000/capita	High	
3. Energy					
Primary energy consumption	2,92	3,22	toe/capita (2012)	Medium	CY
Energy dependence	89	55,4	%	High	
Renewable energy share	7,8	17,9	%	Low	
GHG emissions	12,77	9,47	ton CO_2-eq/capita	High	
4. Agriculture					
UAA	0,975	0,415	ha/capita	High	DK
Cereal yield	7,76	5,20	t/ha	High	
Livestock density	1,324	1,020	LSU/ha UAA	High	
5. Forestry					
Forest area	0,164	0,650	ha/capita	Low	CZ, DE, LU
Forest increment	8,83	5,47	m³/ha	High	
	1,47	2,80	m³/capita (2010)	Medium	
6. Waste					
Total municipal waste	586	464	kg/capita/year	High	UK
Landfill	223	185	kg/capita/year	Medium	
Incineration	93	104	kg/capita/year	Medium	
Recycling	180	104	kg/capita/year	High	
Composting/digestion	34	57	kg/capita/year	Medium	
7. Industry (turnover)					
Wood and paper products	293	854	€/capita	Low	NL
Food products	5.072	1.684	€/capita	High	
Chemical products	2.281	883	€/capita	High	
8. Renewable energy (RE)					
Bioenergy in RE	47%	69%	%	Low	EL, MT
Bioenergy in total energy	2,9%	10,6%	%	Low	
9. Energy infrastructure					
Biofuels prod. Capacity	0,007	0,051	ton/capita	Low	
CHP	7,8%	17,3%	% gross electricity generation	Low	
District heating	0	7.404	km		
	0,0	0,3	m/capita	Low	

Italy

Category	Italy	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	59.685.227	18.040.258	n° 2013		UK, DE, LU, KS
Area	302.073	160.518	km²		
Population density	198	168	n°/km²	Medium	
Land area	0,51	1,42	ha/capita	Low	
2. GDP and trade					
GDP/capita	26	25	€ 1.000	Medium	UK, FR, ES
	99	100	PPS	Medium	
Cross-border movements	5,72	6,87	€1000/capita	Medium	
3. Energy					
Primary energy consumption	2,58	3,22	toe/capita (2012)	Medium	CY, LT
Energy dependence	76,9	55,4	%	High	
Renewable energy share	16,7	17,9	%	Medium	
GHG emissions	7,75	9,47	ton CO_2-eq/capita	Medium	
4. Agriculture					
UAA	0,205	0,415	ha/capita	Low	SI
Cereal yield	4,83	5,20	t/ha	Medium	
Livestock density	0,811	1,020	LSU/ha UAA	Medium	
5. Forestry					
Forest area	0,158	0,650	ha/capita	Low	MD, TK
Forest increment	3,50	5,47	m³/ha	Low	
	0,55	2,80	m³/capita (2010)	Low	
6. Waste					
Total municipal waste	491	464	kg/capita/year	Medium	ES, FR
Landfill	181	185	kg/capita/year	Medium	
Incineration	99	104	kg/capita/year	Medium	
Recycling	122	104	kg/capita/year	Medium	
Composting/digestion	72	57	kg/capita/year	Medium	
7. Industry (turnover)					
Wood and paper products	621	854	€/capita	Medium	ES, LT, UK
Food products	1.865	1.684	€/capita	Medium	
Chemical products	867	883	€/capita	Medium	
8. Renewable energy (RE)					
Bioenergy in RE	52%	69%	%	Medium	FR, MD, SR
Bioenergy in total energy	8,9%	10,6%	%	Medium	
9. Energy infrastructure					
Biofuels prod. Capacity	0,043	0,051	ton/capita	Medium	
CHP	12,7%	17,3%	% gross electricity generation	Medium	
District heating	3.807	7.404	km		
	0,1	0,3	m/capita	Low	

Kosovo*

Category	Kosovo*	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	1.815.605	18.040.258	n° 2013		UK, DE, IT, LU
Area	10.887	160.518	km²		
Population density	167	168	n°/km²	Medium	
Land area	0,60	1,42	ha/capita	Low	
2. GDP and trade					
GDP/capita	3	25	€ 1.000	Low	AL, BA, FYR, UA, MD
	na	100	PPS	Low	
Cross-border movements	0,85	6,87	€1000/capita	Low	
3. Energy					
Primary energy consumption	1,12	3,22	toe/capita (2012)	Low	RO
Energy dependence	24,2	55,4	%	Low	
Renewable energy share	na	17,9	%		
GHG emissions	na	9,47	ton CO_2-eq/capita		
4. Agriculture					
UAA	0,162	0,415	ha/capita	Low	/
Cereal yield	na	5,20	t/ha		
Livestock density	na	1,020	LSU/ha UAA		
5. Forestry					
Forest area	0,265	0,650	ha/capita	Medium	HU, UA
Forest increment	3,23	5,47	m³/ha	Low	
	0,87	2,80	m³/capita (2010)	Low	
6. Waste					
Total municipal waste	417	464	kg/capita/year	Medium	/
Landfill	na	185	kg/capita/year		
Incineration	na	104	kg/capita/year		
Recycling	na	104	kg/capita/year		
Composting/digestion	na	57	kg/capita/year		
7. Industry (turnover)					
Wood and paper products	na	854	€/capita		/
Food products	na	1.684	€/capita		
Chemical products	na	883	€/capita		
8. Renewable energy (RE)					
Bioenergy in RE	95%	69%	%	High	IE, PL
Bioenergy in total energy	12,3%	10,6%	%	Medium	
9. Energy infrastructure					
Biofuels prod. Capacity	na	0,051	ton/capita	Low	
CHP	na	17,3%	% gross electricity generation	Low	
District heating	na	7.404	km		
		0,3	m/capita		

Latvia

Category	Latvia	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	2.023.825	18.040.258	n° 2013	Low	ME, LT, EE, HR
Area	64.573	160.518	km²	Low	
Population density	31	168	n°/km²	Low	
Land area	3,19	1,42	ha/capita	High	
2. GDP and trade					
GDP/capita	12	25	€ 1.000	Low	HU, PL, HR
	64	100	PPS	Low	
Cross-border movements	3,14	6,87	€1000/capita	Low	
3. Energy					
Primary energy consumption	2,17	3,22	toe/capita (2012)	Medium	PT
Energy dependence	55,9	55,4	%	Medium	
Renewable energy share	37,1	17,9	%	High	
GHG emissions	5,37	9,47	ton CO_2-eq/capita	Low	
4. Agriculture					
UAA	0,928	0,415	ha/capita	High	EE, LT
Cereal yield	3,37	5,20	t/ha	Low	
Livestock density	0,259	1,020	LSU/ha UAA	Low	
5. Forestry					
Forest area	1,721	0,650	ha/capita	High	EE
Forest increment	5,83	5,47	m³/ha	Medium	
	9,28	2,80	m³/capita (2010)	High	
6. Waste					
Total municipal waste	312	464	kg/capita/year	Low	RO, SK, AL
Landfill	259	185	kg/capita/year	High	
Incineration	0	104	kg/capita/year	Low	
Recycling	33	104	kg/capita/year	Low	
Composting/digestion	20	57	kg/capita/year	Low	
7. Industry (turnover)					
Wood and paper products	1.427	854	€/capita	High	/
Food products	792	1.684	€/capita	Medium	
Chemical products	107	883	€/capita	Low	
8. Renewable energy (RE)					
Bioenergy in RE	85%	69%	%	High	LT, FI
Bioenergy in total energy	31,0%	10,6%	%	High	
9. Energy infrastructure					
Biofuels prod. capacity	0,095	0,051	ton/capita	High	
CHP	38,3%	17,3%	% gross electricity generation	High	
District heating	1.700	7.404	km		
	0,8	0,3	m/capita	High	

Lithuania

Category	Lithuania	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	2.971.905	18.040.258	n° 2013		ME, EE, LV, HR
Area	65.300	160.518	km²		
Population density	46	168	n°/km²	Low	
Land area	2,20	1,42	ha/capita	High	
2. GDP and trade					
GDP/capita	12	25	€ 1.000	Low	(SK)
	73	100	PPS	Medium	
Cross-border movements	7,18	6,87	€1000/capita	Medium	
3. Energy					
Primary energy consumption	1,92	3,22	toe/capita (2012)	Low	IT, PT, TK
Energy dependence	78,3	55,4	%	High	
Renewable energy share	23	17,9	%	Medium	
GHG emissions	7,20	9,47	ton CO_2-eq/capita	Low	
4. Agriculture					
UAA	0,973	0,415	ha/capita	High	EE, LV, UA
Cereal yield	3,69	5,20	t/ha	Low	
Livestock density	0,290	1,020	LSU/ha UAA	Low	
5. Forestry					
Forest area	0,763	0,650	ha/capita	High	SI, ME
Forest increment	5,07	5,47	m³/ha	Medium	
	3,51	2,80	m³/capita (2010)	High	
6. Waste					
Total municipal waste	433	464	kg/capita/year	Medium	ES
Landfill	270	185	kg/capita/year	High	
Incineration	31	104	kg/capita/year	Low	
Recycling	88	104	kg/capita/year	Medium	
Composting/digestion	32	57	kg/capita/year	Medium	
7. Industry (turnover)					
Wood and paper products	537	854	€/capita	Medium	CZ, EE, IT, LU, PT
Food products	1.233	1.684	€/capita	Medium	
Chemical products	657	883	€/capita	Medium	
8. Renewable energy (RE)					
Bioenergy in RE	92%	69%	%	High	LV, FI
Bioenergy in total energy	19,6%	10,6%	%	High	
9. Energy infrastructure					
Biofuels prod. Capacity	0,067	0,051	ton/capita	Medium	
CHP	35,0%	17,3%	% gross electricity generation	High	
District heating	2.565	7.404	km		
	0,9	0,3	m/capita	High	

Luxembourg

Category	Luxembourg	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	537.039	18.040.258	n° 2013		UK, DE, IT, KS
Area	2.586	160.518	km²		
Population density	208	168	n°/km²	High	
Land area	0,48	1,42	ha/capita	Low	
2. GDP and trade					
GDP/capita	85	25	€ 1.000	High	/
	258	100	PPS	High	
Cross-border movements	12,77	6,87	€1000/capita	High	
3. Energy					
Primary energy consumption	8,01	3,22	toe/capita (2012)	High	BE
Energy dependence	96,9	55,4	%	High	
Renewable energy share	3,6	17,9	%	Low	
GHG emissions	22,56	9,47	ton CO_2-eq/capita	High	
4. Agriculture					
UAA	0,244	0,415	ha/capita	Low	DK, DE
Cereal yield	5,96	5,20	t/ha	Medium	
Livestock density	1,262	1,020	LSU/ha UAA	High	
Forest area	0,161	0,650	ha/capita	Low	CZ, IE
Forest increment	7,49	5,47	m³/ha	High	
	1,29	2,80	m³/capita (2010)	Medium	
6. Waste					
Total municipal waste	616	464	kg/capita/year	High	DK
Landfill	114	185	kg/capita/year	Medium	
Incineration	226	104	kg/capita/year	High	
Recycling	182	104	kg/capita/year	High	
Composting/digestion	131	57	kg/capita/year	High	
7. Industry (turnover)					
Wood and paper products	359	854	€/capita	Medium	LT, PL, PT, UK
Food products	1.259	1.684	€/capita	Medium	
Chemical products	495	883	€/capita	Medium	
8. Renewable energy (RE)					
Bioenergy in RE	84%	69%	%	High	/
Bioenergy in total energy	3,1%	10,6%	%	Low	
9. Energy infrastructure					
Biofuels prod. Capacity	0,000	0,051	ton/capita	Low	
CHP	14,7%	17,3%	% gross electricity generation	Medium	
District heating	na	7.404	km		
	0,0	0,3	m/capita	Low	

Macedonia (FYROM)

Category	Macedonia	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	2.062.294	18.040.258	n° 2013		RO, UA, BA, IE, BG, EL
Area	25.713	160.518	km²		
Population density	80	168	n°/km²	Medium	
Land area	1,25	1,42	ha/capita	Medium	
2. GDP and trade					
GDP/capita	4	25	€ 1.000	Low	UA, BA, KS, AL, MD, SR
	36	100	PPS	Low	
Cross-border movements	1,33	6,87	€1000/capita	Low	
3. Energy					
Primary energy consumption	1,31	3,22	toe/capita (2012)	Low	HR
Energy dependence	46,8	55,4	%	Medium	
Renewable energy share	15,7	17,9	%	Medium	
GHG emissions	4,50	9,47	ton CO_2-eq/capita	Low	
4. Agriculture					
UAA	0,611	0,415	ha/capita	High	RO
Cereal yield	3,38	5,20	t/ha	Low	
Livestock density	0,902	1,020	LSU/ha UAA	Medium	
5. Forestry					
Forest area	0,493	0,650	ha/capita	Medium	BG, HR
Forest increment	4,00	5,47	m³/ha	Low	
	2,22	2,80	m³/capita (2010)	Medium	
6. Waste					
Total municipal waste	384	464	kg/capita/year	Low	BA, SR, UA
Landfill	269	185	kg/capita/year	High	
Incineration	0	104	kg/capita/year	Low	
Recycling	0	104	kg/capita/year	Low	
Composting/digestion	0	57	kg/capita/year	Low	
7. Industry (turnover)					
Wood and paper products	47	854	€/capita	Low	MD, SR, UA
Food products	306	1.684	€/capita	Low	
Chemical products	18	883	€/capita	Low	
8. Renewable energy (RE)					
Bioenergy in RE	51%	69%	%	Medium	SR
Bioenergy in total energy	5,6%	10,6%	%	Medium	
9. Energy infrastructure					
Biofuels prod. Capacity	0,010	0,051	ton/capita	Low	
CHP	6,0%	17,3%	% gross electricity generation	Low	
District heating	185	7.404	km		
	0,1	0,3	m/capita	Low	

Malta

Category	Malta	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	421.364	18.040.258	n° 2013		/
Area	316	160.518	km²		
Population density	1333	168	n°/km²	High	
Land area	0,07	1,42	ha/capita	Low	
2. GDP and trade					
GDP/capita	17	25	€ 1.000	Medium	SI
	86	100	PPS	Medium	
Cross-border movements	6,76	6,87	€1000/capita	Medium	
3. Energy					
Primary energy consumption	1,90	3,22	toe/capita (2012)	Low	/
Energy dependence	104,1	55,4	%	High	
Renewable energy share	3,8	17,9	%	Low	
GHG emissions	7,52	9,47	ton CO_2-eq/capita	Medium	
4. Agriculture					
UAA	0,028	0,415	ha/capita	Low	/
Cereal yield	5,15	5,20	t/ha	Medium	
Livestock density	3,563	1,020	LSU/ha UAA	High	
5. Forestry					
Forest area	na	0,650	ha/capita	Low	/
Forest increment	na	5,47	m³/ha	Low	
	na	2,80	m³/capita (2010)	Low	
6. Waste					
Total municipal waste	582	464	kg/capita/year	High	EL, CY, ME, TK
Landfill	464	185	kg/capita/year	High	
Incineration	2	104	kg/capita/year	Low	
Recycling	32	104	kg/capita/year	Low	
Composting/digestion	29	57	kg/capita/year	Medium	
7. Industry (turnover)					
Wood and paper products	22	854	€/capita	Low	MD
Food products	na	1.684	€/capita	Low	
Chemical products	63	883	€/capita	Low	
8. Renewable energy (RE)					
Bioenergy in RE	47%	69%	%	Low	IE, EL, ES
Bioenergy in total energy	0,7%	10,6%	%	Low	
9. Energy infrastructure					
Biofuels prod. Capacity	0,002	0,051	ton/capita	Low	
CHP	0,0%	17,3%	% gross electricity generation	Low	
District heating	na	7.404	km		
	0,0	0,3	m/capita	Low	

Moldova

Category	Moldova	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	3.559.497	18.040.258	n° 2013		ES, FR, TK, CY, SI, AL, SR, AT, HU
Area	33.846	160.518	km²		
Population density	105	168	n°/km²	Medium	
Land area	0,95	1,42	ha/capita	Medium	
2. GDP and trade					
GDP/capita	2	25	€ 1.000	Low	UA, KS, AL, BA, FYR
		100	PPS		
Cross-border movements	1,68	6,87	€1000/capita	Low	
3. Energy					
Primary energy consumption	1,20	3,22	toe/capita (2012)	Low	LT
Energy dependence	91,0	55,4	%	High	
Renewable energy share	12,6	17,9	%	Medium	
GHG emissions	3,20	9,47	ton CO_2-eq/capita	Low	
4. Agriculture					
UAA	0,702	0,415	ha/capita	High	EE, RO, FYR
Cereal yield	2,85	5,20	t/ha	Low	
Livestock density	0,076	1,020	LSU/ha UAA	Low	
5. Forestry					
Forest area	0,116	0,650	ha/capita	Low	IT, TK
Forest increment	3,70	5,47	m³/ha	Low	
	0,41	2,80	m³/capita (2010)	Low	
6. Waste					
Total municipal waste	724,7	464	kg/capita/year	High	CY, MT
Landfill	561	185	kg/capita/year	High	
Incineration	0	104	kg/capita/year	Low	
Recycling	155	104	kg/capita/year	High	
Composting/digestion	0	57	kg/capita/year	Low	
7. Industry (turnover)					
Wood and paper products	8	384	€/capita	Low	MT, FYR, SR, UA
Food products	195	1.684	€/capita	Low	
Chemical products	13	883	€/capita	Low	
8. Renewable energy (RE)					
Bioenergy in RE	92%	69%	%	High	IT, PL
Bioenergy in total energy	6,3%	10,6%	%	Medium	
9. Energy infrastructure					
Biofuels prod. Capacity	0,000	0,051	ton/capita	Low	
CHP	19,0%	17,3%	% gross electricity generation	Medium	
District heating	755	7.404	km		
	0,2	0,3	m/capita	Medium	

Montenegro

Category	Montenegro	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	620.893	18.040.258	n° 2013		LT, EE, LV, HR
Area	13.812	160.518	km²		
Population density	45	168	n°/km²	Low	
Land area	2,22	1,42	ha/capita	High	
2. GDP and trade					
GDP/capita	5	25	€ 1.000	Low	BG, SR
	40	100	PPS	Low	
Cross-border movements	1,95	6,87	€1000/capita	Low	
3. Energy					
Primary energy consumption	1,79	3,22	toe/capita (2012)	Low	BG, AL
Energy dependence	27,2	55,4	%	Low	
Renewable energy share	26,3	17,9	%	High	
GHG emissions	6,20	9,47	ton CO_2-eq/capita	Low	
4. Agriculture					
UAA	0,359	0,415	ha/capita	Medium	PL, FI
Cereal yield	2,84	5,20	t/ha	Low	
Livestock density	0,528	1,020	LSU/ha UAA	Medium	
5. Forestry					
Forest area	1,368	0,650	ha/capita	High	LT
Forest increment	3,72	5,47	m³/ha	Low	
	3,26	2,80	m³/capita (2010)	High	
6. Waste					
Total municipal waste	508	464	kg/capita/year	Medium	MT, TK
Landfill	420	185	kg/capita/year	High	
Incineration	0	104	kg/capita/year	Low	
Recycling	4	104	kg/capita/year	Low	
Composting/digestion	0	57	kg/capita/year	Low	
7. Industry (turnover)					
Wood and paper products	0	854	€/capita		/
Food products	na	1.684	€/capita		
Chemical products	na	883	€/capita		
8. Renewable energy (RE)					
Bioenergy in RE	44%	69%	%	Low	/
Bioenergy in total energy	15,0%	10,6%	%	Medium	
9. Energy infrastructure					
Biofuels	0,000	0,051	ton/capita	Low	
CHP	0,0%	17,3%	% gross electricity generation	Low	
District heating	0	7.404	km		
	0,0	0,3	m/capita	Low	

Netherlands

Category	Netherlands	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	16.779.575	18.040.258	n° 2013		BE
Area	41.540	160.518	km²		
Population density	404	168	n°/km²	High	
Land area	0,25	1,42	ha/capita	Low	
2. GDP and trade					
GDP/capita	36	25	€ 1.000	High	BE
	131	100	PPS	High	
Cross-border movements	21,54	6,87	€1000/capita	High	
3. Energy					
Primary energy consumption	3,93	3,22	toe/capita (2012)	High	CZ
Energy dependence	26	55,4	%	Low	
Renewable energy share	4,5	17,9	%	Low	
GHG emissions	11,46	9,47	ton CO_2-eq/capita	High	
4. Agriculture					
UAA	0,110	0,415	ha/capita	Low	BE
Cereal yield	8,65	5,20	t/ha	High	
Livestock density	3,573	1,020	LSU/ha UAA	High	
5. Forestry					
Forest area	0,028	0,650	ha/capita	Low	BE, UK
Forest increment	7,50	5,47	m³/ha	High	
	0,17	2,80	m³/capita (2010)	Low	
6. Waste					
Total municipal waste	526	464	kg/capita/year	Medium	BE, AT, SE
Landfill	8	185	kg/capita/year	Low	
Incineration	256	104	kg/capita/year	High	
Recycling	126	104	kg/capita/year	Medium	
Composting/digestion	137	57	kg/capita/year	High	
7. Industry (turnover)					
Wood and paper products	517	854	€/capita	Medium	BE, DE, IE
Food products	3.840	1.684	€/capita	High	
Chemical products	3.001	883	€/capita	High	
8. Renewable energy (RE)					
Bioenergy in RE	83%	69%	%	High	BE, HU
Bioenergy in total energy	4,4%	10,6%	%	Low	
9. Energy infrastructure					
Biofuels prod. Capacity	0,150	0,051	ton/capita	High	
CHP	34,5%	17,3%	% gross electricity generation	High	
District heating	4.000	7.404	km		
	0,2	0,3	m/capîta	Medium	

Poland

Category	Poland	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	38.062.535	18.040.258	n° 2013		SK, DK, PT, CZ
Area	312.679	160.518	km²		
Population density	122	168	n°/km²	Medium	
Land area	0,82	1,42	ha/capita	Medium	
2. GDP and trade					
GDP/capita	10	25	€ 1.000	Low	HR, LV, HU, TK
	67	100	PPS	Low	
Cross-border movements	2,29	6,87	€1000/capita	Low	
3. Energy					
Primary energy consumption	2,45	3,22	toe/capita (2012)	Medium	BG, CZ, SR
Energy dependence	25,8	55,4	%	Low	
Renewable energy share	11,3	17,9	%	Medium	
GHG emissions	10,36	9,47	ton CO_2-eq/capita	Medium	
4. Agriculture					
UAA	0,379	0,415	ha/capita	Medium	PT, ME
Cereal yield	3,80	5,20	t/ha	Low	
Livestock density	0,636	1,020	LSU/ha UAA	Medium	
5. Forestry					
Forest area	0,252	0,650	ha/capita	Medium	CZ, FR, PT, RO, SK
Forest increment	6,63	5,47	m³/ha	Medium	
	1,64	2,80	m³/capita (2010)	Medium	
6. Waste					
Total municipal waste	297	464	kg/capita/year	Low	BG, ES, HU
Landfill	157	185	kg/capita/year	Medium	
Incineration	20	104	kg/capita/year	Low	
Recycling	39	104	kg/capita/year	Low	
Composting/digestion	32	57	kg/capita/year	Medium	
7. Industry (turnover)					
Wood and paper products	446	854	€/capita	Medium	LU, PT, UK
Food products	1.248	1.684	€/capita	Medium	
Chemical products	381	883	€/capita	Medium	
8. Renewable energy (RE)					
Bioenergy in RE	91%	69%	%	High	CZ, EE, KS, MD
Bioenergy in total energy	8,4%	10,6%	%	Medium	
9. Energy infrastructure					
Biofuels prod. Capacity	0,037	0,051	ton/capita	Medium	
CHP	15,9%	17,3%	% gross electricity generation	Medium	
District heating	20.139	7.404	km		
	0,5	0,3	m/capita	Medium	

Portugal

Category	Portugal	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	10.487.289	18.040.258	n° 2013		PL, SK, DK, CZ
Area	92.212	160.518	km²		
Population density	114	168	n°/km²	Medium	
Land area	0,88	1,42	ha/capita	Medium	
2. GDP and trade					
GDP/capita	16	25	€ 1.000	Medium	EL, CY, CZ, (EE)
	78	100	PPS	Medium	
Cross-border movements	2,86	6,87	€1000/capita	Low	
3. Energy					
Primary energy consumption	2,03	3,22	toe/capita (2012)	Medium	IT, LV, LT
Energy dependence	73,5	55,4	%	High	
Renewable energy share	25,7	17,9	%	High	
GHG emissions	6,52	9,47	ton CO_2-eq/capita	Low	
4. Agriculture					
UAA	0,360	0,415	ha/capita	Medium	CZ, EL, PL
Cereal yield	4,24	5,20	t/ha	Medium	
Livestock density	0,539	1,020	LSU/ha UAA	Medium	
5. Forestry					
Forest area	0,308	0,650	ha/capita	Medium	PL, RO, SK
Forest increment	5,51	5,47	m³/ha	Medium	
	1,81	2,80	m³/capita (2010)	Medium	
6. Waste					
Total municipal waste	440	464	kg/capita/year	Medium	IT, PL
Landfill	222	185	kg/capita/year	Medium	
Incineration	104	104	kg/capita/year	Medium	
Recycling	57	104	kg/capita/year	Low	
Composting/digestion	57	57	kg/capita/year	Medium	
7. Industry (turnover)					
Wood and paper products	644	854	€/capita	Medium	CZ, LT, LU, PL, UK
Food products	1.139	1.684	€/capita	Medium	
Chemical products	436	883	€/capita	Medium	
8. Renewable energy (RE)					
Bioenergy in RE	53%	69%	%	Medium	RO, SI
Bioenergy in total energy	13,2%	10,6%	%	Medium	
9. Energy infrastructure					
Biofuels prod. Capacity	0,075	0,051	ton/capita	Medium	
CHP	13,8%	17,3%	% gross electricity generation	Medium	
District heating	na	7.404	km		
	0,0	0,3	m/capita	Low	

Romania

Category	Romania	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	20.020.074	18.040.258	n° 2013		UA, FYR, BA, IE, BG, EL
Area	238.391	160.518	km²		
Population density	84	168	n°/km²	Medium	
Land area	1,19	1,42	ha/capita	Medium	
2. GDP and trade					
GDP/capita	7	25	€ 1.000	Low	TK, SR, ME, BG
	54	100	PPS	Low	
Cross-border movements	1,42	6,87	€1000/capita	Low	
3. Energy					
Primary energy consumption	1,54	3,22	toe/capita (2012)	Low	BA
Energy dependence	18,6	55,4	%	Low	
Renewable energy share	23,9	17,9	%	Medium	
GHG emissions	5,91	9,47	ton CO_2-eq/capita	Low	
4. Agriculture					
UAA	0,695	0,415	ha/capita	High	BG, EE, HU, UA
Cereal yield	3,84	5,20	t/ha	Low	
Livestock density	0,358	1,020	LSU/ha UAA	Low	
5. Forestry					
Forest area	0,348	0,650	ha/capita	Medium	HU, PL, PT
Forest increment	4,40	5,47	m³/ha	Medium	
	1,44	2,80	m³/capita (2010)	Medium	
6. Waste					
Total municipal waste	254	464	kg/capita/year	Low	LV, SK
Landfill	213	185	kg/capita/year	Medium	
Incineration	0	104	kg/capita/year	Low	
Recycling	6	104	kg/capita/year	Low	
Composting/digestion	1	57	kg/capita/year	Low	
7. Industry (turnover)					
Wood and paper products	240	854	€/capita	Low	BG, HU
Food products	452	1.684	€/capita	Low	
Chemical products	113	883	€/capita	Low	
8. Renewable energy (RE)					
Bioenergy in RE	69%	69%	%	Medium	PT, SI
Bioenergy in total energy	12,3%	10,6%	%	Medium	
9. Energy infrastructure					
Biofuels prod. Capacity	0,015	0,051	ton/capita	Low	
CHP	11,2%	17,3%	% gross electricity generation	Medium	
District heating	na	7.404	km		
	0,0	0,3	m/capita	Low	

Serbia

Category	Serbia	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	7.181.505	18.040.258	n° 2013		ES, FR, TK, CY, SI, AL, MD, AT, HU
Area	77.474	160.518	km²		
Population density	93	168	n°/km²	Medium	
Land area	1,08	1,42	ha/capita	Medium	
2. GDP and trade					
GDP/capita	5	25	€ 1.000	Low	BA, FYR, ME, BG, RO
	37	100	PPS	Low	
Cross-border movements	1,35	6,87	€1000/capita	Low	
3. Energy					
Primary energy consumption	2,51	3,22	toe/capita (2012)	Medium	PL
Energy dependence	24,1	55,4	%	Low	
Renewable energy share	32,1	17,9	%	High	
GHG emissions	8,72	9,47	ton CO_2-eq/capita	Medium	
4. Agriculture					
UAA	0,486	0,415	ha/capita	Medium	CZ, EL, ES, HU, FI, AL, BA
Cereal yield	4,78	5,20	t/ha	Medium	
Livestock density	0,549	1,020	LSU/ha UAA	Medium	
5. Forestry					
Forest area	0,335	0,650	ha/capita	Medium	EL, ES
Forest increment	1,86	5,47	m³/ha	Low	
	0,72	2,80	m³/capita (2010)	Low	
6. Waste					
Total municipal waste	336	464	kg/capita/year	Low	BA, FYR, UA
Landfill	272	185	kg/capita/year	High	
Incineration	0	104	kg/capita/year	Low	
Recycling	0	104	kg/capita/year	Low	
Composting/digestion	0	57	kg/capita/year	Low	
7. Industry (turnover)					
Wood and paper products	133	854	€/capita	Low	FYR, MD, UA
Food products	320	1.684	€/capita	Low	
Chemical products	93	883	€/capita	Low	
8. Renewable energy (RE)					
Bioenergy in RE	55%	69%	%	Medium	IT, FYR
Bioenergy in total energy	5,9%	10,6%	%	Medium	
9. Energy infrastructure					
Biofuels prod. Capacity	0,000	0,051	ton/capita	Low	
CHP	36,0%	17,3%	% gross electricity generation	High	
District heating	2.085	7.404	km		
	0,3	0,3	m/capita	Medium	

Slovakia

Category	Slovakia	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	5.410.836	18.040.258	n° 2013		PL, DK, PT, CZ
Area	49.036	160.518	km²		
Population density	110	168	n°/km²	Medium	
Land area	0,91	1,42	ha/capita	Medium	
2. GDP and trade					
GDP/capita	13	25	€ 1.000	Medium	EE, CZ
	75	100	PPS	Medium	
Cross-border movements	4,96	6,87	€1000/capita	Medium	
3. Energy					
Primary energy consumption	2,99	3,22	toe/capita (2012)	Medium	ES, FR, UK
Energy dependence	59,6	55,4	%	Medium	
Renewable energy share	9,8	17,9	%	Medium	
GHG emissions	7,90	9,47	ton CO_2-eq/capita	Medium	
4. Agriculture					
UAA	0,356	0,415	ha/capita	Medium	CZ
Cereal yield	4,67	5,20	t/ha	Medium	
Livestock density	0,334	1,020	LSU/ha UAA	Low	
5. Forestry					
Forest area	0,366	0,650	ha/capita	Medium	CZ, PL, PT
Forest increment	6,96	5,47	m³/ha	Medium	
	2,50	2,80	m³/capita (2010)	Medium	
6. Waste					
Total municipal waste	304	464	kg/capita/year	Low	LV, RO
Landfill	213	185	kg/capita/year	Medium	
Incineration	32	104	kg/capita/year	Low	
Recycling	10	104	kg/capita/year	Low	
Composting/digestion	22	57	kg/capita/year	Low	
7. Industry (turnover)					
Wood and paper products	531	854	€/capita	Medium	SI
Food products	690	1.684	€/capita	Low	
Chemical products	343	883	€/capita	Medium	
8. Renewable energy (RE)					
Bioenergy in RE	69%	69%	%	Medium	BE, DE
Bioenergy in total energy	6,0%	10,6%	%	Medium	
9. Energy infrastructure					
Biofuels	0,048	0,051	ton/capita	Medium	
CHP	77,0%	17,3%	% gross electricity generation	High	
District heating	4.984	7.404	km		
	0,9	0,3	m/capita	High	

Slovenia

Category	Slovenia	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	2.058.821	18.040.258	n° 2013		ES, FR, TK, CY, AL, MD, SR, AT, HU
Area	20.273	160.518	km²		
Population density	102	168	n°/km²	Medium	
Land area	0,98	1,42	ha/capita	Medium	
2. GDP and trade					
GDP/capita	17	25	€ 1.000	Medium	MT
	82	100	PPS	Medium	
Cross-border movements	6,79	6,87	€1000/capita	Medium	
3. Energy					
Primary energy consumption	3,25	3,22	toe/capita (2012)	Medium	ES, FR, UK
Energy dependence	47,1	55,4	%	Medium	
Renewable energy share	21,5	17,9	%	Medium	
GHG emissions	9,20	9,47	ton CO_2-eq/capita	Medium	
4. Agriculture					
UAA	0,233	0,415	ha/capita	Low	IT
Cereal yield	4,74	5,20	t/ha	Medium	
Livestock density	1,019	1,020	LSU/ha UAA	Medium	
5. Forestry					
Forest area	0,610	0,650	ha/capita	Medium	LT
Forest increment	7,29	5,47	m³/ha	High	
	4,48	2,80	m³/capita (2010)	High	
6. Waste					
Total municipal waste	414	464	kg/capita/year	Medium	/
Landfill	109	185	kg/capita/year	Medium	
Incineration	2	104	kg/capita/year	Low	
Recycling	157	104	kg/capita/year	High	
Composting/digestion	20	57	kg/capita/year	Low	
7. Industry (turnover)					
Wood and paper products	772	854	€/capita	Medium	SK
Food products	900	1.684	€/capita	Low	
Chemical products	747	883	€/capita	Medium	
8. Renewable energy (RE)					
Bioenergy in RE	61%	69%	%	Medium	BE, FR, PT, RO
Bioenergy in total energy	10,7%	10,6%	%	Medium	
9. Energy infrastructure					
Biofuels prod. Capacity	0,002	0,051	ton/capita	Low	
CHP	7,1%	17,3%	% gross electricity generation	Low	
District heating	753	7.404	km		
	0,4	0,3	m/capita	Medium	

Spain

Category	Spain	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	46.727.890	18.040.258	n° 2013		FR, TK, CY, SI, AL, MD, SR, AT, HU
Area	505.991	160.518	km²		
Population density	92	168	n°/km²	Medium	
Land area	1,08	1,42	ha/capita	Medium	
2. GDP and trade					
GDP/capita	22	25	€ 1.000	Medium	CY, IT
	94	100	PPS	Medium	
Cross-border movements	4,36	6,87	€1000/capita	Medium	
3. Energy					
Primary energy consumption	2,43	3,22	toe/capita (2012)	Medium	BG, FR, SI, SK
Energy dependence	70,5	55,4	%	High	
Renewable energy share	15,4	17,9	%	Medium	
GHG emissions	7,28	9,47	ton CO_2-eq/capita	Medium	
4. Agriculture					
UAA	0,506	0,415	ha/capita	Medium	EL, SR, TK
Cereal yield	4,00	5,20	t/ha	Medium	
Livestock density	0,613	1,020	LSU/ha UAA	Medium	
5. Forestry					
Forest area	0,397	0,650	ha/capita	Medium	EL, SR
Forest increment	1,92	5,47	m³/ha	Low	
	0,76	2,80	m³/capita (2010)	Low	
6. Waste					
Total municipal waste	454	464	kg/capita/year	Medium	CZ, IT, LT
Landfill	270	185	kg/capita/year	High	
Incineration	44	104	kg/capita/year	Low	
Recycling	88	104	kg/capita/year	Medium	
Composting/digestion	46	57	kg/capita/year	Medium	
7. Industry (turnover)					
Wood and paper products	397	854	€/capita	Medium	IT, UK
Food products	1.867	1.684	€/capita	Medium	
Chemical products	812	883	€/capita	Medium	
8. Renewable energy (RE)					
Bioenergy in RE	38%	69%	%	Low	MT, TK
Bioenergy in total energy	6,0%	10,6%	%	Medium	
9. Energy infrastructure					
Biofuels prod. Capacity	0,117	0,051	ton/capita	High	
CHP	8,5%	17,3%	% gross electricity generation	Low	
District heating	na	7.404	km		
	0,0	0,3	m/capita	Low	

Sweden

Category	Sweden	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	9.555.893	18.040.258	n° 2013		FI
Area	438.576	160.518	km²		
Population density	22	168	n°/km²	Low	
Land area	4,59	1,42	ha/capita	High	
2. GDP and trade					
GDP/capita	44	25	€ 1.000	High	DK
	127	100	PPS	High	
Cross-border movements	9,53	6,87	€1000/capita	High	
3. Energy					
Primary energy consumption	4,93	3,22	toe/capita (2012)	High	SK
Energy dependence	31,6	55,4	%	Low	
Renewable energy share	52,1	17,9	%	High	
GHG emissions	6,07	9,47	ton CO_2-eq/capita	Low	
4. Agriculture					
UAA	0,317	0,415	ha/capita	Medium	EL, HR, FI
Cereal yield	5,13	5,20	t/ha	Medium	
Livestock density	0,565	1,020	LSU/ha UAA	Medium	
5. Forestry					
Forest area	3,163	0,650	ha/capita	High	FI
Forest increment	2,81	5,47	m³/ha	Low	
	8,49	2,80	m³/capita (2010)	High	
6. Waste					
Total municipal waste	451	464	kg/capita/year	Medium	BE, NL
Landfill	3	185	kg/capita/year	Low	
Incineration	228	104	kg/capita/year	High	
Recycling	153	104	kg/capita/year	High	
Composting/digestion	69	57	kg/capita/year	Medium	
7. Industry (turnover)					
Wood and paper products	2.974	854	€/capita	High	AT, FI
Food products	1.827	1.684	€/capita	Medium	
Chemical products	943	883	€/capita	Medium	
8. Renewable energy (RE)					
Bioenergy in RE	64%	69%	%	Medium	AT
Bioenergy in total energy	23,3%	10,6%	%	High	
9. Energy infrastructure					
Biofuels prod. Capacity	0,064	0,051	ton/capita	Medium	
CHP	10,2%	17,3%	% gross electricity generation	Medium	
District heating	23.667	7.404	km		
	2,5	0,3	m/capita	High	

Turkey

Category	Turkey	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	75.627.384	18.040.258	n° 2013		ES, FR, CY, SI, AL, MD, SR, AT, HU
Area	785.347	160.518	km²		
Population density	96	168	n°/km²	Medium	
Land area	1,04	1,42	ha/capita	Medium	
2. GDP and trade					
GDP/capita	8	25	€ 1.000	Low	RO, PL, HR, HU
	53	100	PPS	Low	
Cross-border movements	2,47	6,87	€1000/capita	Low	
3. Energy					
Primary energy consumption	1,70	3,22	toe/capita (2012)	Low	LT
Energy dependence	74,4	55,4	%	High	
Renewable energy share	28,9	17,9	%	High	
GHG emissions	5,85	9,47	ton CO_2-eq/capita	Low	
4. Agriculture					
UAA	0,508	0,415	ha/capita	Medium	ES
Cereal yield	3,20	5,20	t/ha	Low	
Livestock density	na	1,020	LSU/ha UAA		
5. Forestry					
Forest area	0,155	0,650	ha/capita	Low	IT, MD
Forest increment	3,08	5,47	m³/ha	Low	
	0,49	2,80	m³/capita (2010)	Low	
6. Waste					
Total municipal waste	406	464	kg/capita/year	Medium	MT, ME
Landfill	330	185	kg/capita/year	High	
Incineration	0	104	kg/capita/year	Low	
Recycling	0	104	kg/capita/year	Low	
Composting/digestion	2	57	kg/capita/year	Low	
7. Industry (turnover)					
Wood and paper products	na	854	€/capita		/
Food products	na	1.684	€/capita		
Chemical products	na	883	€/capita		
8. Renewable energy (RE)					
Bioenergy in RE	35%	69%	%	Low	ES
Bioenergy in total energy	3,8%	10,6%	%	Low	
9. Energy infrastructure					
Biofuels prod. Capacity	0,000	0,051	ton/capita	Low	
CHP	na	17,3%	% gross electricity generation	Low	
District heating	0	7.404	km		
	0	0	m/capita	Low	

Ukraine

Category	Ukraine	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	45.372.692	18.040.258	n° 2013		RO, FYR, BA, IE, BG, EL
Area	603.549	160.518	km²		
Population density	75	168	n°/km²	Medium	
Land area	1,33	1,42	ha/capita	Medium	
2. GDP and trade					
GDP/capita	3	25	€ 1.000	Low	MD, FYR, BA, KS
	na	100	PPS		
Cross-border movements	2,33	6,87	€1000/capita	Low	
3. Energy					
Primary energy consumption	2,56	3,22	toe/capita (2012)	Medium	/
Energy dependence	27,2	55,4	%	Low	
Renewable energy share	2,7	17,9	%	Low	
GHG emissions	na	9,47	ton CO_2-eq/capita		
4. Agriculture					
UAA	0,942	0,415	ha/capita	High	BG, EE, LT, RO
Cereal yield	4,06	5,20	t/ha	Medium	
Livestock density	0,205	1,020	LSU/ha UAA	Low	
5. Forestry					
Forest area	0,221	0,650	ha/capita	Medium	FR, HU, KS
Forest increment	4,61	5,47	m³/ha	Medium	
	0,98	2,80	m³/capita (2010)	Medium	
6. Waste					
Total municipal waste	277	464	kg/capita/year	Low	RO, BA, FYR
Landfill	209	185	kg/capita/year	Medium	
Incineration	3	104	kg/capita/year	Low	
Recycling	7	104	kg/capita/year	Low	
Composting/digestion	4	57	kg/capita/year	Low	
7. Industry (turnover)					
Wood and paper products	64	854	€/capita	Low	FYR, MD, SR
Food products	434	1.684	€/capita	Low	
Chemical products	98	883	€/capita	Low	
8. Renewable energy (RE)					
Bioenergy in RE	61%	69%	%	Medium	/
Bioenergy in total energy	1,7%	10,6%	%	Low	
9. Energy infrastructure					
Biofuels prod. Capacity	0,000	0,051	ton/capita	Low	
CHP	na	17,3%	% gross electricity generation		
District heating	32.429	7.404	km		
	0,7	0,3	m/capita	High	

United Kingdom

Category	United Kingdom	EU average	Unit	Assessment	Similar countries
1. Population and land surface					
Population	63.905.297	18.040.258	n° 2013		DE, IT, LU, KS
Area	248.528	160.518	km²		
Population density	257	168	n°/km²	High	
Land area	0,39	1,42	ha/capita	Low	
2. GDP and trade					
GDP/capita	30	25	€ 1.000	Medium	IT, FR
	109	100	PPS	Medium	
Cross-border movements	7,30	6,87	€1000/capita	Medium	
3. Energy					
Primary energy consumption	3,05	3,22	toe/capita (2012)	Medium	HR, SI, SK
Energy dependence	46,4	55,4	%	Medium	
Renewable energy share	5,1	17,9	%	Low	
GHG emissions	9,15	9,47	ton CO_2-eq/capita	Medium	
4. Agriculture					
UAA	0,270	0,415	ha/capita	Medium	FR, HR, AT
Cereal yield	6,63	5,20	t/ha	High	
Livestock density	0,771	1,020	LSU/ha UAA	Medium	
5. Forestry					
Forest area	0,050	0,650	ha/capita	Low	BE, NL
Forest increment	7,98	5,47	m³/ha	High	
	0,37	2,80	m³/capita (2010)	Low	
6. Waste					
Total municipal waste	482	464	kg/capita/year	Medium	IE, FR
Landfill	165	185	kg/capita/year	Medium	
Incineration	102	104	kg/capita/year	Medium	
Recycling	133	104	kg/capita/year	Medium	
Composting/digestion	77	57	kg/capita/year	Medium	
7. Industry (turnover)					
Wood and paper products	354	854	€/capita	Medium	ES, IT, LT, PL, PT
Food products	1.429	1.684	€/capita	Medium	
Chemical products	589	883	€/capita	Medium	
8. Renewable energy (RE)					
Bioenergy in RE	72%	69%	%	Medium	/
Bioenergy in total energy	3,9%	10,6%	%	Low	
9. Energy infrastructure					
Biofuels prod. Capacity	0,019	0,051	ton/capita	Medium	
CHP	5,5%	17,3%	% gross electricity generation	Low	
District heating	361	7.404	km		
	0,0	0,3	m/capita	Low	