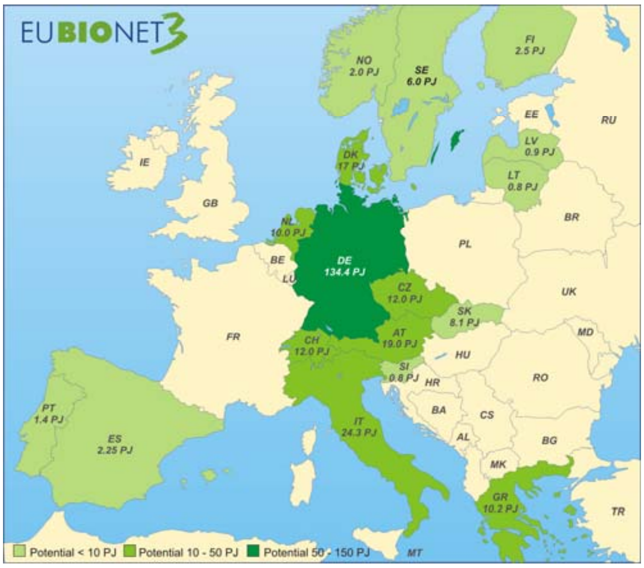
EUBIONET3

Solutions for biomass fuel market barriers and raw material availability - IEE/07/777/SI2.499477

Unexploited biomass sources, availability and combustion properties – D5.1



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INTELLIGENT ENERGY EUROPE

Content

Preface

This publication is part of the EUBIONET III Project (Solutions for biomass fuel market barriers and raw material availability - IEE/07/777/SI2.499477, www.eubionet.net) funded by the European Union's Intelligent Energy Programme. EUBIONETII is coordinated by VTT and other partners are Danish Technological Institute, DTI (Denmark), Energy Centre Bratislava, ECB (Slovakia), Ekodoma (Latvia), Fachagentur Nachwachsende Rohstoffe e.V., FNR (Germany), Swedish University of Agricultural Sciences, SLU (Sweden), Brno University of Technology,UPEI VUT (Czech), Norwegian University of Life Sciences, UMB (Norway), Centre wallon de Recherches agronomiques, CRA-W (Belgium), BLT-HBLuFA Francisco Josephinum, FJ-BLT (Austria), European Biomass Association, AEBIOM (Belgium), Centre for Renewable Energy Sources, CRES (Greece), Utrecht University, UU (Netherlands), University of Florence, UNIFI (Italy), Lithuanian Energy Institute, LEI (Lithuania), Imperial College of Science, Imperial (UK), Centro da Biomassa para a Energia, CBE (Portugal), Energy Restructuring Agency, ApE (Slovenia), Andalusian Energy Agency, AAE (Spain). EUBIONET III project will run 2008 – 2011.

The main objective of the project is to increase the use of biomass based fuels in the EU by finding ways to overcome the market barriers. The purpose is to promote international trade of biomass fuels to help demand and supply meet each other, while at the same time the availability of industrial raw material is to be secured at reasonable price. The EUBIONET III project will in the long run boost sustainable, transparent international biomass fuel trade, secure the most cost efficient and value-adding use of biomass for energy and industry, boost the investments on best practice technologies and new services on biomass heat sector and enhance sustainable and fair international trade of biomass fuels.

The specific objective of WP 5 has been to identify new and unexploited biomass resources, mainly from the agro-industry. On the national level, surveys on biomass resources have been evaluated in order to identify gaps. Finally methods to improve the fuel characteristics of agro-industrial biomass resources has been pointed out. The report has been elaborated by:

- Jorgen Hinge, DTI (Main author, Scandinavian region)
- Eugenius Perednis, LEI (Baltic region)
- Andrej Faber, ECB (Central Eastern region)
- Aino Martikainen, FNR (Central Western region)
- Leonardo Nibbi, UNIFI (Mediterranean region)
- Martti Aho, VTT (cofiring)

Jorgen Hinge, Aarhus Denmark, May 2011

Danish activities supported by

1 Introduction

Bioenergy can be produced from other resources than grain/straw, corn and wood. A conservative estimate is that there is a potential of at least 300 PJ in Europe from agro-industrial residues, which are not currently used for energy purposes. The figure is maybe 2 ½ times larger.

Today, there is an intense debate about whether it is viable to use biomass in large scale production of bioenergy - especially biofuels. One of the criticisms is whether it is improper to use crops that can be used for food or feed. Furthermore in the next decades, a huge pressure on the "traditional" biomass resources like wood and straw can be expected, because so many countries in these years make plans for increased use of biomass for energy.

In the EUBIONET III project the European market for unexploited "alternative" biomass resources is scanned. The main focus was on agro-industrial residues, but other potential biomass has been considered.

1.1 Method

For each country, data sheets have been elaborated for each identified biomass product, listing the most important features of the biomass in question, as well as data on amounts and applicability for different conversion methods (combustion, gasification, biogas, others…). An example of the data sheet is presented in Appendix 1.

Also for each country, the partners have identified relevant surveys on biomass resources and they have evaluated the status, i.e. to identify gaps in biomass resource knowledge.

The national results (data sheets and relevant biomass surveys) have been summarized by region and finally collected in this report.

2 Types and amounts of new and unexploited biomass resources

2.1 European Summary

The data in the project are based on partners’ contacts in EU countries as well as project participants' estimates of the total potential on the basis thereof. The results indicate that there are considerable unexploited resources. The actual reported amounts correspond to an energy potential of approx. 100 PJ, but the assessments which follow, estimates a potential of approx. 300 PJ. This is still only on the basis of biomass, which is detected by direct contacts.

Previous experience from a scan of the Danish market shows a potential of about 500,000 tons of agro-industrial residues alone. If this is scaled up to European level - compared to the number of inhabitants - the potential is around 750 PJ. This is equivalent to slightly less than the total annual energy consumption in Denmark.

In Southern European countries (Greece, Italy, Spain and Portugal) residues from olive production are by far the largest resource. It has been difficult for the partners from these countries to provide precise assessments of the volume, but based on an overall olive harvest of just over 10 million tons, the annual amount of residues would be more than 7 million tons, equivalent to a theoretical energy potential of more than 150 PJ. It should be mentioned that the energy utilization of olive waste is already growing rapidly, as well as for nuts (almond, hazel etc.) shells that in Southern Europe is becoming an interesting potential energy resource, presently already used in substitution of wood pellet fuel into small scale stoves and boilers.

Another large resource is grain screenings, at the European level assessed at a theoretical potential equivalent to 40 PJ. Other biomass types could be residues breweries, the tobacco industry and plant oil (besides olive oil) production, ie. sunflower shells, sheanut shells etc.

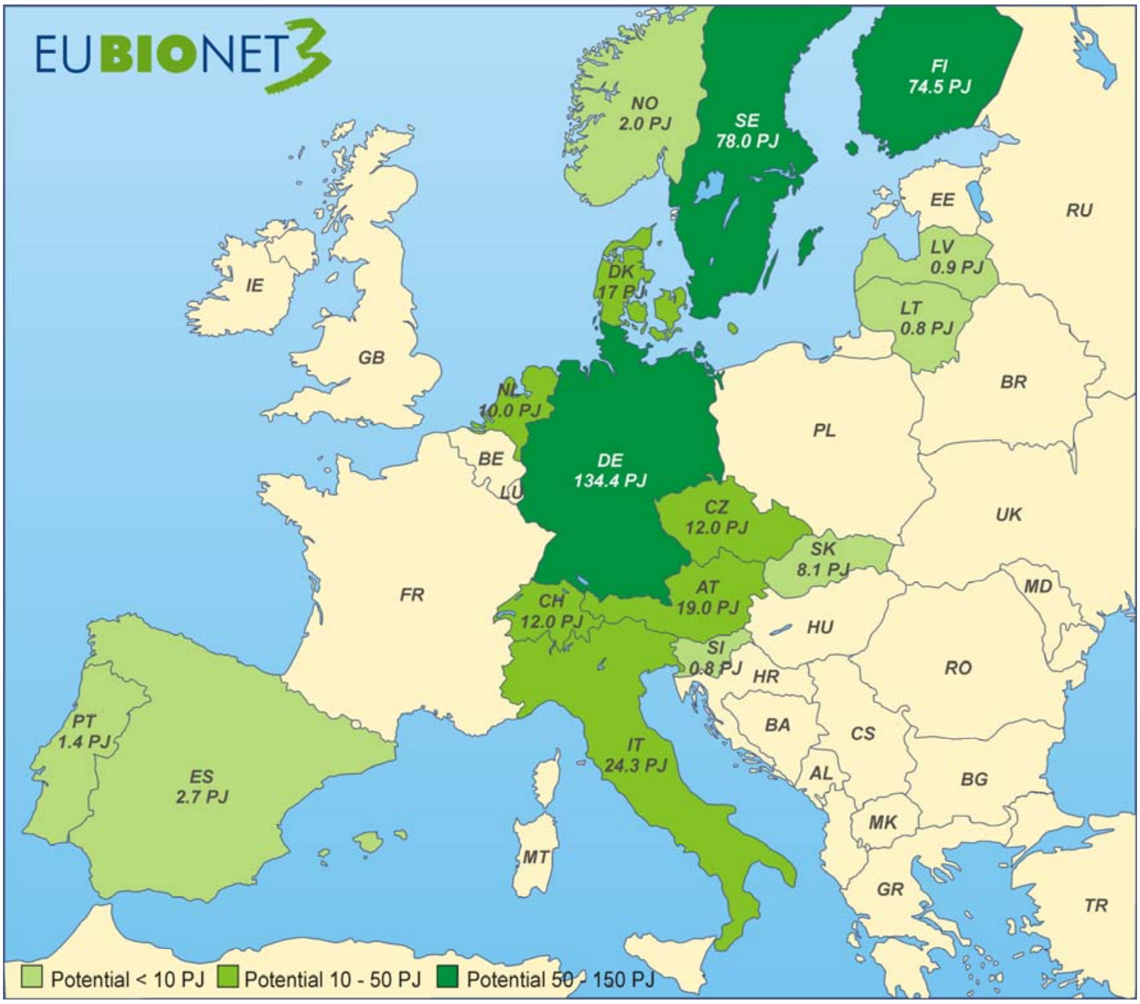

Figure 2.2.1 Identified resources of Agro industrial biomass in partner countries

2.2 Baltic region

2.2.1 Baltic region summary

Table 2.2.1. Energy potential from new and unexplored types of biomass found in Baltic region (Latvia and Lithuania)

Country	Energy potential	Remarks
	PJ/y	
Latvia	0.876	Pot-ale pellets consist more than 54% of new and unexplored biomass products
Lithuania	0.670	
Estonia		
Total in region	1.546	

In the Baltic region 10 new and unexploited biomass products have been identified. The total energy potential for these is estimated at 1.546 PJ annually.

The biomass products are considered applicable for combustion, gasification or biogas production.

Most of the products have a rather high ash content – 5% or more (dry weight basis) – and they are therefore considered to be most suitable for application in large scale conversion plants with specialized equipment for ash removal.

The energy potential from the Baltic countries found in Table 2.2.1 is of course open to discussion:

- The presented results of reports show the big difference of energy potential (in PJ/y) of raw material availability in Scandinavian and Baltic countries. Report shows the big backwardness of availability of raw biomass materials.

- Some of presented raw materials are used only into separate Baltic republic and energy potential isn't considerable (e.g. Buckwheat hulls or chips from Phragmites)

- Some sources e.g. Cheese juices, Meat and bone meal (MBM) and Pot-ale pellets presented into Latvian country report may be available in other countries.

- In the Baltic countries as raw biomass product is use the cottage cheese whey. The consistency of this product is more liquid than cheese whey. This product could be as beneficial fuel in future for energy production, but only in biogas plants.

- At this moment the new and unexploited biomass products identified in Baltic countries are used very slightly. In future the usage of these products will be increased.

- In the mid European countries there are many lakes and closed water ponds accreted with reedy growers. The use of these row productions has economical and environmental profit. It is hard to say when it can be widely used.

2.2.2 Latvia

Table 2.2.2. New types of biomass in Latvia

Biomass type	Amount	Energy potential	Moisture content (as received)	Bulk density	Ash content	Net calorific value (as received)	Applicable for			
	tons/y	PJ/y	%	kg/m^3	% dry	MJ/kg	Combustion	Gasification	Biogas	Other
Pellets from Galega orientalis LV-1	50	0.79 x10^{-3}	App 10.73	607,8	4,47	15.89	X	X	X	
Cottage cheese whey LV-2	7 840	0.132	94.4		13.66	16.87	X		X	
Cheese juices LV-3		0.270	93.8		8.2 (vol%)	17.45	X		X	
Meat and bone meal (MBM) LV-4		0.193 x10^{-3}	1.9		20.27	19.31	X			
Pot-ale pellets LV-5		0.474	8.4	418	7.3	17.70	X	X	X	
Total		0.876								

In Latvia, five new and unexploited biomass products has been identified and described in this project. All five of products are suitable for combustion, whereas two of products also may be suitable for gasification and four for biogas production.

Figure 2.2.2.1 Example of agro-industrial biomass product from Latvia: Pot-ale pellets

The total annual energy potential is estimated at some 0.876 PJ. Pot-ale pellets (LV-5) and cheese juices (LV-3) are by far the most interesting and energy potential of these biomass products is the biggest.

Some of these biomass products e.g. cottage cheese whey and Meat and bone meal (MBM) have a rather high ash content until compared to "traditional wood fuels".

It should be noted that only two of biomass products described in this project Pellets from Galega orientalis and Pot-ale pellets are classifiable according to EN 14962-1.

2.2.3 Lithuania

Table 2.2.3. New types of biomass in Lithuania

Biomass type	Amount	Energy potential	Moisture content (as received)	Bulk density	Ash content	Net calorific value (as received)	Applicable for			
	T/y	PJ/y	%	kg/m3	%	MJ/kg	Combustion	Gasification	Biogas	Other
Buckwheat hulls, LT 1	2000	0.033	5	140	5-7	16.75	X	X		
Cottage cheese whey, LT 2	26850	0.453	94.4		13.66	16.87	X		X	
Chopped Reed canary grass (*Phalaris arundinacea)* *LT 3*	80	0.0014	5.1	57	7	17.54	X	X	X	
Distillers Dried Grains, LT 4		0.182	90	950		11.96	X	X	X	
Chips from Phragmites australis, LT 5	40	0.0007	11.3	57	5	17.5	X	X	X	
Total		0.6706								

In Lithuania, five new and unexploited biomass products has been identified and described in this project. All five of products are suitable for combustion, whereas four of products also may be suitable for gasification and four for biogas production.

Figure 2.2.3.1 Example of agro-industrial biomass product from Lithuania: Buckwheat hulls

The total annual energy potential is estimated at some 0.6706 PJ. cottage cheese whey, (LT 2) and distillers dried grains, (LT 4) are by far the most interesting and energy potential of these biomass products are the biggest.

Some of these biomass products e.g. cottage cheese have a rather high ash content until compared to "traditional wood fuels".

Four of these biomass products described in this project are classifiable according to EN 14962-1.

2.2.4 Estonia

Production of biofuels in Estonia (source: Estonian Institute of Economic Research, 2007)

Solid biofuels

- Fuel wood, wood residues and cutting residues – (28.6 PJ)
- Pellets (338 000 tons, 5.4 PJ)
- Briquettes (~49 000 tons, 0.76 PJ)
- Straw and other herbaceous biomass (900 tons,~0.013 PJ)

Gaseous bioenergy (biogas) – for heat and power production

- Landfill gas (one company Terts Ltd in Tallinn)
- Agricultural biogas (one company in Saarenmaa)
- Biogas production – 11.7 million m^3 (2007).

Primary energy from biomass fuels

- 98.8% of produced solid biofuel's energy originated from woody biomass, 0.2% from agro- and transport biofuels and 1% biogas and black liquor.

According to report of Estonian Institute of Economic Research, the new and unexploited biomass resources aren't described.

Prognosis of additional amounts of bioenergy from non-traditional sources (Estonia)

Herbaceous biomass

- Energy crops, hay of natural grasslands and reed – theoretical accessibility 14.4-28.08 PJ, realistic in short time period 3.6-5.4 PJ.

Agricultural residues

- Straw– theoretical accessibility 9 PJ, realistic 2.9 PJ.

Biogas

- Landfill gas – 6 larger landfills 210 - 250 GWh/a.
- Biogas - manure, sludge and biodegradable waste 96 million m^3 or 2.07 PJ

Total theoretical average is 32.04 PJ and realistic in short-run is 7.2 PJ.

2.3 Central Eastern region

2.3.1 Central Eastern region summary

Table 2.3.1. New types of biomass found in Central-East Europe

Country	Amount	Energy potential
	tons/year	PJ/y
Slovenia	57 176	0.79
Czech Republic	760 000	12.00
Slovakia	456 000	8.09
Total in region	1 273 176	20.88

Based on the resources identified in this report, there's an estimated potential of app. 21 PJ from new and unexploited biomass products.

Most of the products have a rather high ash content – 5% or more (dry weight basis) – and they are therefore considered to be most suitable for application in large scale conversion plants with specialized equipment for ash removal. Some products contain high moisture, thereby low net calorific value, what will require some additional operations to treat it.

The energy potential from the Central-East Europe countries found in Table 2.3.1 is of course open for discussion:

- An energy potential of the by-products in the biofuel production and in the food industry at oil pressing, beer and malt production etc. is high. Some interesting technologies that can effectively exploit this potential are offered in the market, but some of them are not tested in praxis.

- Some sources reported for one country may be available in other countries, they were just not identified in this project (i.e. it could be interesting to verify whether the potential of Solid fractions from animal manure reported from Slovenia also may be available in other countries.)

2.3.2 Slovenia

Table 2.3.2. New types of biomass in Slovenia

Biomass type	Amount	Energy potential	Moisture content (as received)	Bulk density	Ash content	Net calorific value (as received)	Applicable for			
	tons/y	PJ/y	%	kg/m^3	%	MJ/kg	Combustion	Gasification	Biogas	Other
Manure from horse breeding	12 000	0.0264	65-85	720	15-25	<2.2	X	X	X	
Manure from chicken breeding	30 000	0.451	70-85 After drying and pelletizing: M=8-10%	720	15-25	<2.2 15.04 MJ/kg dry matter	X	X	X	
Residues from olive oil processing industry	80	0.0015	4-24	615		18-20	X			
Diluted caramel and nougat	96									
Brewer's grain pellets	15 000	0.280	77-81%	0.45 kg/l	2.5	18.64 MJ/kg dry matter	X		X	
Total	57 176	0.76								

In Slovenia, five new and unexploited biomass products has been identified and described in this project. Four are suitable for combustion, where as two products also may be suitable for biogas production and gasification.

The total annual energy potential is estimated at some 0.76 PJ. This is not a big potential in comparison to other countries, but in spite of this fact, manure from animals and brewer's grain pellets are very interesting. It has proved very difficult to estimate the potential from diluted caramel and nougat.

The described biomass types in general has a very high ash content compared to traditional wood fuel, and they are therefore in general considered to be most suitable for application in large scale conversion plants with specialized equipment for ash removal.

Spent grain after it has been used in the production of beer

Figure 2.3.2.1 Example of agro-industrial biomass product from Slovenia: Dry brewers grain

2.3.3 Czech Republic

Table 2.3.3. New types of biomass in Czech Republic

Biomass type	Amount	Energy potential	Moisture content (as received)	Bulk density	Ash content	Net calorific value (as received)	Applicable for			
	tons/y	PJ/y	%	kg/m^3	%	MJ/kg	Combustion	Gasification	Biogas	Other
Rapecake	600 000	10	10		6.5	18	X	X	X	
Sunflower-cake	30 000	0.5	10		7	17	X	X	X	
Mulching bark	< 40 000	Min. 0.3	38-52	440	5-7	7.5-11	X	X	X	
Barley-impurities and tailings	10 000	0.142	5,5		14.5	14.2	X	X	X	
Sugar-beet	80 000	1.05	12		10.9	13.1	X	X		
Total	760 000	12								

Figure 2.3.3.1 Example of agro-industrial biomass product from the Czech Republic: Rape cake

In Czech Republic, five new and unexploited biomass products has been identified and described in this project. The total energy potential from those four biomass types is estimated at app. 12 PJ. Quantity of rape cake from the rape-oil production is very interesting, it represents a big energy potential. It is necessary to say, that a high content of nitrogen (cirka 5%) and sulphur, this product may cause high emissions of NO_x and SO_x.

The new biomass products are considered applicable for combustion, gasification and/or biogas production.

2.3.4 Slovakia

Table 2.3.4. New types of biomass in Slovakia

Biomass type	Amount	Energy potential	Moisture content (as received)	Bulk density	Ash content	Net calorific value (as received)	Applicable for			
	tons/y	PJ/y	%	kg/m^3	%	MJ/kg	Combustion	Gasification	Biogas	Other
Dried Distillers Grains with Solubles (DDGS)	150 000	2.5	10-12	800	7-10	16 - 19	X			X
Rapeseed	300 000	5.5	5	800	6.1	17-21.8	X		X	
The malting wastes	6 000	0.09	5		11.6	15.26	X			
Total	456 000	8.09								

In Slovakia, three new and unexploited biomass products has been identified and described in this project. The total energy potential for those five biomass types is estimated at 8.09 PJ.

Dried Distillers Grains with Solubles (DDGS) and rapeseed are very interesting.

DDGS are products of bioethanol production. They are produced of cut parts drying liquid discharged from the distillation column. Liquid shapes are inhomogeneous mixture of insoluble and soluble particles with a water content of about 90%. Mechanical separation and evaporation of water dries slops in powder form.

Mouldings of rape are produced as solid residues within pressing and extraction of rape seeds with solvent. After mechanical separation from solvent are mouldings almost without moisture and, with 2% of oil content. They look coarse powder.

Mouldings and stillage in powder forms are unusable for energy use. In the minority relative to other solid fuels they could be cofired. Particularly in the calcine and straw it is high risk to the boiler to melt stillage and straw at low ash melting temperature (600 ° C). Raw materials are physically and mechanically adjusted to a final shape of (micro) granules and they are applicable to combustion in fluidized bed boilers with no addiction of other fuels. Fluid fuel boiler that can produce steam and electricity to the parameters (temperature 530 ° C) which is not possible with any other biomass burning.

2.4 Central Western region

2.4.1 Central Western region summary

Table 2.4.1 New types of biomass found in Central-West Europe

Country	Amount	Energy potential
	tons dry matter/year	PJ/y
Netherlands	560 000	10.20
Austria	7 334 638	18.97
Germany	49 000 000	134.40
Total in region	57 000 000	163.60

In Germany and in Austria were several new bioenergy sources identified. The biggest single potential is straw in Germany, 130 PJ. According the definition of this study, straw falls not under the definition of new and unexploited biomass products. Without straw the energy potential identified in this report in Central-West Europe is 34 PJ annually. Most of the biomass resources are residues and by-products from agriculture and food production industry.

Problematic during the identification of the potential quantities was that due to the high utilization rate of biomass, the feedstock market in the Netherlands is getting increasingly competitive and companies don’t want to let competitors know how much biomass they process. As a result it was not possible to identify more than only one unexploited biomass resource, chicken manure, in the Netherlands.

2.4.2 Netherlands

Table 2.4.2. New types of biomass in Netherlands

Biomass type	Amount	Energy potential	Moisture content (as received)	Bulk density	Ash content	Net calorific value (as received)	Applicable for			
	tons/y	PJ/y	%	kg/m³	%	MJ/kg	Combustion	Gasification	Biogas	Other
Chicken Manure	1.2-1.4 Million[1]	10.2[2]	19.3-46.6[3]	605-625[4]	10-17.5	12.7[5]	x	x	x	x
Total	1.2-1.4 Million	10.2	19.3-46.6	605-625	10-17.5	12.7	X	X	X	X

Despite intensive research only one biomass stream, which meets the for this report defined criteria for new bioenergy sources (less- or unexploited, available at least 10,000 tonnes per year and should be mainly agro-industrial waste products, i.e. biomass residues produces at a central site, and not dispersed on the field or in the forest) could be identified in the Netherlands.

The theoretical, not utilised, potential of chicken manure is 10.2 PJ/year. About 0.4 million tonnes of the annual production (1.2-1.4 million tonnes) is used as a fertiliser and basically the entire rest could be used for large-scale combustion. 440,000 tonnes are already used for energy production in the chicken manure combustion plant in Moerdijk.

Martin Junginger identified for this report some reasons for the shortage of new and unexploited biomass resources through interviews with experts in the food production sector and other experts.

Almost all biomass is in the Netherlands already used in one way or other and biomass streams like animal fats etc. are already utilized and have an economic value which often prevents the use for energy. Secondly, the Dutch food processing industry has already been looking at the use of biomass for energy and biomass amounts of 10,000 tons or more are basically all utilized. Unutilized biomass streams are mostly too small or are available only irregularly (e.g. rejected pallets of food stuff). Third discussed reason is that due to the high utilization rate of

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[1] Estimated total production (of which app. 0.8 Mio t already used as fertilizer, 0.44 Mio t already combusted).
[2] Based on 800,000 tonnes.
[3] Depending on the purpose for which the chicken were grown (meat or eggs).
[4] As received.
[5] With moisture content of 27.3 w-%.

biomass, the feedstock market is getting increasingly competitive and companies may not want to let competitors know how much biomass they process.

2.4.3 United Kingdom

No available information.

2.4.4 Austria

Table 2.4.4.1 New types of biomass in Austria

Biomass type	Amount	Energy potential	Moisture content (as received)	Bulk density	Ash content	Net calorific value (as received)	Applicable for			
	tons/y[6]	PJ/y	%	kg/m³	%	MJ/kg	Combustion	Gasification	Biogas	Other
Horse litter	600 000[7]	0.768	60	260	5-10	5.6-6.2	X[8]		X[9]	X[10]
Sunflower seed shell and sunflower press cake pellets	32 077.3	0.706	< 15	500-600[11]		18.6-22.0[12]	X		X	X[13]
Reed	100 000		-	121[14]	5-7	17[15]	X		X	X[16]
Gras-hay	1 Million[17]	17.5	15	121[18]	5-7	8-8.5	X		X	X[19]
Stone fruits kernel	10 100	0.00018	n.a	n.a.	2-5	16-18	X			X[20]
Viniculture residues	100 300-136 800[21]	2.43	50-<30	190	3.5-4.5	17.75[22]	X		-	X[23]
Total	**7 334 638**	**18.97**								

[6] Dry matter
[7] In total; estimated potential for energy production: 120 000 t
[8] Applicable for combustion if wood saw dust is used for litter; the applicability is limited if straw is used.
[9] Applicable for biogas production if straw is used for litter; but not if wood sawdust is used.
[10] As fertilizer for agricultural areas
[11] Moisture content 10 w-%.
[12] Moisture content 15 w-%.
[13] Animal feed.
[14] Moisture content 10 w-%.
[15] On dry matter basis.
[16] Insulating material, building material, rush mats, cane roof material.
.[17] 6.45 Mio tons total; up to 1 million tons (dry matter) are not used for animal feed and could be used for thermal and technical applications.
[18] Moisture content 10 %.
[19] Animal feed, litter, GREEN BIOREFINERY-fibre, lactic acid, protein production.
[20] Fatty acid production, cosmetic industry, food production.
[21] Theoretical potential: 2.2 to 3 tons per hectare; Austria: 45 600 ha.
[22] Dry matter.
[23] Remain in the vineyards as organic fertilizer.

In Austria, six new and unexploited biomass products have been identified and described in this project. All are suitable for combustion, whereby the applicability of horse litter with straw is limited on combustion plants. Horse litter, sunflower residues, reed and hay can be used for biogas production also.

Many of the identified resources are used in some way already, e.g. as animal feed, fertilizer, or construction material (cane roofs). Only viniculture residues and stone fruits kernels are rather unused resources.

The total annual energy potential is estimated at 19 PJ. The highest potential has hay, which should be available also in other European countries, as well as horse litter and reed. The availability of sunflowers and wine plants is restricted to the warmer countries in Europe. Even though e.g. sunflowers grow in Scandinavia, it's cultivation for energy production wouldn't be economical. The same applies for many stone fruit trees.

Horse litter and sunflower press cake pellets shouldn't be used as a domestic fuel. Because of high nitrogen, sulphur and chlorine their combustion in small plants may exceed the emission values and therefore they should be combusted only in high quality plants under controlled combustion conditions and with end-of pipe-technologies. The horse litter should be mixed with wood chips because of its high moisture level.

Figure 2.4.4.1 Example of agro-industrial biomass product from Austria: Sun-flower shell pellets Please under figure text, is number correct

2.4.5 Germany

Table 2.4.5.1 New types of biomass in Germany

Biomass type	Amount	Energy potential	Moisture content (as received)	Bulk density	Ash content	Net calorific value (as received)	Applicable for			
	tons/y	PJ/y	%	kg/m^3	%	MJ/kg	Combustion	Gasification	Biogas	Other
Beer draff	2 Million[24]	2.35	75-80			20.14[25]	X		X	X[26]
Straw	46 Million	130[27]	14	n.a.	4,5-6	14.4[28]	X			X[29]
Grape marc	262 500	0.32	70			9.7	X		X	
Fruit juice manufacturing wastes	697 647[30]	1.73	High[31]	n.a.	n.a.	n.a.	X[32]		X	X[33]
Flotsam	28 500	0.009	30-70			3	X		X	
Total	49 Million	134.4								

Five new and unexploited biomass products were identified and described in Germany. Three of them are residues from the food and beverage industry, beer draff, grape marc and fruit juice manufacturing wastes, which all can be used for biogas production. Residues from fruit processing may not be available in all countries in such amounts that the energy production would be profitable, but beer draff and straw are resources available everywhere.

Flotsam is available only in coastal regions. Because it's collection is expensive and the energy content rather low, the energy production may be profitable only regions, where it would be collected because of other reasons, e.g. beach cleaning for tourism, dike protection, anyway.

Straw is resource which wasn't actually defined as a "new and unexploited biomass resource" in this research, but since the bioenergy production from straw is very

[24] Estimation: 20-45% available for energy production.
[25] Dry matter.
[26] Animal feed
[27] Estimation; if 20% of annual straw production is used for energy production.
[28] Dry matter.
[29] For biofuels of the 2. generation.
[30] Estimation: 25-50% available for energy production (174,412-348,823 tons/a).
[31] Differs depending on fruit or vegetable and production techniques, examples: carrot pomace 86%, apple pomace 76%.
[32] High energy need for drying the pomace before combustion problematic.
[33] Ethanol production.

low in Germany (3 PJ), but potential very high, it is also mentioned in the German report.

2.5 Mediterranean region

2.5.1 Mediterranean region summary

Table 2.5.1 Potential amounts and energy for new types of biomass found in Mediterranean Region

Country	Amount	Energy potential
	tons as received/year	PJ/y
Italy	1 359 600	24.28
Greece	742 255	10.20
Portugal	78 279	1.39
Spain	3 825 086	2.67
Total in region	**6 005 220**	**38.54**

The greatest potential from new materials is widely from olive mills residues (Figure 2.5.1 and Table 2.5.2). This residue is presently exploited in Spain (amounts are not taken into account within this survey since the exploitation is presently well assessed) and presents great potentials in the other surveyed countries, especially in Italy, where its bioenergy use is growing within the very last years.

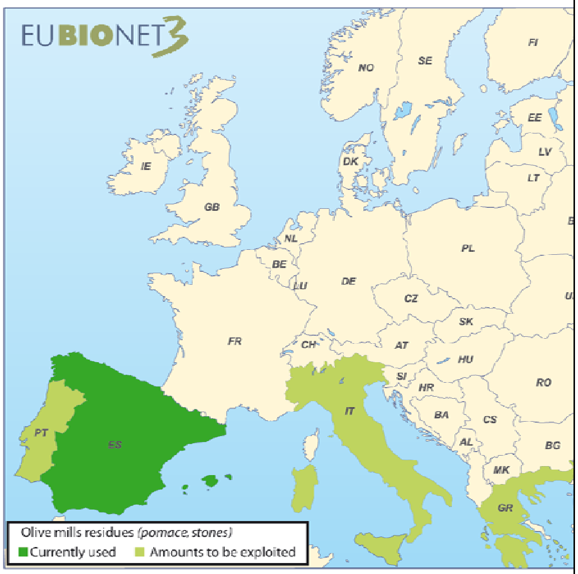

Figure 2.5.1 Olive mills residues utilisation for energy purposes: status in the surveyed countries

Figure 2.5.2 Rice food industry residues utilisation for energy purposes: status in the surveyed countries

Residues from rice food industries (figure 2.5.2 and table 2.5.2) are also very important for future potential in Greece, Portugal and Spain, while in Italy this material is widely used for bionergy in Northern Italy where several plants burn this residue, together with wood chips, for energy production.

Another important material not completely exploited for bioenergy use is the shells from several kinds of nuts (walnuts, almond and hazelnuts) in Greece, Italy and Spain (Figure 2.5.3 and table 2.5.2).

In Greece and in Spain a potential of residues of cotton manufacturing (stalks and ginning residues) is present with important amounts (Figure 2.5.4 and Table 2.5.2).

The other amounts per material are presented within Table 2.5.2

Figure 2.5.3 Nut shells utilisation for energy purposes: status in the surveyed countries

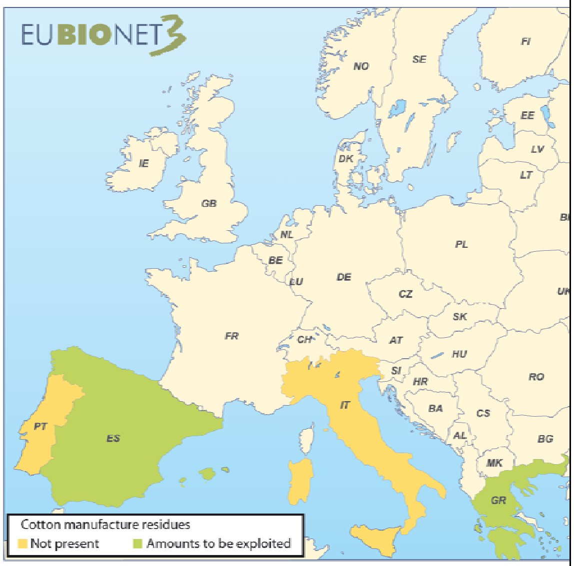

Figure 2.5.3 Rice food industry residues utilisation for energy purposes: status in the surveyed countries

More than 6 million tons of new materials could enter into the biomass to energy market in the four surveyed European Mediterranean countries (Greece, Italy, Portugal and Spain).

These new materials are potentially exploitable mostly through combustion and also through gasification and anaerobic digestion.

The total energy potential, excluding wet brewery residues for biogas, is about 38.5 PJ per year.

The residues of olive mills (exhausted olive pomace or olive stones) are the most interesting material not completely exploited, and its full exploitation will result in an increase up to 30 PJ of gross energy potential, excluding the already important contribution present in Spain.

Rice industry residues and cotton manufacture residues are also very important. Nuts shells from several kinds of nuts (almond, walnut and hazelnut) are already used for energy production in combustors or even in small scale boilers instead of wood pellet, and they could result in a total amount of about 2.4 PJ/year increase in gross energy potential in the surveyed countries.

Table 2.5.2 - Potential available per material typologies

Biomass type	1000 tons/year (as received)	PJ/year (as received.)	Countries
Olive mills residues	1 833.79	30.61	Greece, Italy and Portugal
Rice husks and shells	196.81	2.80	Greece, Portugal and Spain
Nut (walnut, almond and hazelnut) shells	780.25	2.39	Greece, Italy and Spain
Cotton manufacture residues	162.39	2.20	Greece and Spain
Pellets from olive oil and cork residues	20.00	0.36	Portugal
Fruit kernels from canneries	7.68	0.11	Greece
Tobacco waste	4.30	0.06	Italy
Wet brewers grains	3 000.00	-	Spain

2.5.2 Italy

Table 2.5.2.1 New types of biomass in Italy

Biomass type	Amount	Energy potential	Moisture content (as received)	Bulk density	Ash content	Net calorific value (as received)	Applicable for			
	tons/y	PJ/y	%	kg/m^3	%	MJ/kg	Combustion	Gasification	Biogas	Other
Exhausted Olive pomace[34]	1 260 000	22.700	5.5	850	4.3	18.704	X	X	X	X
Olive stones[35]	*60,000*	*10.800*	6.1	979	1.6	18.778	X	X		
Tobacco Waste	4 300	0.065	-	-	-	-	X	X	X	
Hazelnuts shells	47 300	0.752	5	360	3	15.9	X	X		
Almond shells	48 000	0.763	10.75[36]	400	2.8[37]	15.945[(36)]	X	X		
Total	**1 359 600[(34)]**	**24.279[(34)]**								

In Italy the following other "new" materials could be technically available but presently do not offer a potential which is economically suitable for biomass to energy.

Cork residues

Italy is one of the main cork producers in the world, being the production almost completely concentrated in the Sardegna region. Italian production (15,000 tons/year) is mostly concentrated in Sardegna region (12, 000 tons/year)[38]. The material has already several uses:

- Bottle corks;
- Biohousing and Bioarchitecture;
- Design gadgets;
- Clothing
- Handycraft;
- New technologies (i.e. aerospace insulants).

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[34] Total amounts of material and energy for by products of olive mills must not be taken into account as the sum of separate totals. Olive stones are part of exhausted olive pomace if these are not stoned before further process. Thus, the amounts related to exhausted olive pomace contain also the potential of olive stones.
[35] Depending whether stones are extracted from virgin pomace (most common) or exhausted pomace.
[36] Average value based on a range
[37] Most common on a range of values
[38] http://www.sugheronaturale.it/

The material to be used for bioenergy should be, thus, the residues of manufacturing. By the way, residues, which should be expected as few percentage points of the production, do not represent a valuable amount for the biomass to energy chain. Furthermore, some pilot projects of selected waste recycling[39] [2] already active, aim to the recovery of wine corks to be re-used for bio-housing purposes, where the material is used as natural insulator.

Feathers and plumes

A bioenergy project aimed at recovering feathers and plumes from old clothing and furniture items (eiderdowns, feather pillow and padded jackets) is starting in Emilia Romagna Region; amounts are presently under evaluation but they seem to be not enough large in order to start up a bioenergy chain.

Wider amounts should derive from food industry (feathers and plumes from aviculture food industry). Part of this material is already used as insulating for clothing and biohousing. An evaluation of residues potential in Italy is presently not possible, since this kind of waste undergoes a unique code (020203 - Wastes from the preparation and processing of meat, fish and other foods of animal origin; (non hazardous) Materials unsuitable for consumption or processing) together with several other materials. As from the 2006 waste disposal data (MUDA) the total amount of this CER code waste for Italy is about 128,000 tons/year as received.

[39] *http://www.rilegno.it/_vti_g2_newsArt.aspx?idA=113*

2.5.3 Greece

Table 2.5.3. New types of biomass in Greece

Biomass type	Amount	Energy potential	Moisture content (as received)	Bulk density	Ash content	Net calorific value (as received)	Applicable for			
	tons/y	PJ/y	%	kg/m^3	%	MJ/kg	Combustion	Gasification	Biogas	Other
Rice Husks	33 342	0.530	6.0 - 10.0	73 - 130	13.0 - 25.0	13.26 - 13.95	X	X		
Cotton ginning residues	149 250	2.130	7.2 - 15.0	25	2.0 - 15.0	13.04 - 14.07	X			
Fruit kernels from canneries	7 680	0.110	4.8 - 20.0	474 - 540	0.65 - 1.6	15.19 - 18.54	X			
Exhausted olive pomace	550 043	7.400	6.5 - 30.0	567	2.6 - 9.6	12.17 - 17.78	X			
Walnut shells	130	0.002	8	336	1.1-6.0	-	X			
Almond shells	1395	0.020	3.3 -9.7	400 - 425	0.55 - 4.81	15.07 - 16.10	X	X		
Hazelnut shells	415	0.006	5.0–12.45	319.14	0.7 - 1.1	17.2 - 18.88	X			
Total	**742 255**	**10.198**								

2.5.4 Portugal

Table 2.5.4. New types of biomass in Portugal

Biomass type	Amount	Energy potential	Moisture content (as received)	Bulk density	Ash content	Net calorific value (as received)	Applicable for			
	tons/y	PJ/y	%	Kg/m^3	%	MJ/kg	Combustion	Gasification	Biogas	Other
Exhausted Olive pomace	23 745	0.511	10.0 - 12.0	622	4.6	13.9 - 19.2	X	X	X	
Pellets from olive oil and cork residues	20 000	0.360	8.9	-	3.9	18.0 - 22.2	X	X		X
Rice husks	34 534	0.518	13	-	15	15	X	X		X
Pine shells	12 000	0.211	11	-	-	17.6	X	X		
Almond shells	1 584	0.028	11	-	-	17.6	X	X		
de-alcoholised grape bagasse	69 840	0.620	20	-	-	8.88	X	X		
Total	**161 703**	**2.248**								

Figure 2.5.4.1 Example of agro-industrial biomass product from Portugal: Rice husks

2.5.5 Spain

Table 2.5.5. New types of biomass in Spain

Biomass type	Amount	Energy potential	Moisture content (as received)	Bulk density	Ash content	Net calorific value (as received)	Applicable for			
	tons/y	PJ/y	%	kg/m^3	%	MJ/kg	Combustion	Gasification	Biogas	Other
Rice Shells	128 934 – 143 260	1.755	7.0 - 12.0	650 - 700	7	18.85 - 20.95	X			
Wet brewers grains	3 000 000	-	75 - 80		7.0 - 10.0	3.08			X	
Almond shells	683 010	0.848	8.0 - 12.0	> 1 000[40]		14.67 - 16.76	X			
Cotton stalks	13 142	0.066	7.0 - 12.0	650 - 700	3.16	18.85 - 20.95	X			
Total	3 825 086[41]	2.669[42]								

Figure 2.5.5.1 Example of agro-industrial biomass product from Spain: Almond shells

[40] As briquettes
[41] Total considering the net calorific value for rice shells
[42] Excluding Wet brewers grains, that is not computable

2.6 Scandinavian region, including Finland

2.6.1 Scandinavian region summary

Table 2.6.1. Energy potential from new and unexplored types of biomass found in Scandinavia

Country	Energy potential	Remarks
	PJ/y	
Sweden	78	Stumps account for 72 PJ
Norway	2	
Denmark	17	Including solid fractions from animal manure and aquatic biomass (algae)
Finland	72.0 2.5	Only forest residues – technical potential 115 PJ of which 48 PJ is exploited Stalk residues from oil plant
Total in region	99.5	

Based on the resources identified in this WP, there's an estimated potential of 99.5 PJ from new and unexploited biomass products. Finland is not included in the region, however a potential of 115 PJ from forest residues and 2.5 PJ stalk residues from oil plants has been identified from one of the Finnish surveys.

The energy potential from the Scandinavian/Nordic countries found in Table 2.6.1 is of course open to discussion:

- Whereas some of the products may not in reality be available for energy production (i.e. because of "competition from other purposes", outphasing of production etc.), others may increase in amount.
- Some sources reported for one country may be available in other countries, they were just not identified in this project (i.e. it could be interesting to verify whether the huge potential of stumps reported from Sweden also may be available in other countries.)
- Aquatic biomass in the form of algae is a new and unexplored resource when it comes to energy production. At the moment it is hard to say, if and when – and to what extent - it can be explored; if so, the resource may be huge (and available to all countries with water assets).
- Solid fractions from animal manure represent another very interesting resource in terms of energy potential. However, the exploitation of the resource is open to debate, because it may to some extent result in depletion in soil quality if some of the manure carbon is not re-circulated to the farmland.

2.6.2 Sweden

Table 2.6.2. New types of biomass in Sweden

Biomass type	Amount	Energy potential	Moisture content (as	Bulk density	Ash content	Net calorific value (as received)	Applicable for			
	tons/ y	PJ/y	%	kg/m³	%	MJ/kg	Combustion	Gasification	Biogas	Other
Stumps (SE-5)		72.00	App 50	300	1.4-7.0	19.7 – 20.1 MJ/kg dry matter	X			
Pellets from distillers waste		?	67		5 (of dry matter)	17.5 (M=10%)	X		X	
Cereal screenings		1.76[1)]	10-12		9-13,4 (vol%)	14.2-14.6	X		X	
Pellets from rape seed residues	120, 000	4.32	9-11	(close to density of wood pellets)	5-8	18.2-22.5 MJ/kg dry matter	X			
(Landfill gas)		0,21								X
Total		78 PJ								

In Sweden, four new and unexploited biomass products have been identified and described in this project. All four are suitable for combustion, whereas two products also may be suitable for biogas production.

The total annual energy potential is estimated at some 78 PJ. As a reference, stumps are however by far the most interesting, the theoretical potential amounting to about 72 PJ a year. It has furthermore proved very difficult to estimate the potential from pellets from distillers waste, as most of the material today is used for animal feed.

It should be noted, that all four types have a rather high ash content (compared to "traditional wood fuels"), which may indicate, that these biomass types should be used in larger boiler plants with ash removal equipment (as opposed to small scale / "private" boilers)

Besides the four new biomass types, gas from landfills has been described; this falls not under our definition of new and unexploited biomass products; anyway, the potential is estimated at 59 GWh – equal to 0.212 PJ.

A general remark to use of agricultural field residues like straw for most areas in Sweden is that the soils to a large extent are minerogenic with relatively low percentages of organic content. This means a high share of residues needs to be ploughed down in order not to lose productivity.

2.6.3 Norway

Table 2.6.3. New types of biomass in Norway

Biomass type	Amount	Energy potential	Moisture content (as received)	Bulk density	Ash content	Net calorific value (as received)	Applicable for			
	tons/y	PJ/y	%	kg/m3	%	MJ/kg	Combustion	Gasification	Biogas	Other
Grain screenings	18 700	0.25	<20		<4	13.1	X			
Oat husk	>15 000	0.20	<20		<4	13.1	X			
Brewery mash	App 6 000 (dry matter	0.86	(>70?)						X	
Bone meal	44 000 (dry matter)	0.63	5			14.4 (biogas)			X	
(straw)	>400 000	(>5.4)	<20	80-125	3-5		X			
Total		1.94								

In Norway, four new and unexploited biomass products has been identified and described in this project. The total energy potential from those four biomass types is estimated at app. 2 PJ.

The new biomass products are considered applicable for combustion and/or biogas production

Furthermore the straw potential has been described; this falls not under our definition of new and unexploited biomass products; anyway the potential is estimated at more than 5.4 PJ.

2.6.4 Denmark

Table 2.6.4. New types of biomass in Denmark

Biomass type	Amount	Energy potential	Moisture content (as received)	Bulk density	Ash content	Net calorific value (as received)	Applicable for			
	tons/y	PJ/y	%	Kg/m^3	%	MJ/kg	Combustion	Gasification	Biogas	Other
Pellets from shea nut shells (DK-1)	>10 000	>0.19	8.2	700	7	18.7	X	X		
Solid fractions from animal manure (DK-2)	3 million	19.5 (est. realiza ble potenti al 9.75)	65-85 (8-10 as dried pellets)	720	15-25	0-2.2 (12-16 as dried pellets)	X	X	X	
Grain screenings (DK-4)	~100 000	1.1	15	120-250	5-8	11-14	X			
Mash from breweries (DK-5)	150 000	0.6	75-80			20 (on dry matter basis			X	
Aquatic biomass-algae (DK-6)		1.8-9	70-90		8-18	0-8.5			X	
Total		17.1								

In Denmark, five new and unexploited biomass products has been identified and described in this project. The total energy potential for those five biomass types is estimated at 17.1 PJ. This includes the assumption, that half of the theoretical potential for energy production from solid fractions from animal manure and half of the estimated potential from aquatic biomass can be realized.

In a national project an amount of some 278,000 tons (dry matter) of agro-industrial biomass products annually has been estimated (Nikolaisen, 2010) with an estimated energy potential of some 17.5 PJ. This does not include the solid fractions from animal manure or the aquatic biomass; if these are included, an annual potential of some 32.7 PJ can be estimated for Denmark.

Figure 2.6.4.1 Example of agro-industrial biomass product from Denmark: Pellets from grain screenings

The biomass is considered applicable for combustion, gasification or biogas production. The described biomass types in general has a very high ash content compared to traditional wood fuel, and they are therefore in general considered to be most suitable for application in large scale conversion plants with specialized equipment for ash removal.

3 Overview of biomass surveys

3.1 Baltic region

3.1.1 Baltic region recommendations

Baltic countries presented 6 surveys of biomass. In one of these was shows all renewable resources potential that are available for energy production into another's survey covers a lot of information concerning qualitative parameters and availability of resources of biomass potential. The survey gives very good information on different types of energy production from biomass. In this context it means, that the surveys described in this project is considered up-to-date and covering the most important biomass resources in the region.

Unfortunately in these surveys there is little information of possibilities of enlargement of the raw material base.

3.1.2 Latvia

Many surveys on biomass potential have been made in Latvia. The latest one covers all fields of renewable energy resources including biomass and sets the overall potential, but the potential mainly is taken from surveys done in previous years (2005, 2006) adding only few updates. It can be considered that new calculations and estimations are necessary to make paying more attention to biomass for biofuel production and green biomass potential.

In the latest years mainly the surveys on setting up the wood biomass potential from forestry (stumps, branches, etc.) from woodworking industry and non forest areas (bank of ditches, overbrowned willows, untended territories) have been made. In this specific field the potential has been set more or less clearly, except the information on used wood potential that has not be defined clearly yet, because the statistical data are not available, but still some estimations have been made. Also, there is still lack of information about short rotation coppice.

Surveys on biogas production from biomass have been done as well. The problem regarding these surveys is that in different surveys the estimated potential varies a lot that does not provide a precise date on the biogas potential. The difference is, based on the data on availability of green biomass for biogas production, which overlaps with the agriculture lands for food production. A much clearer view is on manure potential for biogas production as the statistic on livestock is available.

The potential of biomass for biogas production is still unclear, despite that many surveys have been done. Mostly in these surveys not potential, but the amount of biomass that is needed for biofuel production to reach the EU defined target on biofuels is mentioned. The main problem for setting the potential is that it is still hard to separate the territories that are used for example for rape cultivation for biofuel production, for energy crops cultivation for biogas production, and the agricultural lands for food production. These fields overlap often, so it is not possible to define the potential clearly.

The existing surveys on biomass resources in the datasheets are selected based on the publishing year and information that is covered by the survey and have been considered as the most important from the responsible person on datasheets point of view.

3.1.3 Lithuania

There are currently developed two national studies on renewable energy development in Lithuania. They are: Lithuanian and renewable energy resources, promoting the use of the 2010-2020 Action Plan (Lithuanian Association of biomass energy LITBIOMA, 2008) and energy production from renewable energy resources in 2008-2025 study on the (Lithuanian Energy Institute, 2007).

In these studies the analyses of use of RES in energy production until 2020-2025 were investigated. Separate types of RES forecasts were made on the basis of the existing potential, as well as in the study the RES-E, RES-H and biomass fuel production forecasts was performed. In this study methodology for analysis of the development of RES and description of the assumptions were not detailed presented.

It is necessary to specify potentials of some types of biomass (forest residues, straw, grass). In the study also noted some trends for the biomass sector. In some regions of Lithuania number of high power boiler is growing rapidly and lack of wood fuel has been observed in some areas. In future this situation may limit the further production of biomass energy development.

Based on these assumptions, and national circumstances, it can be stated that Lithuania has favourable conditions for significantly increased use of biomass for district heating sector, and reduce natural gas requirements.

3.1.4 Estonia

No survey summary.

3.2 Central Eastern region

3.2.1 Central Eastern recommendations

Regarding the Central-East Europe region it can be said that the biomass potential is ascertained sufficiently. Slovinsko monitors the forest biomass and biomass from production and waste, but has no official data on agricultural biomass.

In reference to new and unutilized biomass types, no complex national surveys exist in this field. It is very difficult to obtain relevant data from production, the companies has no tendency to publish such information even if it is regarding waste and by-products.

A lot of companies in the food-industry segment in the region start to consider utilisation of biomass very seriously. Evaluation of economic benefit from use of biomass as an energy carrier is a fundamental task today.

3.2.2 Slovenia

In Slovenia there are few researches that include biomass potential, but, as it turned out, they are not publicly available. For example energy crops used for biogas are done extensively in the HSE company, as a lot of wood biomass potential studies have been made in Gozdarski inštitut and Zavod za gozdove.

Slovenia Yearbook energy statistics cannot include energy balance that doesn’t report wood fuels individually but group all renewables and municipal/industrial waste together.

Again, like for forestry statistics, wood and other biomass energy is seen as a minor item which receives little attention.

The gross inadequacy of the “official” fuelwood production data shows in some way that the energy use is not adequately recognized and studied in the national context. Moreover, this situation misleads the analysis of forest role in the energy sector as well as the analysis of the share of wood fuels in the national energy mix.

Some other resources, which are publicly available with data on estimates on biomass potential national wide:

1. http://www.biomasa.zgs.gov.si/files/Literatura/potencial-LB2.pdf?PHPSESSID=687176d98412de2bf4dc9fef6526fb17
2. http://www.digitalna-knjiznica.bf.uni-lj.si/vs_humar_matjaz.pdf
3. http://www.biomasa.zgs.gov.si/index.php?p=obcine
4. Jejčič, Viktor,Poje, Tomaž: Možnosti uporabe kmetijske biomase za energetske namene v Sloveniji; Utilization possibilities of biomass from agriculture as an energy supply in Slovenia; Aktualni zadaci mehanizacije poljoprivrede /
5. Modic, Jurij: Uporaba in vrednotenje biomase = [Use and evaluation of biomass] : diplomska naloga, Fakulteta za strojništvo, Ljubljana

The survey evaluation gives a good picture on national wood biomass resources, but needs to be updated. Also estimation of potential has to be elaborated. There is a constant lack of other biomass statistics like energy crops, straw, grass, oil from rape seed etc. that would be publicly available.

3.2.3 Czech Republic

Plans about renewable energy sources are quickly changing in the Czech Republic. There are two main points of view: Ministry of Industry and Trade prepares energy conceptions, and Ministry of the Environment prepares alternative suggestions to protect the environment. These institutions mostly relate to their own data. The most thorough and widely reputable national survey is "Report from independent expert commission for assessment of energy needs of the Czech Republic in long-term time period", where potential of different sources of energy is evaluated. The useful potential of biomass is there determined as 276 PJ/a, it is approximately 40 % of the theoretical potential.

The Czech Republic has a large number of arable land in comparison with EU (73.8 % against 54.3 %), much of it is situated in mountain and sub-mountain areas with broken terrain and hard climate conditions. Intensive agriculture production is not economical profitable at present.

On the present, regional surveys are generated as a part of regional energy conceptions. These sources of biomass should be involved for analysis: cereal and rape straw, purposefully grown biomass - fast growing tree species and selected grass species, grasslands, waste from forest, waste from wood manufacturing.

References:

http://www.vukoz.cz/__C1256D3B006880D8.nsf/$pid/VUKITFHYND3B

http://energie.tzb-info.cz/t.py?t=2&i=6056&h=12&pl=49

http://energie.tzb-info.cz/t.py?t=2&i=5902&h=205&pl=49

3.2.4 Slovakia

In comparison to other renewables in Slovakia, biomass represents a source with the largest utilizable potential. The energy potential of agricultural biomass is theoretically approx. 15% of annual energy consumption in the Slovak Republic, which is 800 PJ.

Estimates of overall utilizable potential of agro biomass (only agriculture) vary from 86.2 PJ to as much as 106.05 PJ.

Total potential of biomass (from forestry, agriculture and wood processing industry) is 147 PJ according Action Plan for Biomass for the years 2008 – 2013.

In terms of technically utilizable potential (e.g., potential, that can be used after the introduction of available technology and that is limited by administrative, legal and environmental obstacles, not only by economical ones) the largest share among RES is held by biomass (<60%). However, there are problems of objective quantification of technically utilizable potential of biomass (as well as other RESs) due to ambiguity of data and missing unified methods for its calculation in Slovakia.

Despite relatively large technically utilizable potential of biomass in Slovakia and current low level of its use, it is necessary to take into account that development of 'biomass industry' depends on reliability of supply and prices of the input raw material for fuel production, as well as on the growth of transport costs and accessibility of biomass from the point of view of the terrain.

Neverless Technical and Test Institute of Agricultural Rovinka evaluated very seriously the potential of biomass in agriculture sector.

Immediately available potential, which is minimally used, lies in the agricultural biomass for combustion . The theoretical amount of energy 67.8 PJ produced by biomass combustion, it would be possible to use 10-30% in agriculture field, what could cover the whole heat demand in the sector. 10-20% could be used for market purposed.

3.3 Central Western region

3.3.1 Recommendations for Central Western region

In all countries in the considered region there are several studies on biomass potential available.

Most of the biomass resources are residues and by-products from agriculture and food production industry. The use of waste and secondary products is recommendable since they don't compete with food production or with other uses of biomass as raw material.

A biomass resource which may have high potential in some countries is aquatic biomass. The technical and economical feasibility should be researched further.

For all unexplored resources apply that the sustainability criteria should be taken into account when calculating the feasibility of a new biomass type for bioenergy production. An unlimited removal of some biomass types can lead to negative ecological and social effects (erosion, soil depletion etc.) but a moderate use should be investigated.

Important is also not only the identification of new biomass resources but to develop new and better technical solutions to produce bioenergy form existing biomass resources.

The conclusions of the country studies show that there is need to harmonise the studies, assumptions and data bases. Much research on biomass resources and technical solutions is needed before an optimal use of bioenergy can be achieved.

3.3.2 The Netherlands

There are a number of recent surveys covering (parts of) the biomass potential in the Netherlands. Of these, Koppejan et al. (2009) /36/ provide by far the most detailed and comprehensive overview, covering basically all biomass in the Netherlands in a reasonably detailed manner. The other surveys typically cover only parts of the overall biomass potential, and vary in terms of quality from good (Kuiper en de Lint, 2008 /37/; Grafhorst 2007 /38/) to "quick-and-dirty". The study by Koppejan et al. is thus seen as leading, but could of course be further updated and provide more detailed data.

Elaboration of the potential of the secondary agro-biomass produced in e.g. food processing industries would be interesting. The potential is in principle known to the industry itself, but kept largely confidential. The sector is currently assessing its own resources and may publish them in the future.

Some industry actors have high expectations for the production of aquatic biomass in the Netherlands in the coming years, though mainly for the production of high-value products (e.g. proteins). However, opinions regarding the economic and technical feasibility range widely. A critical review of determining factors and an analysis of the possible future ranges of production (depending on different scenarios) could provide a better estimate of how much aquatic biomass could contribute to the bioenergy production in the Netherlands.

Koppejan et al. (2009) /36/ recommends in their study that two types of biomass should be given more attention:

Large amounts of biomass currently not utilized are primary by-products, i.e. branches and tree tops (left in the forest) and stalks and straw (left in the field). An unlimited removal of these biomass types can lead to negative ecological effects (erosion, soil depletion etc.) but a moderate use should be investigated. However, economic/logistical challenges are as yet preventing the utilization of these streams Manure (especially wet cow and pig manure) still poses a major environmental problem in the Netherlands. An integral processing of this manure by e.g. fermentation could not only result in the use of more bioenergy, but also in fewer emissions of methane and N_2O. One of the biggest bottlenecks is the use of the digestate as fertilizer.

3.3.3 United Kingdom

The first report from the United Kingdom is quite comprehensive as it presents the availability of the UK to produce bioenergy crops and the impacts that the expansion or greater productivity may have in terms of environmental, social and economic issues. It also presents future scenarios to 2020.

It also presents some case studies outside the UK in Europe and the results of surveys and consultation process for two UK case studies. The report was funded by the Department of Energy and Climate Change the National Non For Food Centre (NNFC) by SAC Consulting.

The advantage of the report is the presentation of different crops as per the objectives previously described. Nevertheless, there is no information regarding the metrics of energy production in the UK. This makes it difficult to compare with other reports and would be advisable to complete the information with this information for future scenarios.

The second report was produced for the UK Energy Research Centre. The report presents an overview of biomass availability in the UK although data tends to be from 2008 as no more recent data has been collected. It also presents the current contribution from domestically produced biomass to primary energy supply in the UK; a review of estimates of the UK biomass resource base.

This review identified 14 different reports from where the analysis was produced to estimate future biomass dated from 2002 to 2009. The conclusions show that there is need to harmonise the studies, assumptions and data bases.

3.3.4 Austria

Basically there is a number of existing biomass resource surveys in Austria. Especially the potential of traditional resources as wood and agricultural biomass, for example straw or miscanthus, are very well described and subject of many national studies. There are also studies on rare and almost unexploited biomass sources, like vineyard residues available. Many of these surveys are not older than two years, so the data which are available are still up to date.

All these studies includes forecast with estimations and uncertainties. According to the used methods, there could be slight differences in results, but the trend and tendency is almost the same through all these studies: There is still a big potential in forestry as well as in agriculture for biomass production, which is not used at the moment.

3.3.5 Germany

In Germany there are and have been many research projects on bioenergy potential. Several national and regional surveys have been published in the last years.

The share of bioenergy in primary energy production should rise from 792 PJ in 2007 to 1,309 PJ in 2020. It is quite likely that no significant reserves of unused arable land will emerge in Germany. In many federal states, measures have been taken to preserve permanent pasture. To make bioenergy expansion sustainable; i.e. economic and environmentally efficient while at the same time alleviating potential conflicts concerning its use, other types of potential must be exploited.
This is especially the case as regards biomass potential that has not yet been exploited or which has only been exploited to a limited extent: forest waste, biomass from landscape maintenance, biomass from manufacturing industry (waste and secondary products) and waste. The National Biomass Action Plan plans to tap into residues and by-products that are not in competition with food production or other material usages.

Much research is needed before an optimal use of bioenergy can be achieved. New research approaches are to be explored for sustainable production of vegetable biomass. The research should focus on development of new technical solutions to produce bioenergy. [43]

[43] National Biomass Action Plan for Germany
http://www.bmu.de/files/english/pdf/application/pdf/broschuere_biomasseaktionsplan_en_bfpdf;

3.4 Mediterranean region

3.4.1 Recommedations for Mediterranean region

Regarding the existing biomass potential surveys in the Mediterranean regions, a lack of available information is pointed out in almost all countries, and where the surveys are present, a data update on a time-regular basis is requested.

3.4.2 Italy

All the presented surveys agree on the general difficulty about achieving a reliable result for the evaluation of biomass potential, and also use, in Italy.

The lack of reliable data has been pointed out also on a paper by Pettenella and Ciccarese published on the Magazine "Sherwood" (June 2009, n.154) "Stock e flussi nel sistema forestale. Un tentativo di lettura incrociata dei dati italiani" ("Stocks and Flows in The forestry system. An attempt at a comparative reading of Italian data"). Authors point out the fact that in the last few years some interesting data have been published concerning the management of the Italian forests. These numbers, completed through the traditionally available information resources may give a more consistent picture of stocks and biomass flow ratio in Italy. An analysis of the data, unfortunately, points out incoherence between the different data resources.

In general, incoherence is due to the fact that data have been produced at regional level by different studies (i.e. the Regional energy plans of each Italian Region evaluate the biomass to energy potential of the territory) that did not follow nor a common approach nor common guidelines.

The work published by ENEA in 2009 whose results are available on a web-GIS is presently the most comprehensive source of information available on the biomass potential for Italy. Data can be browsed at the following web at www.atlantebiomasse.enea.it

The work has been performed on a GIS basis; the biomass "production" areas have been pointed out; on the basis of the characteristics of the territory these areas belong to, different productivities have been taken into account. The results are in some cases available at a Province or even on a Municipality level of detail.

The ITABIA and CRB reports are surveys that present the data that were available at the moment when the Reports have been published.

The work by ENEA if regularly updated and improved, could constitute a solid and reliable basis for a first step for a biomass availability evaluation on the national territory.

3.4.3 Greece

In the study "Investigation of agricultural and animal wastes in Greece and their allocation to potential application for energy production" (2007) it is important that several thermo-chemical conversions, for biomass to energy, are taken into consideration in the methodological approach, but the estimation of theoretical, technical, economical, environmental and sustainable potential of agricultural biomass is more feasible. A strong point of this study is the involvement of supervisors from the agricultural sector, providing important information about the exploitation of biomass.

Actually, the results of the study are derived by a literature review and not by analysis of primary data of agricultural statistics or field trials. This makes the update of data and results very difficult. Additionally, data about biomass characteristics from Phyllis database are reliable but not site specific.

Studies "Agricultural biomass in Greece. Current and future trends" (2003) and "Capabilities for the administration of biomass residues from the agricultural sector for energy production" (2007) follow less or more the same approach but livestock wastes are not included in the second study. The use of national statistics that are based on NUTS regions classification gives the opportunity for annual update of results and the spatial distribution of biomass potential.

The use of new varieties of species, cultivated in rural areas, and the change of relation between yields of crops' production and their residues makes the update of product to residues coefficients necessary. This estimation must be based on field trials. The same work (update of database) must be done for characteristics of types and fractions of agricultural biomass, as well.

The environmental and sustainable potential of agricultural biomass should be assessed in the future.

3.4.4 Portugal

The Survey "Lignocellulosic by-products from agro-industrial sector - characterization of the Portuguese situation" enabled the characterization of by-products and residues from the agro-food industrial sector, namely its composition and regional distribution. Furthermore, the characterization of the different output materials produced by subsector, respective quantities, current applications and economic value were also possible, thus enabling to identify the major materials that would profit more from the development and introduction of new valorisation processes.

However, the survey does not aim to estimate the energy potential of by-products and wastes from agro-food industries. A mail survey on Portuguese companies selected from a comprehensive database constructed from official data was developed. The obtained response rate was 17,2%. The sample has a good geographical and subsector coverage that adequately represents the target sector.

The purpose of the survey "Evaluation of the energy potential of biomass in the Algarve" was to assess and map the potential energy associated with biomass resources in the region of the Algarve. The achievement of this objective, taking into account the various energy conversion technologies for each instalment of biomass was calculated energy potential, based on a survey of existing information and updated after evaluation and treatment of data collected.

3.4.5 Spain

BIORAISE is a computer GIS based tool specifically designed for the calculation of the agricultural and forest biomass resources and costs existing in selected locations. The tool has been developed in the framework of the UE Fifth Framework R&D Project CHRISGAS (www.chrisgas.com).

The present scope of BIORAISE is to evaluate the forest and agricultural residual biomass resources existing in the following Mediterranean UE countries: Spain (except Canary Islands), Portugal, France, Italy and Greece. Regarding forest biomass, the calculation method is based on the use of the European cartography of the land uses Corine Land Cover (CLC, 2000) and yield tables of relevant forest species. For agricultural biomass, the method uses data of agricultural surface and production data obtained from EUROSTAT. This information has been processed and integrated in the Corine cartography database. Therefore, biomass resources are presented for the different land use categories of Corine.

This tool allows calculating the biomass resources existing within a determinate surface around a previously selected site. The potential of total biomass resource is calculated from an average productivity value (called MAPV) assigned to each 250 m side ground surface pixel, according to the corresponding ground uses in Corine. Biomass available is calculated from the potential introducing several environmental restrictions.

The PROBIOGAS study determines the amount of raw material using statistical indicators and ratios, giving results at provincial and district levels. The amounts are taken into account when a feasible management (collection, transport, storage) is possible also taking into account alternative uses for the biomass.

The ACV-COCO aim to calculate the real potential of greenhouse emissions reduction in Spain by means of the co-firing implementation, taking into account agricultural and forest residual biomass, through a spatial analysis of residual biomass taking into account possible scenarios for the development of energy crops.

3.5 Scandinavian region, including Finland

3.5.1 Recommendations for Scandinavian region

In general, the Scandinavian region can be considered "reasonably covered" with biomass surveys. In this context it means, that the surveys described in this project is considered up-to-date and covering the most important biomass resources in the region.

As for new and unexploited biomass types, there are of course no (except for Denmark) comprehensive national surveys on this. The resources committed to the partners in this project does not leave room for thorough national studies, so the scope for this WP has been to identify new types of biomass products (agro-industrial and other) with a potential for energy production.

Anyways, experience from Denmark has shown that even with substantial efforts, it may be difficult to get precise figures. Part of this is because companies having for instance agro-industrial waste products as part of their production residues are sometimes reluctant to make figures public, as it is a competition parameter.

As the possibilities in algae cultivation and utilization for energy production are gradually unfolded, potentials should be estimated on national, regional and EU level.

3.5.2 Sweden

As Bioenergy constitutes a major share of Swedish energy supply several initiated potential surveys have been made during the last years. The three national surveys that were chosen for this study were produced by SVEBIO (the Swedish Bioenergy Association), LRF (Swedish Farmer's Association) and the 2006 Oil Commission appointed by the Swedish Government. Other important surveys worth mentioning is *e.g.* the short term forecast by the Swedish Energy Agency and reports by the Swedish Board of Agriculture. It should also be commented that different outcomes of the cited surveys is partially dependant on the various pre-conditions respectively.

In the 2008 SVEBIO survey potential is defined as maximum amount of available fuel, with available technology and with ecological constraints. The report is in principle not a forecast, that there is a potential does not mean the entire amount of fuel will be used. The report estimates potentials, both short-term and long-term. Short-term potential refers to the potential which in principal is available today or at least probably will be available in 2020. The report is based entirely on facts from other investigators. This report should therefore be seen as a comprehensive compilation of material available from governmental investigations and other experts. Regarding the potential for agro biomass most of the used information are from a governmental investigation (Bioenergy from the agriculture, SOU 2007:36), which is (according to the report) an ambitious review of opportunities to use agro biomass. In the SOU 2007:36 a number of models were made with different assumptions. The 2020 potential for energy from agrobiomass was estimated at about 140 PJ. As a reference current use is in the order of 5 PJ.

The 2005 LRF survey potentials should be seen as assessments of what is technically and environmentally feasible. Nor this survey is a prognosis. What amount of biomass that will be used depends on a variety of factors such as the industry's own efficiency and initiative as well as social and economic policies of international competition. The information in the report is a compilation of different reports but also LRF's own assumptions and calculations. Emphasis is put on what the agricultural sector can provide. The 2020 agrobiomass for energy potential was estimated at 79 PJ.

The 2006 Oil Commission based their estimations on an extensive data background material, and partly from the Commission's hearings and by materials made available for the Commission from various professional organizations and interest groups. The Commissions has had access to data from the Swedish Energy Agency, the Swedish Board of Agriculture, LRF, SVEBIO, SLU, the Swedish Forest Industries Federation and others. The values presented were only estimations as the market was judged to have a crucial influence on the development. The 2020 agrobiomass potential was thus estimated at 43 PJ.

The three surveys can be downloaded from these web sites:
http://www.svebio.se/attachments/33/902.pdf
http://www.bioenergiportalen.se/attachments/42/453.pdf
http://www.sweden.gov.se/content/1/c6/06/62/80/bf5c673c.pdf

Other relevant surveys can be found on "The Swedish Bioenergy Portal":
http://www.bioenergiportalen.se/Default.asp?p=1368&pt=&m=865&categoryid=232

3.5.3 Norway

In addition to the two surveys filed in the project, there is also some other (including the EUBIONET III country report delivered last year).

When comparing the different sources we see that the reported potentials differ, but in general they find a total potential in the range of 90 – 110 PJ. The largest potential in all studies is from forests and forest industries, followed by waste (both industrial and household). Those studies that also include biomass from agricultural products (eg. straw and oil seeds) conclude that the potentials for these are small. This is not surprising given the rather low portion of the land (about 3%) used for agriculture.

The two surveys filed link the potentials to the energy price. This is very important – especially for Norway with rather low energy prices and a generally high cost level. Simply put: there is enough energy available (technically), but bioenergy has to compete against "old" energy. Hence, an evaluation of the costs is important. One of the surveys also analyzes the market situation – to some extent. However, the need for "market creation" and building of infrastructure could be emphasized more.

The surveys seem to give an adequate and reasonably correct picture of the current situation in Norway. Waste and biomass from forests will – at least in the short to medium term – be the most important bioenergy sources in Norway.

There is ongoing research on biogas production and utilization of marine sources like macro and micro algae. Regarding the latter, we have seen no surveys as this research is in a rather early phase.

3.5.4 Denmark

The two Danish surveys described in this project are considered to cover the national resources very well. They serve as basis for much of the most recent Danish work in the field of biomass resources.

In a national project, large efforts have been made to identify new and unexplored biomass resources in the form of agricultural waste. However it has proven difficult to get information from many companies (and if information is provided, it is confident).

There are some preliminary estimation on potential for algae cultivation and biomass potential. They are however not included in the national surveys, and the estimations must be taken with much precaution until more research in the area has been completed.

3.5.5 Finland

The three Finnish surveys described in this project are considered to cover the national resources very well.

1. Kärhä,K. Metsäteho Oy, Elo, J. & Lahtinen, P. Pöyry, Räsänen, T. & Pajuoja,H. Metsäteho Oy, Availability and use of solid wood-based fuels in Finland [Kiinteiden polttoaineiden saatavuus ja käyttö Suomessa 2020, TTS Tutkimuksen tiedote, Luonnonvara-ala:metsä 10/2009],

2. Pahkala, K, Hakala, K, Kontturi, M. Niemeläinen, O.MTT, Global potential of agrobiomass for energy [Peltobiomassat globaalinan energianlähteenä, MTT Maa- ja elintarviketalous 137, 2009. p. 53],

3. Asplund, BENET Oy, Flyktman, M. & Uusi-Penttilä, P. VTT, Estimation of the possibilities to reach EU targets for renewables in 2020 [Arvio mahdollisuuksista saavuttaa uusiutuvien energialähteiden käytön tavoitteet vuonna 2020 Suomessa, FINBIOn julkaisu 42, 2009]

First survey is covering the solid wood-based fuels in Finland, the second is covering agrobiomass potential for energy use, and the third also includes potential for biogas production. Biomass resources in Finland mostly originate from forest operations, either forest residue from thinning or logging, or by-products of wood processing industry. Annual theoretical potential of forest residue is about 45 million m^3 solid, and technical potential 16 million m^3 solid, which is about 115 PJ.

VTT has estimated that availability of forest biomass will be in 2020 in total 72 PJ and is divided as follows: (Asplund et al. 2009):

- logging residues from final felling, 3.6 PJ (based on cost level 3.0 – 3.9 €/GJ
- stumps and roots, 18.4 PJ (based on cost level 3.9 – 5 €/GJ
- forest wood from young stands and first thinnings, 50 PJ (based on cost level 5 – 7 €/GJ)

Currently the theoretical resources of straw from grain growing is about 48 PJ, stalk residues from oil plant production about 2.5 PJ, and reed canary grass, about 0.7 PJ (Pahkala et. al 2009). Use of straw is still marginal in Finland about 6 tons (90 GJ) and mainly cofired with peat in CHP plants. Residue from turnip rape and oilseed rape (89 000 ha) could be a potential fuel. Also low quality grains are used 119 TJ in 2006 and 68 TJ in 2007. Reed canary grass cultivation and harvesting technologies have been developed in recent years, but the cultivation area is about 20 000 ha.

4 Improving fuel characteristics of agro-industrial biomass products

Exploitation of agro-industrial residues (and other "alternative biomass) is not without challenges. Often there will be a high water and/or ash content or there may be a chemical composition that causes problems during combustion.

There are different approaches to meeting these challenges:

- Choosing a proper conversion technology may reduce difficulties
- Improving the physical characteristics of the biomass, i.e. reducing water content, pelletizing etc.
- Improving the chemical characteristics of the biomass, i.e. using additives to counteract negative influence of for instance Chloride in the biomass during combustion.

4.1 Conversion methods

Although pre-treatment of agrobiomass products may make the utilization of the products more feasible, pre-treatment is often adding considerable costs to the handling chain.

Therefore, it is basically important to select the conversion technology (i.e combustion, fermentation, gasification etc.), for which as little pre-treatment as possible is necessary.

For instance for biomass types with high moisture content like algae and animal manure/slurry, costs for drying the material to a degree, where combustion or thermal gasification is applicable may be high, whereas the products can be fed directly into biogas digesters for immediate utilization.

Also the “costs” in terms of energy balance should be considered. For separated fractions from animal manure/slurry, there is a net energy surplus by combustion, when the moisture content is lower than 85%, and with a moisture content of 70%, there is a net surplus of 600kWh/ton /36/.

Another way of optimizing conversion of “difficult” biomass types is to adjust the conversion technology – like for instance co-combustion of difficult biomass types with other fuels. In section 4.1.1, EUBIONET III partner VTT from Finland has described challenges and solutions for co-combustion of agro-biomass with coal.

4.1.1 Cofiring of agro-biomass with coal

4.1.1.1 Comparison of different combustion technologies in view of co-firing issues

Cofiring fossil fuels with agrobiomass can significantly reduce CO_2 emissions in electricity production. In many countries (China as an example) largest portion of electricity has been produced with coal combustion. However, the potential to bring agrobiomass to combustion can be significant. Large quantities of agrobiomass (like different straws) are globally wasted on the fields or nearby.

The most important in-furnace problems which can appear during combustion of agrobiomass are:

(a) High temperature superheater corrosion (possible to all common techniques of power plant combustion: pulverised fuel (PF)- fluidised bed (FB)- and grate combustion (GC) [1-16])
(b) Ash slagging due to low melting chemical compounds which can occur in all ways of combustion. FB combustion is based on the use of sand to stabilise combustion and to maximise heat transfer to the fuel. Presence of sand may sometimes enhance ash slagging leading to a phenomenon called sand bed agglomeration. [17-28]

Furnace conditions, as temperature distribution (T.D.), can differ much between these ways of combustion. T.D. affects to the in-furnace combustion chemistry. Among the ways of combustion discussed here, maximum furnace temperature is lowest and temperature distribution is most even in circulating fluidised bed (CFB) combustion, where circulating sand prevents temperature peaking in the furnace. Temperature peaking is stronger in bubbling bed combustion (BFB), where the sand does not circulate. Highest furnace temperatures in BFB are not much lower than in GC. Instead, pulverized combustion even with air staging (needed to NO_x reduction) usually produces highest furnace temperatures among the mentioned ways of combustion. However, superheater temperatures can be in the same level in all these ways of combustion, although very effective GC power plants (with steam temperatures 540-560 ^oC) are not yet in the market.

Fluidised bed combustion is a good option to co-firing, if ways can be found to prevent superheater corrosion and sand bed agglomeration. Combustion process can be effectively stabilised by the sand. Instead, grate combustion is not usually a good option to co-firing, because then combustion process can fluctuate too much leading to high emissions of CO, C_xH_y and unburnt matter in the fly ash. Instead, grate combustion is a good technology to challenging fuels when fired alone. PF plants are often large (magnitude 1 GW_{th}). Due to agrobiomass production potential at reasonable distances from the power plant and logistical and storing reasons, higher biomass portions than 10 % of fuel energy are challenging to produce. High energy density (like in biomass pellets) can improve the situation, if the fuel costs remain acceptable to the power plant. Small portions of biomass (< 10% on energy basis), do not usually cause in-furnace problems.

4.1.1.2 High temperature superheater corrosion: problem determination

High temperature superheater corrosion is due to chlorine deposition followed by reactions between chlorine and metal. Such corrosion is possible at high steam temperatures. One can put a rough risk limit (for example T_{steam} = 420 ^oC), but the real limit is dependent to Cl mass flow as alkali chlorides, gas temperature and alloy, construction and placement of the superheaters.

The key method to prevent superheater corrosion is to prevent chlorine deposition. Alkalis (K and Na), which are usually present as excess in relation to Cl, play a key role as Cl carrier into the deposits, but they are not corrosive. Instead, chlorine forms elemental Cl in the deposit, which reacts with the superheater metal. Such protective elements can prevent or reduce markedly Cl deposition, which can destroy alkali chlorides before they will enter to the superheater area. Figure 1 shows the situation if there is a lack in the mass flows of such protective elements in the furnace. Even if the figure has been drawn with forest biomass, it prevails with agrobiomass.

During the last ten years, VTT has developed such sampling and analysis technology, which enables simultaneous measurements of alkali chloride mass flows at the superheater area and Cl deposition into the superheater simulators. Results from such measurements are valuable in superheater corrosion problem determination and solution. Alkali chloride mass flow is analysed after sampling and simultaneous fractioning of the finest fly ash by so called low pressure impactor (LPI). Alkali chlorides (usually present in fly ash particles smaller than 0.64µm formed by condensation during the sampling) are then analysed from the fractionated fly ash. Deposits, collected to removable coupons, are analysed at three locations in Aabo Akademi University. Figures 4.1.2 and 4.1.3 show an example of VTT's measurement results with bark at BFB combustion conditions in a pilot scale reactor. Even if Cl concentration in bark was low (about 0.02 wt%), and mass flow of Cl in alkali chlorides low 5 mg/Nm^3 6% O_2 , Cl concentrations up to 7 wt% were found at one location in the deposit. Even such Cl concentration may lead to corrosion, or at least increasing fouling of superheaters. Blending 7 % of energy recycled fuel REF (with 0.64 wt% Cl comparable for example to low-quality straw) increased Cl mass flows in alkali chlorides and Cl deposition significantly. High Cl concentrations (as 15-25 wt%) lead to firm deposits and fast metal loss from the superheaters (Figs. 4.1.2 and 4.1.3).

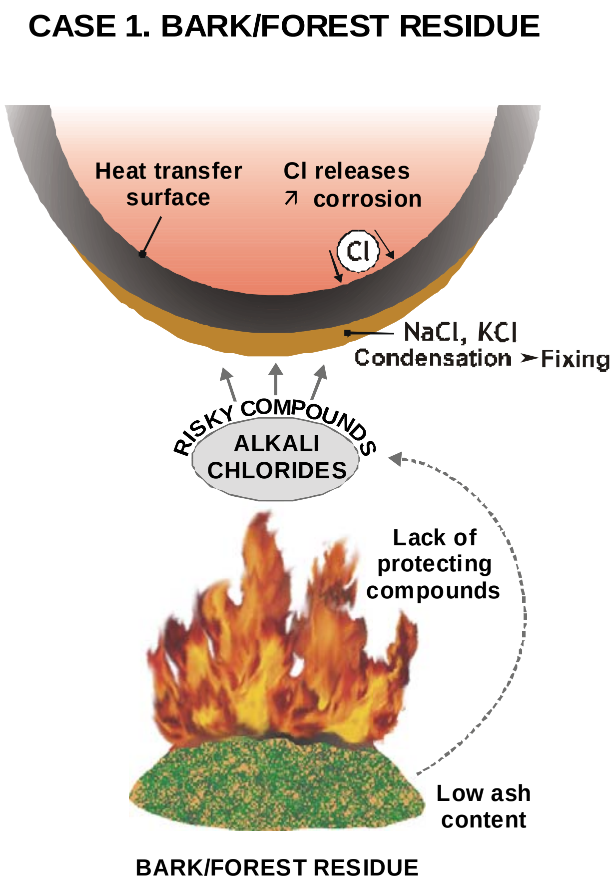

Figure 4.1.1. Chlorine accumulation to the superheaters during biomass combustion starting high temperature Cl-corrosion if steam temperature exceeds ≈ 420 °C. /29/

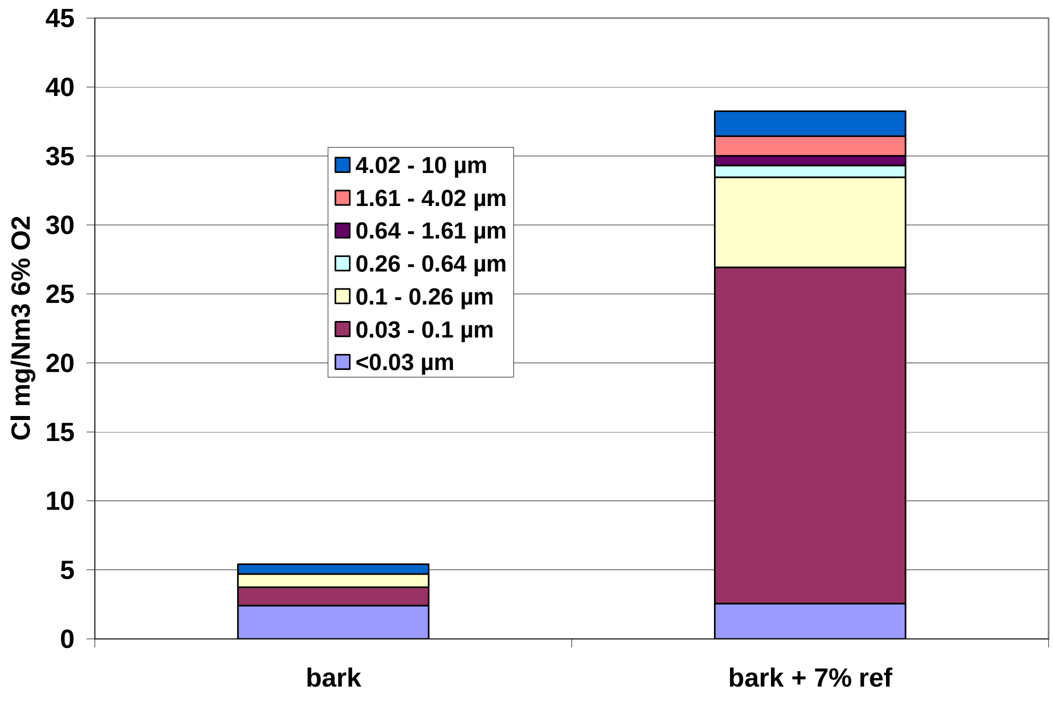

Figure 4.1.2. Mass flows of Cl in alkali chlorides (sum in fly ash < 0.64 µm) during combustion of bark and bark blended with REF (comparable to low-quality straw in its Cl content). Research at BFB conditions. /30/

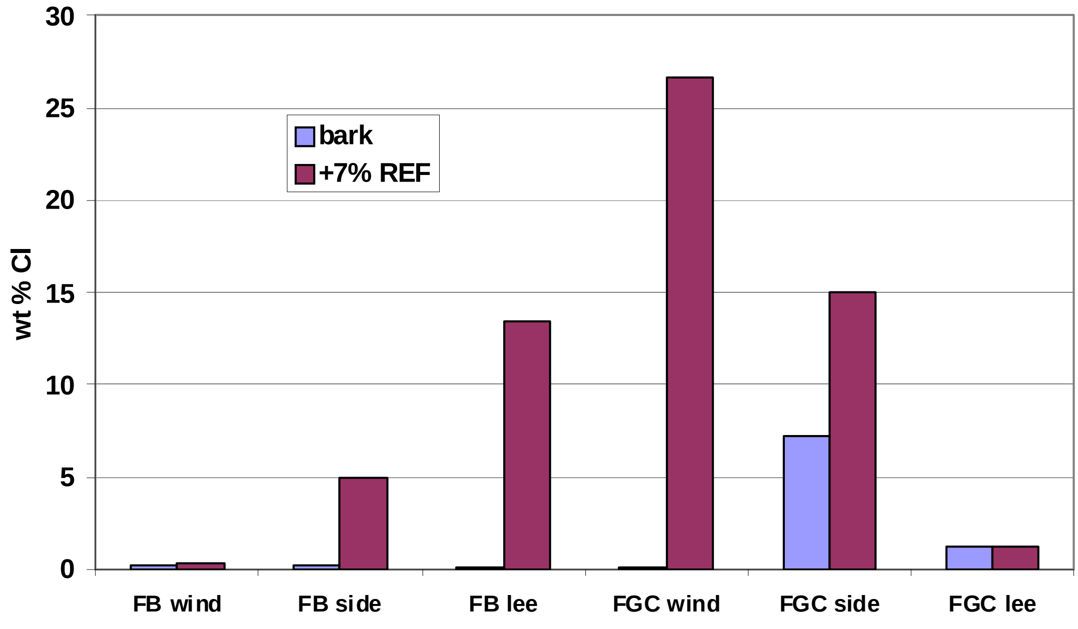

Figure 4.1.3. Deposition of chlorine at conditions of Fig 2. Cl concentrations were measured at three locations from the deposit. FB = freeboard, FGC = Flue gas channel /30/

4.1.1.3 High temperature superheater corrosion: problem solution by co-firing means

Sulphur (originated for example from fossil fuels) can be oxidized up to +6 (sulphur trioxide, SO_3) in the furnace, which reacts fast with alkali chlorides to bind alkalis and liberate HCl (eq. 1):

$$2MCl + SO_3 + H_2O \rightarrow M_2SO_4 + 2\,HCl \qquad (1)$$

where M is K or Na

Reaction 1 is called sulphation and has been applied to prevent Cl deposition, because HCl cannot condense on the superheaters. Reactions between sulphur dioxide (SO_2) and alkali chlorides are too slow to reduce effectively alkali chlorides concentration in the furnace. Most of S is present as SO_2 in the furnace, and SO_3 only at lower concentrations. This is one reason, why high excess of sulphur in relation to chloride is needed for effective sulphation of alkali chlorides. High excess of S can lead to high SO_2 emissions, which increase flue gas cleaning costs. Safe limits to S/Cl molar ratio in the feedstock have been suggested, but the same prevails with this ratio as with Cl content in the fuel: no precise safe limit can be given. S/Cl ratio = 4 might be safe, if the molar Ca/S ratio in the feedstock is low enough (because calcium binds sulphur as shown by eq. 2), but real situation is still more complex, and for example such a ratio as $S/(Ca+2K+2\,Na)_{reactive}$ has been presented, where reactive means water soluble fraction of these elements.

$$SO_2 + ½O_2 + CaO \rightarrow CaSO_4 \quad \text{and} \quad SO_3 + CaO \rightarrow CaSO_4 \qquad (2)$$

Co-firing agrobiomass with coal can reduce or prevent Cl deposition by two means: by sulphation (as described above) or by aluminium silicate reaction (Eq. 3, Fig. 4.4.4).

$$Al_2O_3{*}2SiO_2 + 2\,MCl + H_2O \rightarrow M_2O{*}Al_2O_3{*}2SiO_2 + 2HCl \qquad (3)$$

where M is K or Na

Coal ash is often rich with aluminium silicates, where their mass fraction can sometimes approach 90 wt%. However, it is important that these silicates are free from alkalis, because, as shown by Eq. 3, alkali aluminium silicates are inert in alkali capture (as end products of reaction 3). The coal effective in reaction 3 should contain> 85 wt% aluminium silicates, less than 0.5 wt% Na and K and less than 5 wt% Fe_2O_3 and CaO which, in addition to dilution of effective silicates, may have inhibiting power to reaction 3.

CASE 2. PROTECTING POWER OF COAL

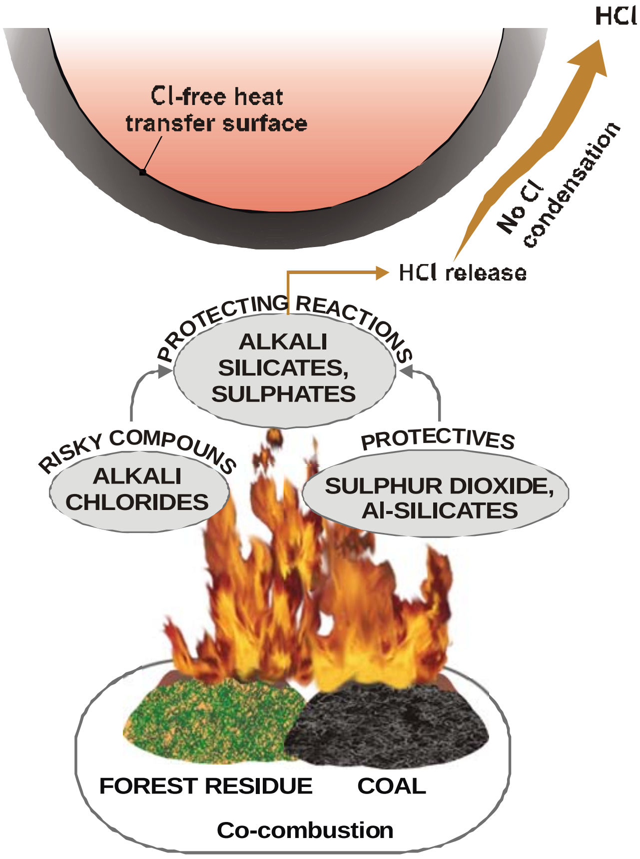

Figure 4.1 4. Protecting power of coal against Cl deposition based on sulphation (Eq. 1) and aluminium silicate reaction (Eq. 3). The mechanisms remain the same if forest residue is replaced by agrobiomass. /16, 31, 32, 33/

The result from the combustion research, where refuse-derived fuel (RDF, containing 0.64 wt% Cl, comparable to low quality straw) was co-fired with two different coals and bark has been presented in Figs. 4.1.5 and 4.1.6. Mass flow of Cl in condensed alkali chlorides (165 mg/Nm^3 in particles smaller than 0.64µm, see Fig. 5) during combustion of bark/RDF blend produced huge concentrations of Cl in the deposits (Fig. 4.1.6). The protective power of the two coal samples selected to this study was studied in blends of about 40% coal on energy basis. The protective power of the South African coal (SAC) sample with high aluminium silicate content exceeded clearly that of the particular Polish coal (PC) sample with clearly higher alkali, calcium and iron contents. Sulphur contents were similar in both coals (about 0.6 wt%). The alkali chloride mass flow during combustion of the SAC-containing blend was about 25 mg/Nm^{3}m whereas this flow was about 60 mg/Nm^3 for the PC-containing blend (Fig. 5). In contrast to the situation with SAC containing blend, Cl contents in deposits were risky during combustion of PC-containing blend (Fig. 4.1.6).

Cynara is an energy crop growing in the Mediterranean area. It tends to absorb high Cl amounts from the soil. The Cynara tested in VTT contained about 1.7 wt% Cl. Cofiring of such biomass with coal cannot be done at high biomass portions even if the particular coal has high protection capability (as VTT's SAC sample). The upper limit to safe co-firing was 20 % SAC on energy basis (Figs 4.1.7 and 4.1.8).

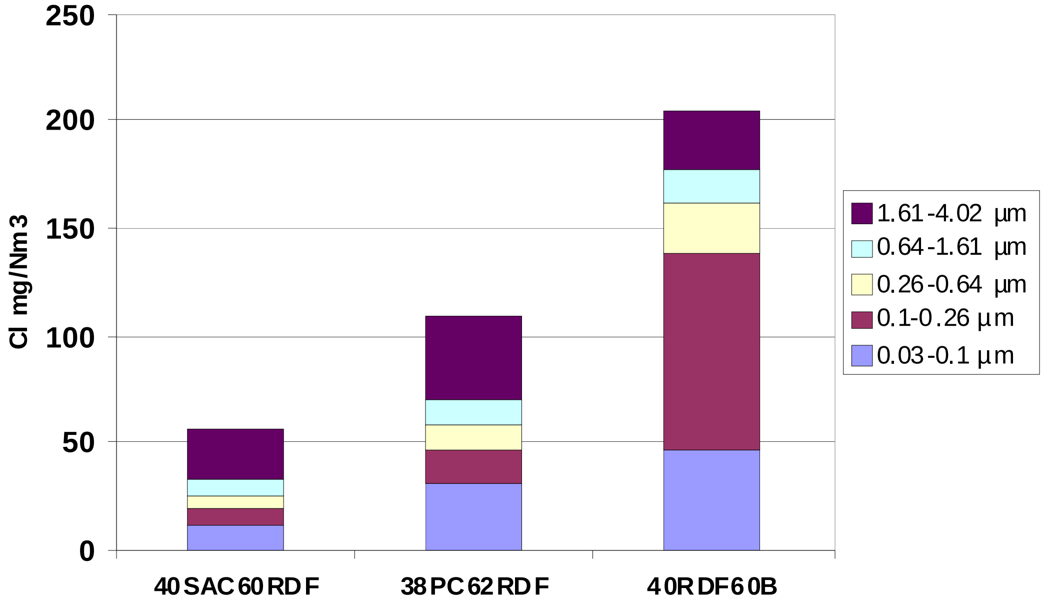

Figure 4.1.5. Mass flows of Cl in alkali chlorides (sum in fly ash of < 0.64 µm) during co-firing of refuse derived fuel (comparable to low quality straw) with two coals and bark combusted in VTT's pilot-scale CFB-reactor /32/

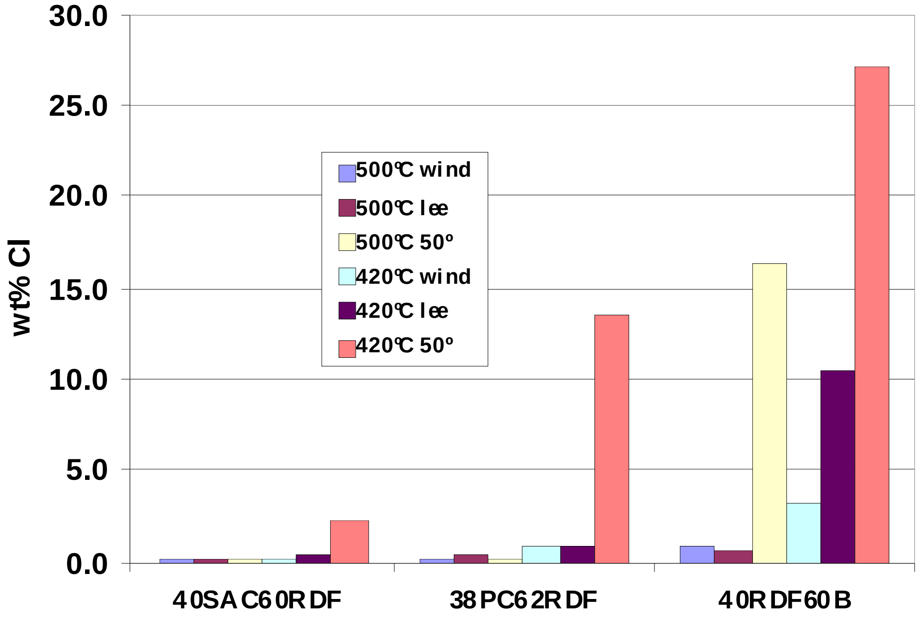

Figure 4.1.6. Chlorine deposition at three positions of the deposits collected at two metal temperatures at combustion conditions of Figure 4.1.5. /32/

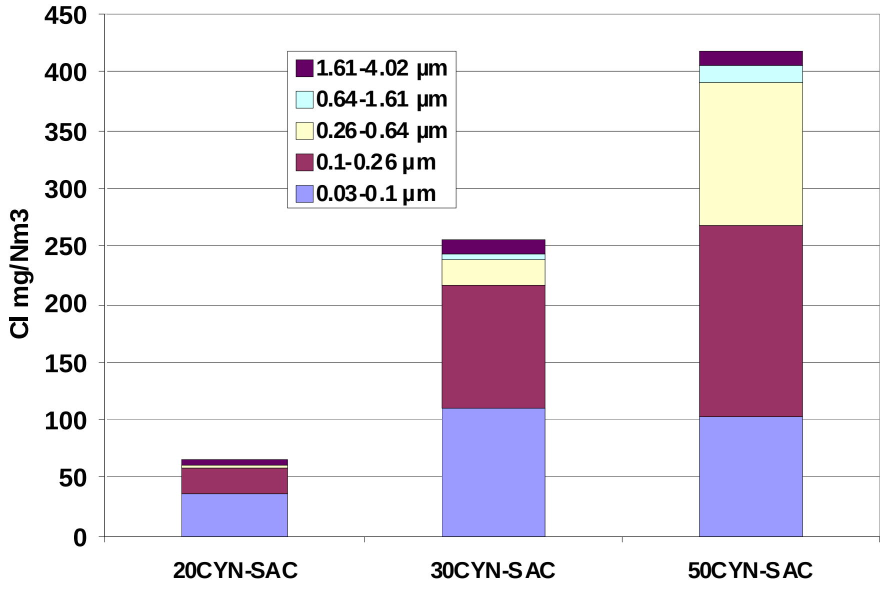

Figure 4.1.7. Mass flow of chlorine in alkali chlorides during co-firing of Cynara (energy crop with extremely high Cl content) with high-quality coal from South Africa. Reactor: VTT's pilot-scale CFB. /33/

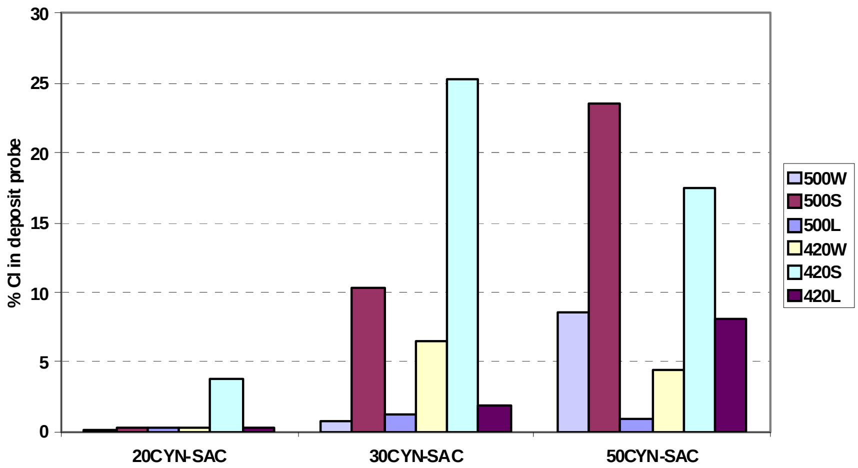

Figure 4.1.8. Chlorine deposition at three positions of the deposits collected at two metal temperatures at combustion conditions of Figure 4.1.7 /33/.

4.1.1.4 Bed agglomeration in FB combustion

High alkali concentrations in the fuel may cause stronger ash related problems in FB furnace compared to GC and PC, because alkalis in the fuel can react with silica in the sand forming so called agglomerates which can grow fast and lead to shut downs (Fig. 9). Such problems can, however, be reduced by flue gas re-circulation, additives or by using SiO_2 free bed material instead of natural sand. Low melting compounds in the fuel ash can cause problems also in PC and GC.

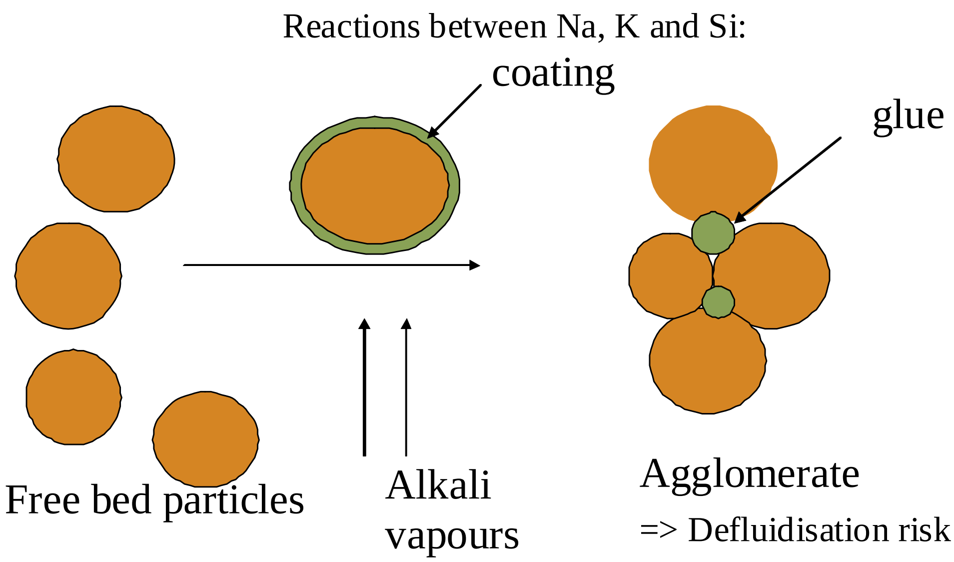

Figure 4.1.9. Illustration of bed agglomeration which can occur in BFB or CFB power plants.

With the need to utilise agrobiomass in co-firing with coal, there is an increasing risk of operational problems, such as bed agglomeration. Experimental results which can assist in predicting bed agglomeration based on fuel composition are currently incomplete. Modern fuel analysis, such as chemical fractionation, and the application of different modelling tools can lead to more effective methods. Additionally, techniques of measuring agglomeration can be further developed.

Results on the correlation between bed agglomeration and bed temperature have been widely presented /17-28/. The risk of bed agglomeration and the agglomeration rate, once initial formation occurs, increase with temperature /17/. Start temperature of defluidisation is dependent on bed temperature, bed material, particle size of bed, stoichiometry and the flow rate of gas through the bed /17/. Bed agglomeration tends to start at lower temperature using silica sand beds than with sands whose SiO_2 concentration is lower or even zero. Potassium originating from biomass is one of the key elements in agglomerates with silica sand because low-melting-point K_2O-SiO_2-type compounds are formed /21/. Recent research results indicate calcium especially to participate in the formation of low melting compounds (Al mullite form Al_2SiO_5 but also do sulphur, aluminium and phosphorus) /21/.

Hot burning char particles inside the bed have been found to be the main instigator of bed agglomeration; for example those emitting potassium chloride vapour. The temperature of small particles can greatly exceed that of the bed material /17,20,21/. Agglomeration strength has been measured by treating fuel ash in laboratory-scale fluidised bed reactors. The properties of agglomerates have also been determined with a re-fluidisation test /21/.

Based on the results of VTT's cofiring tests with Chinese coal and straw, a method to estimate whether agglomeration (which strength has been indicated as factor S in the figure) occurred or not was devised. Results utilised so called chemical fractionation, where the fuel was shaken in different solvents. Result from water extraction (molar sum of water soluble Na, K, Cl, Ca, P, Mg, Fe, Al and Si) was found to predict bed agglomeration in the best way. The critical limit of bed agglomeration was somewhere between 150-200 mmol/kg D.S. water soluble elements in the fuel blends when the sand bed temperature was 830± 10 ^{o}C. In contrast to typical agrobiomass, portion of water soluble ash forming elements in coals is usually very low. Therefore, blending agrobiomass, like straw, to coal increases water soluble fraction. Combustion of straw-coal blends containing more than 30 % Chinese straw (on energy basis) often led to bed agglomeration.

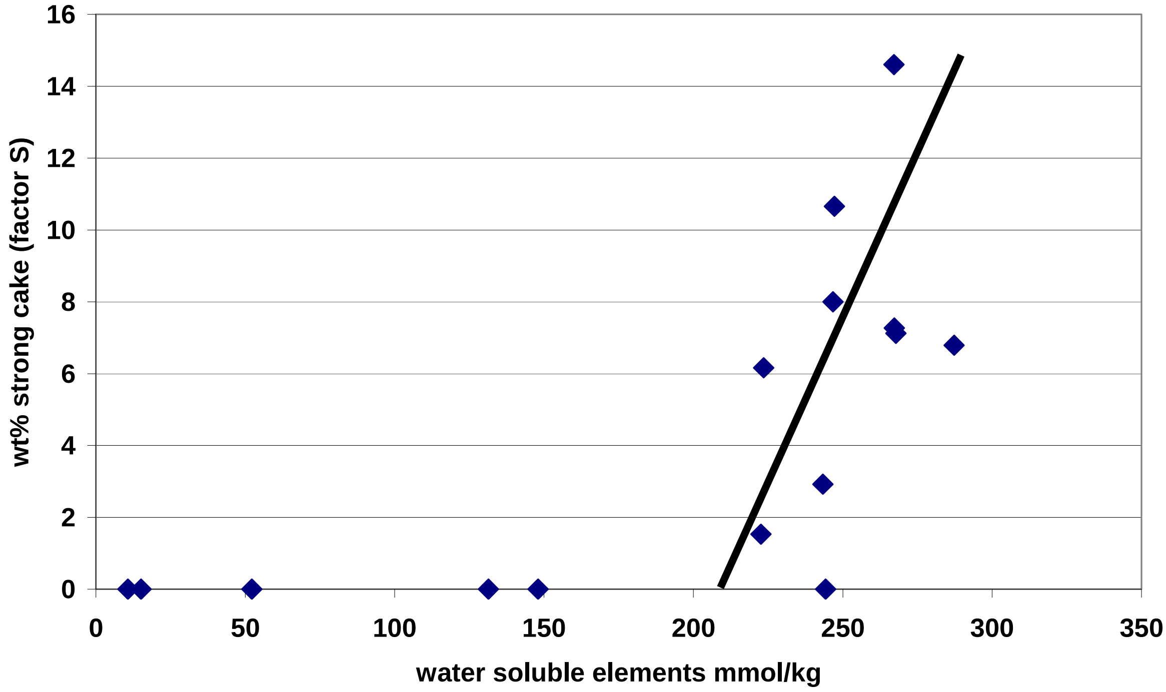

Figure 4.1.10. The measured dependency between mole fraction of water soluble main ash constituents and bed agglomeration tendency. VTT's result at BFB conditions with Chinese fuels. Factor S=0 means no bed agglomeration. T_{bed} = 830±10 °C. /34/

4.2 Pre-treatment of biomass

As described in 4.1, choosing a proper conversion method may solve many problems in using agro-industrial and other biomass products with "difficult" physical and chemical properties. However, in many cases, it may not be possible to use the "best conversion method", or there may be other reasons for using a certain conversion technology – like for instance combustion.

In these cases different kinds of physical and/or chemical pre-treatment of the biomass may be recommendable – or even necessary. The pre-treatment can serve different purposes depending on the conversion technology.

4.2.1 Pre-treatment for optimizing combustion characteristics

Biomass is often regarded as "difficult fuel" for combustion. This is especially so for biomass other than wood and wood products. A classic example is straw, which contains high concentrations of potassium and chlorine. When straw is combusted in large applications, condensation of potassium chloride on surfaces initiate ash deposition as well as chlorine-induced high temperature corrosion. Furthermore, straw has a rather high ash content (4-5%) compared to for example wood pellets, making it a nuisance to remove ash from small boilers. And finally straw ash has a rather low ash melting point, often resulting in slag formation.

To improve the combustion characteristics several pre-treatment methods can be applied:

- "Washing" of the biomass can remove a substantial part of the difficult substances in the biomass (i.e. potassium and chlorine in straw)

- Using additives for slag abatement/prevention of deposit formation, including:

    - Combustion catalysts; in order to improve the combustion

    - Coating inhibitors; intended to prevent sulphur related coatings

    - Corrosion inhibitors; used to prevent chlorine and aerosol related corrosion and fouling

4.2.2 Pre-treatment for optimizing energy production from biological and biochemical conversion methods

For conversion methods, in which biological or biochemical processes are applied, different pre-treatment methods may be applied in order to improve the processes and increase the energy yield. Examples include:

- Enzymatic pre-treatment; enzymes are typically used to speed up biological and biochemical processes like for instance degradation of low soluble chemical structures in the biomass

- Thermo-chemical pre-treatment; a combination of heating and a chemical treatment (for instance with acid) can also "open" chemical structures

- A combination of pressure and temperature (steam explosion) also results in the opening the biomass structure

- Grinding or milling of the biomass can improve the degradability of the biomass, simply by increasing the surface of the biomass to be exposed to the microbial activity

4.2.3 Pre-treatment for optimizing biomass logistics

Also, in order to optimize biomass logistics and supply, pre-treatment of the biomass is often recommendable. In this context, a simple handling operation like baling of straw is regarded as pre-treatment. Other examples of pre-treatment with the purpose of optimizing logistics rather than optimizing combustion/conversion characteristics are:

- Drying; in order to improve storage stability

- Chipping; in order to ease transport

- Pelletizing/briquetting; in order to ease transport and reduce transport costs

- Torrefaction; in order to improve storage stability and increase density to reduce transport costs

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Appendix 1

EUBIONET III – WP5 Enlargement of the raw material base

Data collection sheet

Identification of less- and unexploited biomass resources

Name of biomass product: Exhausted olive cake	
Basic information	
1.1 Country	Portugal
1.2 Partner	CBE – Biomass Centre for Energy
1.3 Filled in by	Teresa Almeida teresaalmeida.cbe@mail.telepac.pt
1.4 Sheet no	PT-1
1.5 Date	3/5/2010
Origin of raw material	
2.1 Raw material type(s) (add photo of biomass product)	Olive cake (pomace) is the solid by product obtained from the extraction of olive oil. It consists of pieces of skin, pulp, stone and olive kernel. The chemical composition can vary according to the pressing method utilized. 

2.2 Short description of industrial process (schematic drawing of process if applicable)	Depending on the extraction system used on the olive, 3 types of olive pomaces can be considered. In Portugal, 70-85% of the olive pomace is produced in two phases. The main differences between the extracted raw materials are due to moisture content. "Two-phase pomace" has close to 65-70%. Exhausted olive cake is s by-product of the second industrial olive extraction process that remains after oil extraction.
2.3 Classification according to EN 14961-1	3.2.2.4
Description of product	
3.1 Description in words	Exhausted olive cake is the stone, the fat-free solid by-product of the second industrial olive extraction process that remains after oil extraction.
3.2 Moisture content as received	10-12% (ref 1)
3.3 Bulk density	622kg/m^3 (ref 2)
3.4 Ash content	4.6% (ref 2)
3.5a Net calorific value as received in MJ/kg 3.5b Net calorific value on dry matter basis in MJ/kg	13.9 to 19.2MJ/Kg (defined as in EN14961-1 standard) 21.5MJ/kg
3.6 Applicable for the following conversion processes	- Combustion ? X Yes No - Thermal gasification? X Yes No - Biogas production? X Yes No - Other use (explain)
3.7 Other important characteristics regarding quality as a fuel	Exhausted olive cake produces emission of fine particles in the combustion, and has a high content of ash.
Amounts	
4.1a tons per year as received 4.1b tons dry matter per year	23 745 tons (ref 1)
4.2 Energy potential, GJ/year	511 GJ/year
Availability	
5.1 Number of production sites	n.a.
5.2 Amounts per production site	
5.3 Logistical considerations	High transport cost
5.4 Considerations regarding future potential	The expectation is to increase the availability of the product due to investment made in new areas of olive groves

Other features	
6.1 Environmental impacts	
6.2 Other relevant information	50-60% of this material is used directly on plants for energy
Reference /source of information	
Public references	http://hdl.handle.net/10400.9/470 (ref1) http://hdl.handle.net/10400.5/570 (ref 2)
Confidential references (to be deleted in reporting)	

Appendix 2 – List of national surveys by country

Baltic region

Country	Survey title	Reference/link
Latvia (LV-1)	Biomass sustainability criteria application and development of measures	Authors: Latvia University of Agriculture, Research Institute "Silava", Ltd „Vides projekti” Reference: http://lvafa.gov.lv/faili/petijumi/Biomasas_izmantosana.pdf
Latvia (LV-2)	The potential of renewable resources in Latvia. Renewable energy and its future development	Author: Construction, energy and housing state agency Reference: -
Latvia (LV-3)	Cultivation and use of energy crops. Handbook. Energy production from wet biomass or biogas production	Author: V.Dubrovskis, „Vides projekti” Ltd. Reference: http://www.videsprojekti.lv/lv/arhivs/357/
Lithuania (LT-1)	Lithuanian renewable energy promotion action plan over the period 2010-2020 (applied research). (in Lithuanian)	Author: Lithuanian biomass energy association LITBIOMA Reference: http://www.ena.lt/doc_atsi/Atsi_EI.pdf

Country	Survey title	Reference/link
Lithuania (LT-2)	Study on Energy Generation Capacities From Renewable Energy Sources in 2008-2025. Final report, 128pp. (in Lithuanian)	Author: Lithuanian Energy Institute, leader V.Katinas Reference: http://www.lsta.lt/files/studijos/2007/21_AEI_studija.pdf
Lithuania (LT-3)	National Biomass and biofuels production and use of the technological platform for a feasibility study	Author: Institute of Botany, Lithuanian Agriculture University, Lithuanian Forest Research Institute, Lithuanian Energy Institute, Lithuanian Forest Owners Association, Lithuanian District Heating Association, Ltd. "Bionovus, UAB Axis Industries, Lithuanian biofuel suppliers and manufacturers association LITBIOMA Reference: http://www.ntplatformos.lt/index.php?-470207420

Central – Eastern region

Country	Survey title	Reference/link
Slovenia (SI1)	Slovenia Wood Energy Information System (SWEIS)	Rudi Drigo Forestry Specialist - Wood energy planning and forest resources monitoring Živan Veselič Slovenia Forest Service http://www.fao.org/docrep/009/j8027e/j8027e06.htm http://www.zgs.gov.si/fileadmin/zgs/main/img/CE/biomasa/BIOMASA_ANG_PROJEKTI/Wisdom_Slovenia.pdf
Czech Republic (CZ1)	Methodology and analysis of biomass potential in Czech Republic	4.3 CENIA, Czech Environmental Information Agency Ing. Kamila Havlíčková, Ph.D.: *havlickova@vukoz.cz* Mgr. Lenka Jirásková: *lenka.jiraskova@cenia.cz*, Ing. Jana Petruchová: *jana.petruchova@cenia.cz* Ing. Jitka Faugnerová: *jitka.faugnerova@cenia.cz* http://www.cenia.cz/__C12572160037AA0F.nsf/showProject?OpenAgent&PID=CPRJ78DGTDJA&cat=about

Country	Survey title	Reference/link
Czech Republic (CZ2)	Report from independent expert commission for assessment of energetical needs of Czech Republic in long-term time period	Josef Bubeník, Vladimír Dlouhý, František Hrdlička, Miroslav Kubín, Petr Moos, Petr Otčenášek, Václav Pačes (chairman), Edvard Sequens, Vladimír Vlk. http://www.tscr.cz/?lang=cz&pg=0370
Slovakia (SK1)	Biomass action plan for the period 2008-2013	4.4 Ministry of Agriculture SR, Ministry of Economy http://www.land.gov.sk/sk/index.php?navID=2&navID2=2&sID=26&id=1214
Slovakia (SK2)	The utilization agricultural biomass for energy purposes	4.5 Ing. Štefan Pepich, PhD., Ing. Peter Rusňák From Technical and test Institute of Agricultural http://www.sktc-106.sk/kontakt.html

Central – Western region

Country	Survey title	Reference/link
Netherlands (NL-1)	Availability of Dutch Biomass for elektricity and heat in 2020 [: Beschibaarheid van Nederlandse biomassa voor elektriciteit en warmte in 2020]	Koppejan, J., Elbersen, W., Meeusen, M., Bindraban, P (2008) http://www.senternovem.nl/mmfiles/Beschikbaarheid%20Biomassa%20in%202020_tcm24-320154.pdf
Netherlands (NL-2)	Domestic biomass potential. Biomass from nature, forest, landscape, urban green and wood chains [Binnenlands Biomassapotentieel. Biomassa uit Natuur, Bos, landschap, stedelijk groen en hout keten]	L. Kuiper, S. de Lint (January 2008) http://www.bioenergienoord.nl/random/ecofysrapport.pdf
Netherlands (NL-3)	Valuable waste. A concise overview of the developments on the Dutch waste market in 2007 [Waardevol afval. Een beknopt overzicht van de ontwikkelingen op de Nederlandse afvalmarkt anno 2007]	H. Grafhorst (2007) http://www.pwc.com/nl_NL/nl/assets/documents/pwc-afvalrapport2007.pdf
UK (UK-1)	An assessment of the potential impact on UK Agriculture and the Environment of meeting renewable feedstock demands	Booth E, Walker R, Bell J, McCracken D, Curry J, SAC Knight B, Innovation Management Smith J, Gottschalk P, Aberdeen University Biddle A, PGRO (July 2009) NNFCC Project 08-005 Project funded by NNFCC http://www.nnfcc.co.uk/metadot/index.pl?id=9645;isa=DBRow;op=show;dbview_id=2457
UK (UK-2)	The UK bio-energy resource base to 2050: estimates, assumptions, and uncertainties	Raphael Slade; Ausilio Bauen and Rob Gross (March 2010) UKERC Working Paper 31st March 2010: REF UKERC/WP/TPA/2010/002 http://www.google.co.uk/url?sa=t&source=web&cd=8&ved=0CDQQFjAH&url=http%3A%2F%2Fwww.ukerc.ac.uk%2Fsupport%2Ftiki-download_file.php%3FfileId%3D727&rct=j&q=agro%20biomass%20for%20energy%20survey%20UK&ei=jzZfTJfhBMfKjAfG7aXxAw&usg=AFQjCNHGXK8CQ7WTNRNipkXt-rTDlNL8Ug
Austria (BLT1)	Strategies for reaching an optimal use of biomass potentials in Austria until 2050 with respect to GHG emission reduction [Strategien zur optimalen Erschließung der Biomassepotenziale in Österreich bis zum Jahr 2050 mit dem Ziel einer maximalen Reduktion an Treibhausgasemissionen]	Reinhard Haas, Gerald Kalt, Lukas Kranzl, Andreas Müller (2008) http://www.eeg.tuwien.ac.at/research/projects_detail.php?id=86
Austria (BLT2)	Biomass resource potential in Austria – Study by order of RENERGIE Raiffeisen Management Company for Renewable Energy Ltd. [Biomasse-Ressourcenpotenzial in Österreich - Studie im Auftrag der RENERGIE Raiffeisen Managementgesellschaft für erneuerbare Energie GmbH]	Monika Langthaler, Eva Plunger, Dr. Andreas Walzer, Franz Raab, Manfred Prosenbauer, Werner Löffler, Herbert Haneder, Josef Hainfellner (May 2007) http://www.lk-projekt.at/uploads/tx_skreferenz/Biomassestudie.pdf

Country	Survey title	Reference/link
Austria (BLT3)	Renewable Energy 2020 – potentials in Austria [Erbeuerbare Energie 2020 – Potentiale in Österreich]	Günter Liebel, Manfred Wörgetter, Georg Greutter, Dr. Veronika Koller Kreimel, Bernd Vogl, Robert Wurm (May 2008) Federal Ministry of Agriculture, Forestry, Environment and Water Management
Germany 1	Erneuerbare Energien (Renewable Energies)	Volker Lenz, Andre Schwenker, Martin Kaltschmitt (2010) An article published in the magazine "BWK – das Energie-Fachmagazin" BWK Bd. 62(2010) Nr. 4 ISSN: 1618-193X
Germany 2	Biogaserzeugung durch Trockenvergärung von organischen Rückständen, Nebenprodukten und Abfällen aus der Landwirtschaft - Abschnitt 2: Erhebung der mit Trockenfermentationsverfahren erschließbaren energetischen Potenziale in Deutschland Vergleichende ökonomische und ökologische Analyse landwirtschaftlicher Trockenfermentationsanlagen (Biogas production of organic residues, by-products and waste from agriculture through dry fermentation – section 2: Survey of the energetic potential of dry fermentation in Germany- Comparative economical and ecological analysis of agricultural dry fermentation installations)	Universität Rostock Lehrstuhl für Verfahrenstechnik / Biotechnologie in Kooperation mit Institut für Energetik und Umwelt gGmbH und der Bundesforschungsanstalt für Landwirtschaft University Rostock Chair of process engineering /biotechnology In cooperation with Institute for Energy and Environment and Federal Agricultural Research Center (2007) http://www.fnr-server.de/ftp/pdf/literatur/TV/Abschnitt2-IE.pdf
Germany 3	Analyse und Bewertung der Nutzungsmöglichkeiten von Biomasse Untersuchung im Auftrag von BGW und DVGW Band 2: Biomassepotenziale in Deutschland, Nutzungstechniken und ökonomisch-ökologische Bewertung ausgewählter Nutzungspfade (Analysis and assesment of possibilities of use of biomass Study by order of BGW and DVGW Volume 2: Biomass potentials in Germany, utilisation techniques and economic-ecological assessment of selected utilisation paths)	Stephan Ramesohl, Karin Arnold, Martin Kaltschmitt, Frank Scholwin, Frank Hofmann, André Plättner, Martin Kalies, Sönke Lulies, Gerd Schröder, Wilhelm Althaus, Wolfgang Urban, Frank Burmeister (2005) http://www.biogaseinspeisung.de/download/Endbericht-Band2_IEL.pdf
Germany 4	Monitoring zur Wirkung der Biomasseverordnung Monitoring on the effect of the biomass ordinance	Franziska Müller-Langer, Janet Witt, Daniela Thrän, Sven Schneider, Frank Baur, Mark Koch, Uwe R. Fritsche, Kristin Wiegmann (2007) http://www.umweltdaten.de/publikationen/fpdf-l/3657.pdf
Germany 5	World in Transition – Future Bioenergy and Sustainable Land Use	German Advisory Council on Global Change (2009) ISBN 978-1-84407-841-7 http://www.wbgu.de/wbgu_jg2008_en.pdf

Mediterranean region

Country	Survey title	Reference/link
Italy	Censimento potenziale energetico biomasse, metodo indagine, atlante Biomasse su WEB-GIS (*Biomass to energy potential survey, survey method, Biomass atlas on WEB-GIS)*	*www.enea.it* Home > La Ricerca > Energia > Ricerca di Sistema elettrico > Censimento potenziale energetico biomasse Report RSE/2009/167
Italy	I traguardi della bioenergia in Italia. Elementi chiave per gli obiettivi al 2020. Rapporto ITABIA 2008 (*Bioenergy targets in Italy. Key elements for the 2020 targets. Report 2008 ITABIA)*	*www.itabia.it* la conoscenza del settore > testi digitali
Italy	Documento propedeutico alla redazione del Piano Nazionale Biocarburanti e Biomasse agroforestali per usi energetici (*Preparatory document for the drafting of a National Plan for agroforestry Biofuels and Biomass energy uses*)	*CRB www.crbnet.it* Relazione Tecnica CRB-07-RT-13-FB-1 *(only in hardcopy)*
Greece	Investigation of agricultural and animal wastes in Greece and their allocation to potential application for energy production	http://www.sciencedirect.com/
Greece	Agricultural biomass in Greece. Current and future trends	ISBN 92-64-10555-7
Greece	Capabilities for the administration of biomass residues from the agricultural sector for energy production	Proceedings of the 2nd international workshop of the Hellenic Solid Waste Management Association *(hard copy)*

Country	Survey title	Reference/link
Portugal	Os subprodutos agro-industriais de natureza lenhocelulósica – caracterização da situação portuguesa *(Lignocellulosic by-products from agro-industrial sector - characterization of the Portuguese situation)*	*http://repositorio.lneg.pt/handle/* *10400.9/470*
Portugal	Avaliação do potencial de biomassa da Região do Algarve *(Evaluation of the energy potential of biomass in the Algarve)*	*http://www.territorioalgarve.pt/* *Storage/pdfs/* *Volume_II_ANEXO_K4.pdf*
Spain	Aplicación SIG para evaluación de recursos de biomasa agrícola y foresta *(GIS tool for Biomass Resources Assessment in Southern Europe)*	http://bioraise.ciemat.es/bioraise/
Spain	PROBIOGAS	http://www.probiogas.es/
Spain	ACV COCO: Determinación del potencial real de reducción de emisiones de efecto invernadero en España mediante co-combustión. Actividad 2: Evaluación de los recursos de biomasa *(ACV-COCO: Determination of the real potential of greenhouse emissions reduction in Spain by means of the co-firing implementation. Work Package 2: Biomass resources assessment)*	http://circe.cps.unizar.es/ acvcoco/es/index.htm

Scandinavian region, including Finland

Country	Survey title	Reference/link
Sweden (SE-1)	4.6 Report: Bioenergy potential - Supply - Demand	Svebio http://www.svebio.se/attachments/33/902.pdf
Sweden (SE-2)	4.7 LRF's (The Federation of Swedish Farmers) energy scenario for 2020 – Renewable energy from agriculture and forestry provide new business opportunities and a better environment. A summary of: Environmental analysis Potentials Markets	Main author: Erik Herland http://www.bioenergiportalen.se/attachments/42/453.pdf
Sweden (SE-3)	4.8 Towards an oil-free Sweden 4.9 The information is from Appendix 1: Background facts	4.10 The commission against oil dependency (Commission appointed by the Swedish Government to develop a comprehensive program to reduce Sweden´s dependency on oil) http://www.sweden.gov.se/content/1/c6/06/62/80/bf5c673c.pdf
Norway (NO-1)	Biomass – enough for all good purposes?	Torodd Jensen og Knut Hofstad Report for Norwegian Water Resources and Energy Directorate http://www.kanenergi.no/oslo/kanenergi.nsf/Attachments/biorapport.pdf/$FILE/biorapport.pdf

Country	Survey title	Reference/link
Norway (NO-2)	Bioenergy in Norway – potentials, markets and policy instruments	Bjørn Langerud,Ståle Størdal, Halfdan Wiig and Morten Ørbeck Report commissioned by the Ministry of petroleum and energy. ØF-rapport nr.: 17/2007 ISBN: 978-82-7356-619-5 ISSN: 0809-1617
Denmark (DK-1)	Energy from biomass – Resources and technologies analyzed in regional perspective	Uffe Jørgensen, Peter Sørensen, Anders Peter Adamsen og Inge T. Kristensen, Faculty of agricultural sciences, Aarhus University http://www.agrsci.dk/djfpublikation/index.asp?action=show&id=1021
Denmark (DK-2)	Biomass resources	Danish Energy Agency http://www.ens.dk/da-dk/undergrundogforsyning/vedvarendeenergi/bioenergi/biomasseressourcer/sider/forside.aspx
Finland (SF-4)	Value chains for biorefineries of wastes from food production and services – ValueWaste	Kahiluoto, H., Kuisma, M., Knuuttila, M. Joona, J., Virtanen, M. Rinne, T., Horttanainen, M. Havukainen, J, Karttunen, P. Luoranen, M. Grönroos, J. & Myllymaa, T. Value chains for biorefineries of wastes from food production and services – ValueWaste, Biorefine programme 2007 – 2012, Yearbook 2009, Tekes Review 264/2009, p. 209 – 220
Finland (FI-1)	Availability and use of solid wood-based fuels in Finland [Kiinteiden polttoaineiden saatavuus ja käyttö Suomessa 2020, TTS Tutkimuksen tiedote, Luonnonvara-ala:metsä 10/2009]	Kalle Kärhä, Metsäteho Oy, Juha Elo& Perttu Lahtinen, Pöyry, Tapio Räsänen & Heikki Pajuoja, Metsäteho Oy www.tts.fi

Country	Survey title	Reference/link
Finland (FI-2)	Global potential of agrobiomass for energy [Peltobiomassat globaalinan energianlähteenä, MTT Maa- ja elintarviketalous 137, 2009. p. 53]	Katri Pahkala, Kaija Hakala, Markku Kontturi, Oiva Niemeläinen, MTT www.mtt.fi/met/pdf/met137.pdf
Finland (FI-3)	Estimation of the possibilities to reach EU targets for renewables in 2020 [Arvio mahdollisuuksista saavuttaa uusiutuvien energialähteiden käytön tavoitteet vuonna 2020 Suomessa, FINBIOn julkaisu 42, 2009]	Dan Asplund, BENET Oy, Martti Flyktman & Pauliina Uusi-Penttilä, VTT www.finbioenergy.fi