Research report no D 1.1.2 WP 1 Task 1.1
Helsinki 2013

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Report produced for BEST project, Work Package 1.1 (Aalto University)

EU-level Scenarios for primary biomass demand to 2020 & 2030

Sustainable Bioenergy Solutions for Tomorrow

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www.cleen.fi

ISBN 978-952-5947-70-0

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Key words (IEEE taxonomy): Renewable energy sources, Biomass, Cogeneration, Energy conversion, Public policy

Summary

This report involves running detailed scenarios to identify demand for primary biomass for energy purposes in the EU for 2020. These scenarios are also extended to provide less comprehensive indicative scenarios for 2030.

The key basis of the 2020 scenarios are the National Renewable Energy Action Plans (NREAPs), submitted by member states under the 2009 Renewables Directive, in order to map out the pathway to EU's overall 20% Renewable Energy target for 2020. We produce detailed country-level scenarios for 2020, taking these plans as a basis, and produce a number of scenario variations, representing reaching the 2020 objectives with a higher share of CHP, and secondly, with best available technology for all newly built bioenergy plants. Taking the 2020 scenarios as a basis, we make a simplified extension of the scenarios to 2030 based on two different bases: firstly, the European Commission's proposal for a 2030 climate & energy package policy, and secondly; a linear extension of the 2020 Renewable Energy targets. For the 2030 scenarios, results are reported only on a summary basis at EU-level.

The results of this study report a level of primary biomass demand in both 2020 and 2030 which is far in excess of all estimates of availability of biomass for energy purposes within the EU. Therefore, significant biomass imports are necessary. In this regard, we make a number of policy recommendations to promote a stable biomass market; a market capable of providing sufficient investor certainty concerning future fuel supply in order to facilitate the necessary investments in new biomass plants. Furthermore, we recommend technology promotion measures to ensure biomass used in the energy sector is utilized as efficiently as possible. Finally, we make a number of recommendations for future research to take forward the questions raised in this scenario study concerning the future of bioenergy in the EU.

Helsinki, May 2014

Contents

1. Introduction

This report involves running detailed scenarios to identify demand for primary biomass for energy purposes in the EU for 2020. These scenarios are also extended to provide less comprehensive indicative scenarios for 2020.

The key basis of the scenarios are the National Renewable Energy Action Plans (NREAPs) [1] submitted by member states under the 2009 Renewables Directive [2], which provide projections on the use of biomass for electricity, heating and cooling and transport to 2020. These projections are made in respect of mapping a pathway to member states reaching their legally binding renewables target for 2020, and as such represent relatively concrete predictions of the quantities of different forms of renewable energy that member states intend to develop towards reaching the target. Whilst member states are not bound to rigidly stick to the pathway laid out in NREAPs towards reaching the target, we would expect them to be strongly guided by the plans, since they often represent the result of substantial planning and study of the optimum economic pathway for reaching the target.

Taking the 2020 scenarios as a basis, we make a simplified extension of the scenarios to 2030 based on two different bases: firstly, the European Commissions proposal for a 2030 climate & energy package policy, and secondly; an linear extension of the 2020 Renewable Energy targets. For the 2030 scenarios, results are reported only on a summary basis at EU-level; the main purpose of this report was to run the detailed country-level scenarios for the 2020 timeframe and the 2030 results are presented here as ñindicativeò numbers to give some idea how the continuation of bioenergy development beyond the 2020 targets would increase primary biomass demand even further and the implications of this continuation. A detailed analysis for 2030 would be a useful objective for future research in this area.

1.1 Scenarios included in this report

In analysing primary biomass demand for energy purposes by 2020, we will analyse a number of scenarios based upon the NREAPs. We will run the following scenarios:

ï **Baseline scenario** ï based directly on the sectoral development of electricity, heat and transport in the NREAPs, and within this, assuming the same mix between electricity-only and combined heat and power plants set out in the plants

ï **ñCHP plusò scenario** ï reaching the same overall final energy consumption from biomass for electricity & heat as in the NREAPs, but using *less* electricity-only biomass and more CHP. A differentiated approach is applied whereby biomass CHP deployment is adjusted upwards by a higher percentage in countries with large use of district heating ï and therefore a higher biomass CHP growth potential - and by a lesser percentage in others.

ï **ñZero-CHPò scenario** ï this is a highly theoretical scenario intended to give an indication of the primary energy savings benefit of the CHP development already contained in the plans (and indeed existing CHP capacity). In the Zero-CHP scenario, the objective is same overall final energy consumption from biomass for electricity & heat as in the NREAPs but without the use CHP at all ï i.e. only through the use of separate electricity and heat plants. Subsequently, there is a higher demand for primary biomass which can be compared to the baseline scenario to show the benefits of CHP in reducing primary biomass demand.

A key question in developing all of the above scenarios is what conversion factor to use to convert final energy consumption data (in the NREAPs) to primary biomass demand. This conversion factor is of course a question of plant efficiency. In this respect, we have undertaken a detailed analysis of the different plant technologies in use and in planning, and considered the efficiency of these plants in consultation with industry partners in the BEST project and with academic experts. In respect of plant efficiency question, we run a further scenario based upon the baseline scenario, the best available scenario:

- **BAT (Best available technology) Scenario** ï this scenario uses the same basic development of bioenergy as in the baseline scenario (i.e. based directly on the NREAPs), but assumes that all plants built from 2013 onwards are built to the best available technology available ï i.e. the highest possible efficiencies. In contrast, the baseline scenario assumes that the new plants are built as per the ñbusiness as usualò advance in plant efficiency ï i.e. what would be realistically expected rather than what is technically possible. This scenario is intended to give an indication of the primary energy savings that could result if all new plants were built according to the most efficient plant technologies available. As the plant technologies have been defined in consultation with industrial partners who manufacture power plant technologies we believe it represents an interesting indication of the primary energy that could be saved if utilities voluntary chose the most efficient technologies available or if government incentives were put in place to build the most efficient plant possible.

In running all of the above scenarios, there was one further fundamental question in calculating actual primary biomass demand, concerning the ñefficiencyò of the processing of the biomass before its arrival at the electricity, heat or CHP plant. The aforementioned plant efficiency assumptions only take account of the efficiency conversion of the biomass fuel as delivered to the plant gate to final energy in the form of electricity and heat. However, biomass fuel will have undergone varying levels of processing before arrival at the plant. Therefore, the energy content of biomass fuel delivered to the plant will require a significantly higher primary biomass demand in terms of raw biomass (e.g. from forests or agriculture). In view of this, for all of the above scenarios, we present two variations as follows:

- **A. Processing efficiency included** - Scenario variation taking account of primary energy efficiency of raw biomass processing into biomass fuel as delivered to plant i.e. representing demand for raw biomass from forestry, agriculture or waste sources. The sophistication of this analysis is limited by the description of biomass fuel types for electricity and heat plants made in the NREAPs ï there is only differentiation between solid biomass, biogas and bioliquids. Therefore processing efficiency assumptions are distinguished only according to these global fuel typesï even though there will of course be significant variations in the processing efficiency of e.g. different types of forestry and agricultural biomass.

- **B. Processing efficiency not included** - Scenario variation not including primary energy efficiency of raw biomass ï i.e. only representing the primary energy demand of biomass fuel as delivered to plant. We considered it important to include this scenario to give comparability with other studies ï many of which do not make mention of processing efficiency, and to give equivalence with data on primary demand of fossil fuels in the energy sector, which also typically take no account of pre-plant processing energy demand e.g. in coal mining, gas production, etc.

A full explanation on the scenario methodology is given in section 6, where the above scenarios are comprehensively summarised in tabular form (section 6.4.6).

2 National Renewable Energy Action Plans for 2020

2.1 Overview of 2020 RES target and national plans

2.1.1 RES target & directive

The 2009 Renewables Directive (2009/28/EC) sets a new precedent for EU policy on renewable energy sources (RES), with the 20% target for RES in total energy consumption by 2020 representing more than doubling the 2005 level of around 8.5%. The Directive presents Member States with a huge implementation challenge that cannot simply be met by an extension of existing promotional policies for renewables.

The 20% target for renewable energy is calculated as a percentage of total final energy consumption, including all energy use ï electricity, heating & cooling and transport. There are no sectoral targets for electricity or heating/cooling, but a separate 10% target has been set for use of renewable energy in transport.

The overall 20% EU renewables target for 2020 is split into separate targets for individual Member States. These national targets are legally binding on the Member States and represent the first ever legally binding energy portfolio obligations placed on Member States, in contrast to the indicative targets of a 21% share for RES-power in total electricity by 2010 set under the 2001 Renewables Directive [3], and a 5.75% share for use of biofuels in total transport fuels by 2010 under the Biofuels Directive[4]. Notably, neither of these indicative targets is likely to be achieved. Therefore the legislators decided to set legally binding targets for the 2009 directive, in an attempt to avoid the previous disappointments with indicative targets.

As the percentage of renewables in total EU energy was around 8.5% in 2005, the marginal increase required across the EU as a whole to 2020 is 11.5%. Member States have been assigned to achieve different marginal increases in their national RES percentages, on the following principles:

- All Member States must achieve a marginal flat increase of 5,75%
- A further increase, based on national GDP per capita, is applied in addition to the flat 5.75%, such that the total of GDP-modulated targets in principle averages 5,75%
- Some account is taken of significant advances in RES-development already made by Member States such as Sweden and Finland (note comparison with Germany, France, Italy and UK, which have equal or lower GDP per capita but higher marginal targets)

On the basis of the above principles, but with some further allowances to some Member States, the individual targets have been set as follows:

Table 1: National targets under RES directive

Member State	Share of energy from RES in gross final energy consumption (FEC) in 2005 *(s2005)*	Target for share of energy from RES in gross FEC in 2020 *(s2020)*	Marginal increase in share of RES required to 2020 *(q2020)*	Target for 2020 expressed as a multiple of the RES percentage in 2005 *(*2020)*
Belgium	2.2%	13.0%	10.8%	5.9
Bulgaria	9.4%	16.0%	6.6%	1.7
Czech Rep.	6.1%	13.0%	6.9%	2.1
Denmark	17.0%	30.0%	13.0%	1.8
Germany	5.8%	18.0%	12.2%	3.1
Estonia	18.0%	25.0%	7.0%	1.4
Ireland	3.1%	16.0%	12.9%	5.2
Greece	6.9%	18.0%	11.1%	2.6
Spain	8.7%	20%	11.3%	2.3
France	10.3%	23.0%	12.7%	2.2
Italy	5.2%	17.0%	11.8%	3.3
Cyprus	2.9%	13.0%	10.1%	4.5
Latvia	32.6%	40.0%	7.4%	1.2
Lithuania	15.0%	23.0%	8.0%	1.5
Luxembourg	0.9%	11.0%	10.1%	12.2
Hungary	4.3%	13.0%	8.7%	3.0
Malta	0.0%	10.0%	10.0%	Infinite
Netherlands	2.4%	14.0%	11.6%	5.8
Austria	23.3%	34.0%	10.7%	1.5
Poland	7.2%	15.0%	7.8%	2.1
Portugal	20.5%	31.0%	10.5%	1.5
Romania	17.8%	24.0%	6.2%	1.4
Slovenia	16.0%	25.0%	9.0%	1.6
Slovak Republic	6.7%	14.0%	7.3%	2.1
Finland	28.5%	38.0%	9.5%	1.3
Sweden	39.8%	49.0%	9.2%	1.2

UK	1.3%	15.0%	13.7%	11.5

As can be seen from the table above, the challenge varies significantly from one Member State to another. The fourth column (q2020) expresses the marginal increase in the RES share required by each Member State. On this measure, the six Member States with the greatest challenge are:

- UK ï marginal increase required to 2020 (q2020): 13.7%
- Denmark ï q2020: 13.0%
- Ireland ï q2020: 12.9%
- France ï q2020: 12.7%
- Italy ï q2020: 11.8%
- Netherlands ï q2020: 11.6%

It is also interesting to look at the challenge posed by the 2020 target in terms of the multiple that the target represents compared to the Member Stateõs share of renewables in 2005, shown in the fifth column (*2020). Although this figure is rather imprecise in statistical terms since it is based on percentages rather than absolute quantities of Renewable energy, it provides an indication of the challenge that the 2020 target presents in relation to a Member Stateõs progress on renewables so far. Therefore, this figure to some extent indicates which Member States are required to make the largest policy shift from ñbusiness as usualò. On this basis, the six Member States facing the greatest challenge are:

- Luxembourg - 2020 target as multiple of 2005 share (*2020): 12.2
- United Kingdom ï *2020: 11.5
- Belgium ï *2020: 5.9
- Netherlands ï *2020: 5.8
- Ireland ï *2020: 5.2
- Cyprus ï *2020: 4.5

In addition, Malta has to move from a 0% share in 2005 to 10% in 2020, representing a particular difficult challenge given the likely absence of existing RES expertise in this small island state. However, whilst it can be seen that the target is very challenging for a number of member states, the legally binding nature of the target and the continuing public commitment of member states towards reaching it appear to make the 2020 RES targets and the associated NREAPs a reasonable basis for the scenarios in this report, as is further elaborated upon in section 2.2. Indeed for the reasons expressed elsewhere in this paper, the NREAPs represent a rather more exact and reliable basis for scenarios than is typical in energy perspective studies.

2.1.2 National RES Action Plans, interim targets and progress report

The Directive requires that each Member State should submit a National Renewable Energy Action Plan (NREAP) by 30 June 2010, setting out how it plans to achieve its 2020 target. The European Commission issued a strict template for this plan which Member States must adhere to, setting out in detail how they plan to reach their overall RES target through development in the three RES energy sectors ï electricity, heating and cooling and transport [5]. The plans contain a total of 16 tables; for example, in the case of RES Electricity the tables require the Member States to provide year by year projections for both generation and capacity of different types of RES electricity. It is also notable that because the target is based on a percentage of final energy consumption, efforts to improve energy efficiency are also relevant and indeed Member States are required to set out in the plans energy consumption according to business as usual and with enhanced energy efficiency scenarios (the latter scenario is used for the target compliance calculations in the plans).

The Member States are also required to fulfil interim targets under the directive. These interim targets are expressed as a percentage of the total growth in renewables needed between the 2005 baseline percentage and the 2020 target percentage. The interim targets are based on an average of the percentage of renewable energy in final energy consumption taken over a two year period. The interim targets, found in part B of Annex I of the Renewables Directive [2], are as follows:

- 20% average over the years 2011 and 2012
- 30% average over the years 2013 and 2014
- 45% average over the years 2015 and 2016
- 65% average over the years 2017 and 2018

To clarify these interim targets, the example of Finland is explained in the box below follows:

Interim target calculation example - Finland

2005 RES percentage in final energy consumption (FEC) = 28.5%

2020 RES target percentage of FEC: 38%

e.g. 2011-2012 interim target percentage (20% of overall target effort, φ2020):

28.5% + 20%*(38%-28,5%)

= <u>30,4%</u>

The performance against the interim target is to be reported as part of biannual progress reports, the first of which is due by the end of 2011, then end of 2013, 2015, etc. In this progress report, the Member State is only required to report on the share of RES in the different sectors (electricity, heating and cooling, transport) in the preceding two calendar years. Notably, Member States are not required to report on their progress in individual technologies so these progress reports are rather limited in scope. The schedule of interim targets implies that the report due at the end of 2013 is the first in which Member States report on compliance with an interim target ï in this case, that for the period 2011 to 2012.

Member States are subject to one further requirement; if a progress report indicates that a Member State is not in line with the interim target trajectory, it is then required to submit a revised national plan within the following six months, indicating how it intends to re-align with the trajectory.

2.2 Justification for using the NREAPs as a basis for scenarios

As outlined in section 2.1.1, the Renewables target will be quite challenging for some member states to reach. However, as the target is legally binding and member states remain publicly committed to reaching the target, we argue that the 2020 RES targets and the consequent NREAPs provide a good basis for forecasting the development of the bioenergy sector to 2020 (and beyond). Indeed, we believe that the NREAPs represent a rather more exact and reliable basis for scenarios than is typical in energy modelling studies. We would argue that the projections for the development of different forms of Renewable energy made in the NREAP, produced in respect of mapping a pathway to member states reaching the legally binding 2020 RES target, represent relatively concrete predictions of the quantities of different forms of renewable energy that member states intend to develop. Whilst member states are not bound to rigidly stick to the pathway laid out in NREAPs towards reaching the target, we would expect them to be strongly guided by the plans, since they often represent the result of substantial planning and study of the optimum economic pathway for reaching the target. In respect of the latter, the NREAPs represent a substantial body of research work and understanding on national specificities that one could not hope to replicate without extensive research outside of the scope of this study.

Furthermore, very few member states plan to significantly exceed the target and so member states are likely to require the complete mix of technologies in the plans ï including bioenergy - to reach the target. Underperformance in one renewable technology will mean it must be compensated by another technology, to ensure that the state remains on the pathway to reach the 2020 target; however in many cases it will be very difficult to develop technologies to higher levels that set out in the plans since they already represent the limit of feasible development in the short period to 2020. For example, any underperformance in bioenergy would need to be compensated for by an increase in e.g. wind or solar energy ï and yet these technologies are often already projected in the plans to grow very significantly ï and arguably close to the limit of technical and economic potential in many cases. Notably, bioenergy often represents one of the cheapest forms of renewable energy, and so we would rather expect that the objectives for bioenergy development could in some cases even be exceeded to compensate for other technologies which prove too expensive. Furthermore, as stated already, member states are subject to reaching a series of interim targets in the period up to 2020; whilst these are not legally binding, the European Commission is expected to closely monitor member states in regards to these targets and ensure that the required technologies set out in the NREAPs are be developed at sufficient pace to reach the target. Therefore, we argue that all in all, the NREAPs do represent relatively reliable projections of the development of bioenergy to 2020, and we would be surprised to see major deviations from them if member states are actually to reach the binding 2020 objectives. Nonetheless, we do consider it reasonable to model a number of variations upon the NREAP target (see section 1.1, 6.4) reaching the same final energy projections for bioenergies laid out in the NREAPs, but through a different mix of electricity-only and CHP plants (i.e. CHP-plus and zero-CHP scenarios).

2.3 Biomass in the NREAPs

2.3.1 Overview of biomass data available in NREAPs

Biomass and bioenergy feature in a number of tables in the NREAPs, as follows:

The tables marked **À** *below were directly used for gathering data to build the scenarios in this report*

- Table 4b: Calculation table for the renewable energy in transport share (ktoe); Part (I) - Expected consumption of biofuels from wastes, residues, non-food cellulosic and lingo-cellulosic material in transport
- Table 7: Biomass supply in 2006 (i.e. primary biomass supply)
- Table 7a: Estimated biomass supply in 2015 and 2020 (i.e. predicted primary biomass supply)
- Table 8: Current agricultural land use for production of crops dedicated to energy in 2006
- À Table 10a & 10b: Estimation of total contribution (installed capacity, gross electricity generation) expected from each renewable energy technology in [Member State] to meet the binding 2020 targets and the indicative interim

trajectory for the shares of energy from renewable resources in electricity (table 10a, 2010-2014, table 10b, 2015-2020)

- À Table 11: Estimation of total contribution (final energy consumption) expected from each renewable energy technology in [Member State] to meet the binding 2020 targets and the indicative interim trajectory for the shares of energy from renewable resources in heating and cooling 2010-2020 (ktoe)*
- À Table 12: Estimation of total contribution expected from each renewable energy technology in [Member State] to meet the binding 2020 targets and the indicative interim trajectory for the shares of energy from renewable resources in the transport sector 2010-2020 (ktoe)*

As can be seen the list above, the data for the scenarios in this report has been gathered from tables 10, 11 and 12, the tables covering projections for electricity, heating & cooling respectively. The other tables were not used in this study, although tables 7 and 7a on biomass supply are interesting in respect of this research area, particular the projections for biomass supply in table 7a, and analysis of these tables would be a useful in extending the analysis carried in this paper.

2.3.2 Overview of development of bioenergy in the NREAPs

Table 2 below shows the development of bioenergy (in final energy terms) in the three key energy sectors of Electricity, Heating & Cooling and Transport. As can be seen, bioenergy is projected to develop very strongly from the 2005 baseline of the NREAPs towards the 2020 target compliance year. To give comparability between the different datasets, all figures have been converted to TWh. The largest relative growth is seen in the transport sector, where there is a ten-fold increase forecast to reach the 2020 level of 333TWh. Meanwhile biomass heating and cooling has been and will remain the largest bioenergy sector in 2020, although the relative increase is less steep, somewhat less than doubling between 2005 and 2020 (the official terminology of "heating and cooling" used in the NREAPs is somewhat misleading as almost all final energy in this category is actually biomass heating). For electricity, there is also strong development – a more than three-fold increase from 2005-2020. Nonetheless, contrasting with the relative increases, absolute increase in final bioenergy consumption is clearly headlined by biomass heating and cooling, with slightly under a 450TWh increase 2005-2020, compared to 300TWh in transport and just over 160TWh in electricity. However, these figures disguise the effect of these increases on primary biomass consumption – i.e. the key analysis carried out in this report. Without prejudicing the scenario results, it is already prescient to point out that while biomass heating and cooling sees the largest absolute increase, it has by far the highest primary to final energy conversion efficiency of the three energy sectors, followed by transport, with electricity being the least efficient when biomass is utilized in electricity-only plants.

Table 2: Growth of biomass heat, electricity and transport in EU-27, 2005-2020 (from NREAPs)

EU-27 Total biomass consumption (TWh)							
Sector	**2005**	**2010**	**2013**	**2015**	**2020**	**Absolute increase 2005-2020 (TWh)**	**Relative increase 2005-2020 (%)**
Electricity	69	114	149	169	232	163	237 %
Heat & Cooling	614	720	794	850	1047	433	71 %
Transport	33	158	201	226	333	300	923 %
Total	***715***	***993***	***1144***	***1245***	***1612***	***897***	***125 %***

Another interesting overall point to make here is the role of biomass in comparison to other renewable energy technologies in the NREAPs. Taking RES-Electricity as an example, one can see the importance of biomass in relation to the other technologies such as wind and solar (see table 3 below), This further strengthens the argument that the biomass objectives in the NREAPs do need to be achieved if the legally binding targets are to be met; biomass plays a major role in reaching the targets and underperformance in biomass cannot easily be taken up by increasing the role of other (more expensive) RES technologies ï which have already been pushed close their realistically feasible development possibilities in the short period to 2020.

Table 3: Split of RES-Electricity objectives for EU-27 (relative role of biomass)

Split of RES-Electricity objectives for EU-27 (TWh)						
Generation type	**2005**	**2010**	**2013**	**2015**	**2020**	**Relative share in 2020**
Hydro / Tidal	331	340	346	350	370	31 %
Wind	70	166	247	307	487	41 %
Solar	1.5	21	47	61	101	8 %
Geothermal	5.5	6.0	6.6	7.3	11	1 %
Total biomass	69	114	149	169	232	19 %
- Solid biomass	55	77	101	114	156	13 %
- Biogas	12	29	37	44	64	5 %
- Bioliquids	1.5	8.6	10	11	13	1 %
Total	***477***	***647***	***795***	***895***	***1201***	***100 %***

2.3.3 Biomass electricity in the NREAPs

Taking the starting point of an average relative increase of just under 240% in biomass electricity across the EU from 2005-2020 ï an absolute increase of 160TWh, we see significant differences across the member states in the degree of emphasis on biomass electricity (see table 4). The largest absolute rise ï of 35TWh, is seen, unsurprisingly, in Germany, the largest member state, which already starts from a significant base in 2005 (accounting for its relative increase being only slightly higher than average). Other member states with large absolute increases are France (13TWh), Italy (14TWh), Netherlands (11TWh), Poland (near to 13TWh) and UK (17TWh). Concerning relative increase, there are a number of ñoutliersò with very high percentages ï these are somewhat deceiving as several member states start from a very low base (or even zero) in 2005 to reach a rather modest level in 2020. However, a number of member states with genuinely challenging increase can be identified, with both significant relative increases which are also high in absolute terms in view of the energy consumption of the state in question. These are Belgium (9.2 TWh, over 500%), Czech Republic (3.8TWh, over 500%), Latvia (1.2TWh, close to 3000%), Lithuania (1.2TWh, over 17000%), Poland (12.8TWh, almost 900%) and Slovakia (1.7TWh, over 5000%). It is clear that the latter member states place significant emphasis on development of biomass electricity as a part of reaching their overall RES target in 2020. One might also include here the Netherlands, which sees only an average relative increase as it starts from a high base in 2005, but has a planned absolute increase of 11.6TWh which is significant in comparison to the relatively small size of the member state and its consequent energy consumption.

Table 4: Growth of biomass electricity by member state in EU-27 2005-2020 (from NREAPs). NB: Includes biomass electricity from CHP, not stated separately here.

EU-27 Biomass consumption in electricity (GWh)						Absolute increase 2005-2020 (GWh)	Relative increase 2005-2020 (%)
Country	2005	2010	2013	2015	2020		
Austria	2823	4720	4769	4826	5147	2324	82%
Belgium	1791	3007	4565	5952	11039	9248	516%
Bulgaria	0	0	252	803	865	865	NA
Cyprus	0	30	67	84	143	143	NA
Czech Republic	721	2127	3448	3931	4484	3763	522%
Denmark	3243	3772	5773	6034	8846	5603	173%
Estonia	33	241	336	346	346	313	948%
Finland	9660	8090	9430	9880	12910	3250	34%
France	3819	5441	7825	10495	17171	13352	350%
Germany	14025	32777	38562	42091	49457	35432	253%
Greece	94	254	257	504	1259	1165	1239%
Hungary	0	1955	2097	2250	3324	3324	NA
Ireland	116	348	839	887	1006	890	767%
Italy	4675	8645	11686	13712	18780	14105	302%
Latvia	41	72	365	664	1226	1185	2890%
Lithuania	7	148	430	761	1223	1216	17371%
Luxembourg	46	69	142	200	334	288	626%
Malta	0	9	56	140	135	135	NA
Netherlands	5041	5975	10890	13350	16639	11598	230%
Poland	1451	6028	8774	9893	14218	12767	880%
Portugal	1976	2400	3191	3359	3516	1540	78%
Romania	0	67	1200	2050	2900	2900	NA
Slovakia	32	610	1050	1349	1710	1678	5244%
Slovenia	114	298	457	623	676	562	493%
Spain	2652	4228	6260	7143	12200	9548	360%
Sweden	7570	10631	12468	13692	16753	9183	121%
United Kingdom	9109	12330	13560	14290	26160	17051	187%
EU-27	*69039*	*114272*	*148749*	*169309*	*232467*	*163428*	*237%*

2.3.4 Biomass heating & cooling in the NREAPs

Note: Although the category in the NREAPs is described as Biomass Heating *and* Cooling, almost all is in practice Biomass heat, and so it as described as such here for the purposes of simplicity.

Biomass heat is already the most well developed bioenergy sector at the 2005 baseline for the NREAPs, with a final energy consumption of almost 615TWh compared to just under 70TWh for biomass electricity. Nonetheless, the EU average increase of 70% from 2005-2020 is significant, and yet it disguises much larger increases in some member states (see table 5 below). The largest absolute increases between 2005 and 2020 are seen in France (85TWh), Germany (48TWh), Italy (47TWh), Poland (58TWh), and UK (39TWh). Of these, the increase is particularly large in relative terms in Italy (over 240%), Poland (over 5700%) and the UK (almost 600%). Looking to other member states which plan particularly significant Biomass heat development in comparison to past performance and size of country, we find the examples of Belgium (18TWh increase, over 320% in percentage terms), Hungary (almost 15TWh added, starting from zero in 2005), and the Netherlands (10TWh, 135%).

Table 5: Growth of biomass heat by member state in EU-27 2005-2020 (from NREAPs)

EU-27 Biomass consumption in heat (GWh)						Absolute increase 2005-2020 (GWh)	Relative increase 2005-2020 (%)
Country	**2005**	**2010**	**2013**	**2015**	**2020**		
Austria	35274	39716	39984	40275	41949	6675	19%
Belgium	5552	7933	10983	13699	23655	18103	326%
Bulgaria	8420	8536	9571	10804	12479	4059	48%
Cyprus	49	213	252	281	351	302	616%
Czech Republic	16840	21411	24086	25098	27458	10618	63%
Denmark	20457	26109	29377	29377	30738	10281	50%
Estonia	5873	7118	7280	7280	7059	1186	20%
Finland	63849	57917	64895	67454	76874	13025	20%
France	106449	115753	131186	148399	191372	84923	80%
Germany	84445	105740	114776	120824	132059	47614	56%
Greece	11060	11770	12572	13119	14212	3152	28%
Hungary	0	9444	9257	9653	14898	14898	NA
Ireland	2128	2303	3501	4512	5652	3524	166%
Italy	19248	26040	34099	40938	65942	46694	243%
Latvia	12956	11863	13177	13700	16189	3233	25%
Lithuania	7978	7711	9164	10223	11897	3919	49%
Luxembourg	223	272	447	585	964	741	332%
Malta	0	12	26	26	20	20	NA
Netherlands	7525	8315	9944	11397	17678	10153	135%
Poland	1029	45485	47497	49160	59185	58156	5652%
Portugal	29168	25342	27307	27203	27005	-2163	-7%
Romania	36821	32494	33960	34088	45078	8257	22%
Slovakia	4164	5199	6082	6699	8025	3861	93%
Slovenia	5164	4826	5385	5757	6106	942	18%
Spain	40333	43368	44787	47218	54114	13781	34%
Sweden	82317	91673	97280	101022	110380	28063	34%
United Kingdom	6513	3756	6792	11142	45520	39007	599%
EU-27	***613835***	***720319***	***793669***	***849931***	***1046860***	***433025***	***71%***

2.3.5 Transport biofuels in the NREAPs

Transport biofuels have by far the largest increase of the three bioenergy sectors, with an overall increase from 2005-2020 of over 900%. It may appear surprising that such strong development of transport biofuels are planned, since they are typically the most expensive of the three types of bioenergy. However, the planned growth in biofuels is in fact principally driven by the separate 10% RES Transport target in the Renewables directive. Although several types of RES Transport can be used towards this target, (including RES Electricity in electric cars, hydrogen produced from RES, etc), most member states intend to meet the majority of this target using biofuels. Of course there are other pressures to use transport biofuels since they represent a relatively easy way to reduce transport oil demand since biofuels can be used in existing vehicles. Nonetheless, at the 2005 baseline year most member states start from a very low base for biofuels. and yet the total of 300TWh planned in 2020 is significantly in excess of the planned 160TWh in biomass electricity despite starting from a much higher base in that sector. However, it is worthwhile to point out a few exceptions i.e. member states which already have significant experience in biofuels; these include Germany (20TWh in 2005, increase of just over 200% to 2020), France (4.6TWh in 2005, increase of just under 800% to 2020), Sweden (almost 2TWh in 2005, under 400% increase planned to 2020). Most member states do plan very large increase though, with the relative increase depending on their baseline position in 2005 ï in fact 11 member states had no biofuels at all in use in 2005. There are a few member states who plan to increase biofuels significantly beyond the 10% RES Transport target for biofuels; Finland is notable here, in planning to reach a share of biofuels of the order of 20% of final energy consumption in transport, a total of 6.5TWh of biofuels, starting from a baseline of zero in 2005.

Table 6: Growth of transport biofuels by member state in EU-27 2005-2020 (from NREAPs) State here that donâ write about transport (but biofuels included in demand scenarios)

EU-27 Biomass consumption in transport (GWh)						Absolute increase 2005-2020 (GWh)	Relative increase 2005-2020 (%)
Country	2005	2010	2013	2015	2020		
Austria	407	3838	4047	4303	5699	5292	1300%
Belgium	0	3827	4797	5777	9178	9178	NA
Bulgaria	0	384	1047	1849	3303	3303	NA
Cyprus	0	183	227	261	441	441	NA
Czech Republic	35	2710	4152	5094	7815	7780	22229%
Denmark	0	361	2838	2873	3035	3035	NA
Estonia	0	10	229	192	1036	1036	NA
Finland	0	2559	3954	4885	6513	6513	NA
France	4687	31575	33727	34018	41287	36600	781%
Germany	20259	39879	37100	35751	62976	42717	211%
Greece	14	1244	3431	4489	7176	7162	51157%
Hungary	58	1675	2628	2919	5943	5885	NA
Ireland	15	1569	2720	3488	5604	5589	37260%
Italy	2082	11874	17143	20643	29424	27342	1313%
Latvia	35	454	477	454	663	628	1794%
Lithuania	42	640	1047	1268	1942	1900	4524%
Luxembourg	12	483	576	937	2510	2498	20817%
Malta	0	35	49	59	149	149	NA
Netherlands	0	3570	5675	6594	9699	9699	NA
Poland	512	11235	14351	15735	22888	22376	4370%
Portugal	0	3268	3559	4989	5548	5548	NA
Romania	0	2605	3594	4222	5751	5751	NA
Slovakia	0	954	1093	1593	2210	2210	NA
Slovenia	0	471	645	921	2235	2235	NA
Spain	1593	16782	25365	26412	31552	29959	1881%
Sweden	1931	4419	5920	6920	9420	7489	388%
United Kingdom	872	11583	20794	29191	48904	48032	5508%
EU-27	***32553***	***158186***	***201185***	***225836***	***332901***	***300348***	***923%***

2.3.6 Summary of bioenergy sectors in the NREAPs

Quick statement here that table below is summary of the above tables

Table 7 below summarises the content of the tables above for each bioenergy sector (elec, heat, trans) but consider only the period 2012-2020 (i.e. not from 2005 unlike above tables), and therefore represents the ῥoutstandingὸ bioenergy development to reach target. However, the table is somewhat theorectical since all data is taken from the NREAPs ï the 2012 data does not necessarily represent what has already been achieved, although it is reasonable to assume that most countries have achieved their forecast 2012 NREAP objectives by the current year of 2014. Nonetheless, the table should only be used for indicative purposes. With these caveats in minds, we can make some observation the following about the remaining challenges for developing the bioenergy sector. In this regard we categorise the countries here by which bioenergy sector they have the largest absolute growth still to be achieved. This provides indication about the bioenergy sector that each country needs to focus most upon in the period to 2020.

- *Countries with largest outstanding challenge in electricity sector (absolute sectoral growth required 2012-2020):*
  Denmark (4635GWh), Malta (113GWh)

- *Countries with largest outstanding challenge in heat sector:*
  Austria (2070GWh), Belgium (13577GWh), Bulgaria (3291GWh), Finland (13258GWh), France (68768GWh), Hungary (5571GWh), Italy (34785GWh), Lithuania (3303GWh), Netherlands (8362GWh), Poland (1421GWh), Romania (10641GWh), Slovakia (2268GWh)

- *Countries with largest outstanding challenge in transport sector:*
  Czech Republic (4140GWh), Estonia (876GWh), Germany (22609GWh), Greece (4222GWh), Ireland (3268GWh), Luxembourg (2095GWh), Portugal (2256GWh)

As is self evident from the above and the previous tables,further development of biomass heat will play the dominant role in the oputstanding efforts required to reach national bioenergy objectives for 2020. However, between these countries, the relative scale of the challenge varies greatly, since a number of countries already have significant experience in biomass heat; a number of key exceptions of this are as follows Belgium (135% relative increase required to 2020), Italy (112%), Netherlands (90%), and United Kingdom (731%).

Table 7: Sectoral increase by country in absolute (number) and relative (percentage) term for period 2012-2020 (percentages compared to 2012 figure in NREAP, not Eurostat)

EU-27 Sectoral bioenergy development between 2012-2020						
Country	**Electricity**		**Heat&cooling**		**Transport**	
	GWh	**%**	**GWh**	**%**	**GWh**	**%**
Austria	397	8 %	2070	5 %	1733	44 %
Belgium	6936	169 %	13577	135 %	4385	92 %
Bulgaria	745	621 %	3291	36 %	2524	324 %
Cyprus	93	186 %	114	48 %	230	109 %
Czech Republic	1318	42 %	3919	17 %	4140	113 %
Denmark	4635	110 %	3943	15 %	186	7 %
Estonia	10	3 %	-221	-3 %	876	546 %
Finland	3720	40 %	13258	21 %	3024	87 %
France	10680	165 %	68768	56 %	7560	22 %
Germany	12747	35 %	20294	18 %	22609	56 %
Greece	1003	392 %	1907	16 %	4222	143 %
Hungary	1329	67 %	5571	60 %	3419	135 %
Ireland	527	110 %	2477	78 %	3268	140 %
Italy	8109	76 %	34785	112 %	14049	91 %
Latvia	991	422 %	3128	24 %	174	36 %
Lithuania	954	355 %	3303	38 %	1070	123 %
Luxembourg	222	198 %	609	172 %	2095	504 %
Malta	113	514 %	-6	-22 %	105	237 %
Netherlands	7757	87 %	8362	90 %	4559	89 %
Poland	6026	74 %	12421	27 %	9595	72 %
Portugal	525	18 %	-349	-1 %	2256	69 %
Romania	2105	265 %	10641	31 %	2460	75 %
Slovakia	810	90 %	2268	39 %	1175	113 %
Slovenia	261	63 %	907	17 %	1678	301 %
Spain	6223	104 %	9804	22 %	6443	26 %
Sweden	4897	41 %	14966	16 %	3989	73 %
United Kingdom	12900	97 %	40042	731 %	30378	164 %
Average of relative increases across member states	***NA***	***161 %***	***NA***	***67 %***	***NA***	***140 %***
EU-27 total absolute and relative increase	***96033***	***70 %***	***279852***	***36 %***	***138200***	***71 %***

2.4 Notes on scope of scenario analysis relating to NREAPs

It is necessary to make a few notes on the scope of our analysis. In our analysis, we are only concerned with primary energy demand for biomass for the electricity, heat and transport sectors as in included in the NREAPs provided by European member states. This definition gives rise to a number of caveats, as follows:

- Autoproducer heat ï i.e. heat derived from biomass generated in industrial plants ï e.g. pulp plants. We do not include autoproducer heat as part of our final energy calculations, unless it is sold to third parties outside the industrial plant. This limitation is effectively imposed as this type of autoproducer heat is not included in the NREAPs or in statistics supplied to Eurostat. This decisions is further justified by our restriction to consideration to the energy sector as set out in the next point

- Our focus is on expected changes in the EU-27 energy sector in accordance with the NREAPs; biomass use in industry is more affected by industrial production than governmental energy policies, heat production determined by industrial needs (steam parameters etc.)

3 EU 2030 energy & climate policy

The European Commission's policy framework for 2030 energy and climate policy was launched on 22st January 2014. In essence this framework represents the beginning of next stage in EU energy and climate policy after the political agreement on 2020 energy and climate objectives in 2007 and subsequent directives and regulations put in place in 2009-12 (Renewables directive [2], Third phase of EU emission trading system [6], Energy efficiency directive [7]). The framework is published as a communication [8] and accompanying Impact Assessment [9]. The framework follows up a Green Paper [10] and subsequent consultation on 2030 policy carried in 2013 [11]. The framework proposes a number of targets and objectives for energy and climate policy, some of the key points are given below:

Greenhouse gas emission targets:

- A 40% cut in greenhouse gas (GHG) emissions relative to 1990. Of this emission cut:
  - A 43% cut is to be achieved in the sector within EU Emissions trading
  - A 30% in sector outside emissions trading (these cuts are against a 2005 baseline).
  - This greenhouse gas cut is to be achieved only by domestic effort, and without international offsets.
  - This target is broadly in line with the EC's longer term climate objectives laid out in the 2050 Energy Roadmaps launched in the end of 2011 [12], which proposed a XX cut in GHG emissions by 2050 against a 1990 baseline [13].
- If a global climate change agreement is achieved in 2015, no additional conditional GHG target is set. If additional ambition at EU level is needed towards the global agreement this could be assisted through opening up access to international credits rather than solely through added domestic effort.

Regional co-operation, internal energy market and energy security:

- Strengthening regional cooperation between Member States to improve the cost efficiency of reaching common energy and climate challenges while furthering market integration
- Improving energy security, through e.g. integrated markets, import diversification, sustainable development of indigenous energy sources, investment in the necessary infrastructure, end-use energy savings and supporting research and innovation.
- Enhancing investor certainty by providing clear signals now on how the policy framework will change after 2020

Renewable energy

- No concrete Renewables target for member states, but a proposed 27% target binding upon the European Union as a whole.
    - The European Commission estimates that this 27% target would anyway be reached automatically as a consequence of the targeted 40% cut in greenhouse gas emissions.
    - The 27% overall target for RES in final energy consumption is estimated to equate to a share of around 45% for Renewables in electricity, relative around 21% today and estimated to be 35% in 2020).

- Improved biomass policy necessary to maximise resource efficient use of biomass to deliver robust and verifiable GHG savings

The 2030 policy Communication includes a number of significant semantic changes to approach of the 2020 Energy and Climate package, taking account of some of the shortcomings of the latter package and the altered political and economic reality at the current time compared to when the outline of the 2020 package was agreed in 2007:

- Greater emphasis on integrating energy and climate targets with the development of a functioning internal energy market, rather than targets which distort the market (“policy coherence”)
- No specific RES targets for member states – drawing away from need to subsidise RES
- Increased focus on cost efficiency in general

The Communication on the 2030 presents only a policy framework, the actual legislation required to put the targets and measures and place will be brought forward later and is subject to agreement with the European Council (i.e. member state governments) and the European Parliament. However, even before this, overall political agreement is needed on the proposed targets. The lack of a concrete RES target upon member states is already in reaction to the fact that a number of member states are diametrically opposed to any further national RES targets. There are unlikely to be difficult objections to the rather weak the target proposed at EU level, the legally binding nature of which seems rather doubtful, and with also likely to be anyway achieved if the 40% GHG cut is reached. Indeed the European Parliament has already called for the target to be raised to 30% [14], although this does not infer political support at member state level.

The agreement on the 40% GHG cut is thus far proving challenging to achieve rapidly; whilst the European Parliament supports the target, a European Council meeting in March 2014 failed to achieve agreement and now it is planned to reach agreement at a summit on 22-23rd October [15]. However, a general agreement seems rather likely, perhaps with some further special dispensations to certain industries or member states.

The targets set out in the 2030 Climate and Energy Communication can be summarise as follows:

EC 2030 targets (proposal)	***GHG reduction,*** *(baseline 1990)*	***ETS sector, GHG reduction*** *(baseline 2005)*	***ETS, yearly reduction in emissions to 2021*** *(as already in place in ETS 3rd phase)*	***ETS yearly reduction in emissions from 2021*** *(proposed)*	***Non-ETS sector GHG Reduction*** *(baseline 2005)*	***RES: target, as % of final energy consumption*** *(binding on EU but not member states)*	***Energy Efficiency***
Target	-40%	-43%	-1.74%	-2.2%	-30%	27%	No concrete target

An interesting part of the communication concerns the mention of an improved biomass policy, to ñmaximise resource efficient use of biomass to deliver robust and verifiable GHG savingsò. The details here are lacking and the policy appear aimed more at transportation biofuels rather than the use of biomass in the electricity and heat sectors. Notably, the Commission states the intention in the communication to ensure member states do not keep in place any subsidies for ñfirst generationò biofuels after 2020 - i.e. biofuels derived from food products. However, this policy could extend to verifying GHG saving of biomass used in the electricity and heat sector, which have thus far been treated as zero emission in regard of the emission trading system. Any re-framing of bioenergy in this respect ï i.e. taking into account forest and land use changes may put pressure to reduce bioenergy ambitions ï by restricting supply from certain sources ï or at least alter bioenergy sourcing policies. However, it is impossible to predict any such progress with any certainty. Nonetheless, we have assumed in our scenario calculations for 2030 that biomass will form a lower proportion of total RES growth from 2020-2030 than for the period 2005-2020 stated in the NREAPs. Our approach to setting the scenarios for 2030 is set out in section 6.4.7, and significantly relies on the impact assessment [9] accompanying the 2030 communication, which contains the modelling underpinning the proposed 2030 targets.

4 CHP in the EU-27

There are large differences in use of combined heat and power (CHP) across Europe, broadly indicated by the varying use of district heating across member states as shown in table 8. The percentage of citizens served by CHP varies from e.g. 1% in the UK to 67% in Lithuania. While a significant part of heat in district heat (DH) networks is provided by heat only plants, there is an increasing trend towards fulfilling DH demand from combined heat and power, partly driven by the better economics of CHP plants, which allow production of relatively low-value heat in combination with higher-value electricity.

Nordic countries have been exemplary in efficient use of CHP. With CHP plants it is possible to reach over 90% total efficiency, thus CHP plants are far more energy efficient than electricityï only plants, and typically more efficient than heat-only plants, the efficiency of which tends to be around 85%. When considering the bioenergy sector, it is clear that CHP plants can significantly reduce primary energy requirements and in this respect enhance the sustainability of utlilizing the limited biomass

In Nordic countries, CHP plants are usually operated according to heat demand. However, in Germany for example, large-scale CHP is usually driven by electricity production rather than heat production [16]. Indeed, if needed, all CHP plants can usually be driven in electricity-only mode, if there is no demand for heat. New CHP plants may have higher power to heat ratio, meaning that power plant produces more (high value) electricity and less heat than previous CHP plants with same total efficiency. In order to build more CHP plants, it must be remembered that both electricity and heat demand should be considered.

Looking to the growth of CHP, one should first distinguish between the three largest sectors of bioenergy plants: main activity CHP plants, electricity-only production and auto-producer production of wood-based bioenergy by industrial facilities (often CHP in itself, e.g. in pulp and paper plants). In recent years Main activity CHP and Electricity-only plants have grown more strongly and in 2011 all three types of production were between 22 ï 24 TWh per year in EU-27 [17]. The constant growth of Main activity CHP production has increased the need for district heating (DH) networks. Functioning large-scale DH networks also increase the potential of building bigger CHP plants, which is for example the case in Finland.

Eastern Europe is a case in point. Many Eastern European countries already have significant DH networks. Most of these countries are producing heat with CHP plants fuelled by fossil fuels, mainly coal. Part of the coal could be easily replaced with biomass.

In certain countries (Austria, Finland and Sweden) the development and utility rates of DH and share of renewable energy in CHP are already at a high level, thus making it harder to increase the use of RES in CHP. In the countries with a high RES share in CHP the easiest way, replacing coal with biomass in CHP, is not always possible, although some potential remains.

Table 8: Use of district heating, and existing and future objectives for Renewables (biomass) in CHP for EU member states

Country	Citizens served by DH [18] *(Euroheat & Power, 2013)*	Share of renewables in CHP [19] *(Statistics Finland, 2008)*	Targeted biomass in CHP growth 2012 - 2020 *(NREAPs)*	Targeted biomass in CHP growth 2012 -2020 *(NREAPs)*
	%	%	GWh	%
Austria	21	32,5	355	11 %
Belgium	NA	8,9	1996	203 %
Bulgaria	17	0	745	621 %
Cyprus	NA	0	0	0 %
Czech Rep.	38	4,2	1335	42 %
Denmark	61	14,9	4628	110 %
Estonia	54	7,1	10	3 %
Finland	50	46	3590	
France	7,4	23,5	10680	165 %
Germany	12	6,7	13110	171 %
Greece	NA	1,4	74	101 %
Hungary	NA	5,4	2848	2006 %
Ireland	NA	0,7	514	1094 %
Italy	5	4,9	2528	76 %
Latvia	64	3,1	710	323 %
Lithuania	67	4,3	955	356 %
Luxembourg	NA	9,5	215	209 %
Malta	NA	0	0	0 %
Netherlands	5	1,8	4589	124 %
Poland	41	1,9	2513	98 %
Portugal	NA	39,6	0	0 %
Romania	19	0	2105	265 %
Slovakia	36	2,3	810	90 %
Slovenia	15	5,4	261	63 %
Spain	NA	0	1019	67 %
Sweden	48	75,3	4898	41 %
United Kingdom	1	3,7	1680	799 %

In most of the Western European countries there is limited district heating network available. Large-scale CHP is therefore not such an easy possibility as it is in the Eastern European countries. Most of these countries are planning to build dedicated electricity-only biomass plants. Instead of electricity-only plants, smaller scale CHP could be an alternative in these countries e.g. on industrial/commercial sites, large housing units and also micro-CHP in single family homes. The actual amount of CHP will still remain low when compared to countries with functioning DH networks, but the countries could still use CHP to decrease primary demand for biomass compared to separate heating and power production.

According to Table I it is clear that countries planning a major growth of CHP are primarily concentrated in Eastern Europe. As an example Hungary is planning to produce over twenty times more electricity with biomass CHP in 2020 than in 2012. There are a few countries (Cyprus, Greece, Malta and Portugal), which are not planning to increase biomass CHP production mainly due to size of the country or low heat demand. The relevance of the potential for future CHP growth is paramount in this study, because of the use of a CHP-plus scenario ï using more biomass CHP than proposed in the NREAPs ï the methodology of which is set out in section 6.3.3.

5 Bioenergy fuel chain and production EU-27

5.1 Biomass pre-plant processing

5.1.1 Forest-based supply chain

The supply chains of forest-based biomass are mainly determined by the position of comminution (cutting/crushing the wood into small pieces) processes in the chain and the way and form the raw material is transported (Figure 1). The main types of supply chains are:

- terrain comminution: chipping at the harvesting site,
- roadside comminution (separate chipper and chip truck): comminution with a chipper or crusher at a roadside landing and road transportation of chips using a separate chip truck from the roadside to the plant,
- roadside comminution (integrated chipper-chip truck): comminution and road transportation of chips with the same unit, a so-called integrated chipper-chip truck,
- terminal comminution: forest chip raw materials (loose or bundled) are sent to the terminal for comminution, and then transportation of the chips by truck/train/barge from the terminal to the plant, and
- comminution at plant: forest chip raw materials (loose or bundled) are sent to the plant for comminution.

The supply chains can further be divided into centralised or decentralised chains. In centralised chains comminution takes place in the terminals or at the plant. In decentralised chains comminution takes place either at the roadside at harvesting sites or in intermediate storages. The centralised methods are ideal for very large volumes, which allow high load factors for machines. This results in lower comminution costs, as all operations can be done with the same machines in the same place without delays. Because of high investment costs, comminution at the plant is suitable for bigger power plants with significant use of forest biomass. In the decentralised methods, the chipping or crushing is directly linked to the transportation system and cannot operate separately. This makes decentralised chains very vulnerable to machinery breakdowns.

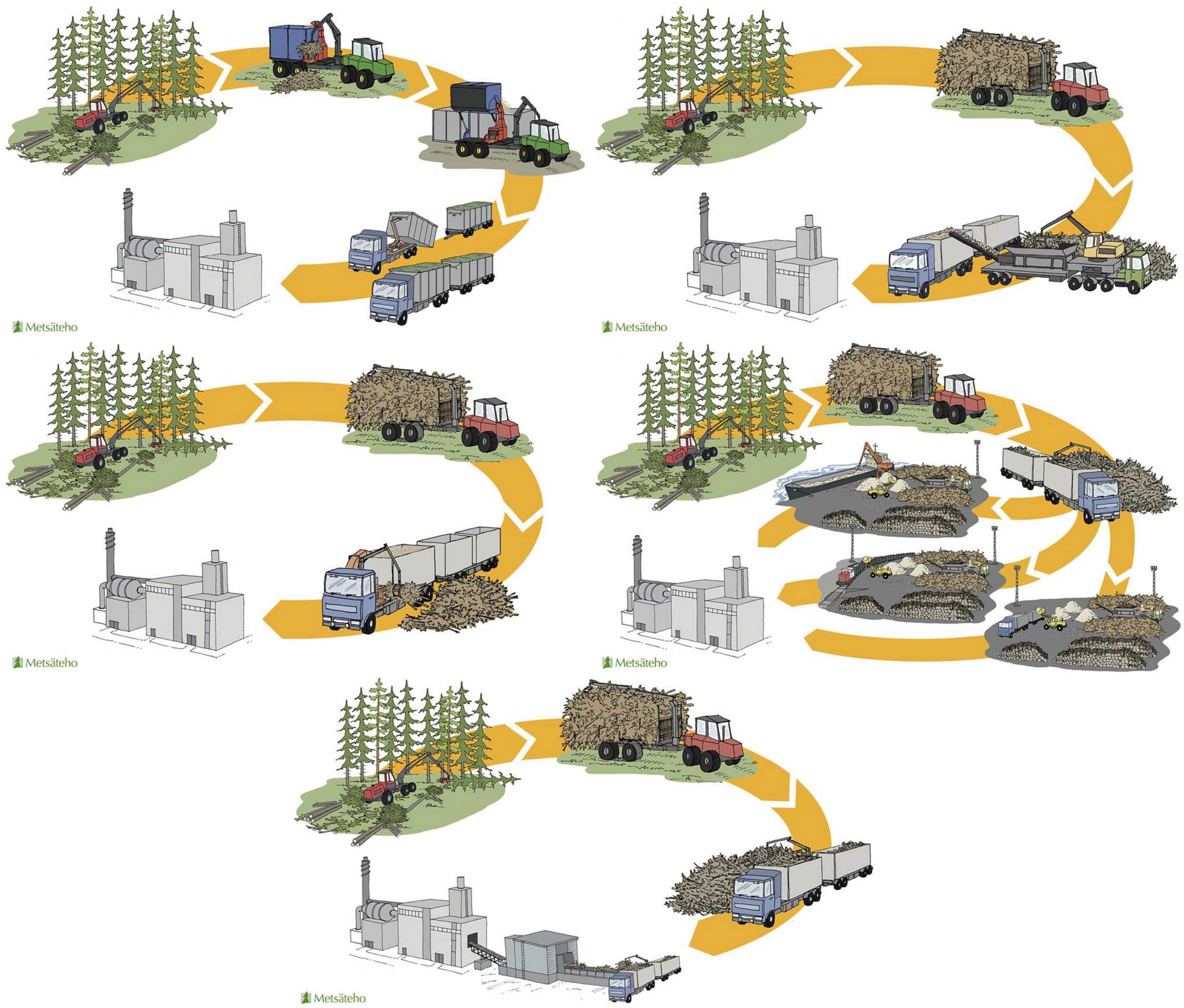

Figure 1: The principles of different supply chains for forest-based biomass fractions (Source: Metsäteho Oy) Top left - terrain Chipping, Top right - roadside comminution (separate chipper & chip truck); Middle left - roadside comminution (integrated chipper-chip truck); Middle right - comminution at terminal; Bottom - comminution at plant

The transportation system typically consists of special trucks or rail wagons that depend on the material's type and destination. On the harvesting sites the residues, small diameter wood and stumps are transported to the roadside (or intermediate storages) by forwarders with a wider cargo space and grapples designed specifically for those materials. From the roadside (or intermediate storages) ready-made wood chips are then typically transported to the power plant by special made chip trucks. Residues, small side wood and stumps are transported to the terminal or plant by so-called residue trucks with dynamic cargo space.

5.1.2 Agricultural feedstock chain

Unlike the relatively mature forest bioenergy sector, the agricultural sector offers significant potential to increase bioenergy supply. Here we cover three key types of agricultural bioenergy feedstock with high growth potential: Straw, Short Rotation Coppice and Agro-Industrial Residues. There is of course a much wider range of agricultural feedstocks, but these three show particularly high growth potential in the medium term using existing, well understood, cultivation and harvesting techniques in European soil and climate conditions.

5.1.2.1 Straw

Straw is a by-product resulting from the growing of commercial crops, primarily cereal grain. Of the total straw production, only a minor part is used for energy purposes. The major part is used in agricultureǿs own production, e.g. as bedding in livestock housing systems. A considerable amount of straw is also used for heating, grain drying etc. in agriculture.

Description of straw supply chain:

- **Harvesting and baling of Straw**
  When the grain fields are harvested, the straw is left in long rows. The farmer will normally be interested in having the straw removed as soon as possible to be able to start preparing the soil for the following year's crop, but the power plant may want the straw left in the field during one or two showers before it is gathered. Experience has shown that straw which has been exposed to a little rain has a reduced content of chlorine and potassium, thereby reducing the risk of operational problems at the power plant. In practice, it may, however, be difficult to gather the straw at the perfect time. Many farmers are dependent on available capacity at the local machine pool and, above all, the straw must be dry before it is gathered ï otherwise it will be rejected at the power plant or the district heating plant.
  In the agricultural industry, several kinds of bales are used, from small straw bales of approx. 12kg up to big bales of approx. 500kg. Power plants only accept the big bales and most heating plants also only receive the big bales.

- **Transport of Straw**
  In many ways, big bales are an excellent solution for gathering the straw from the field, but are less effective for the transport to the power plant. A truck has room for only 24 bales, equal to 12 tonnes of straw, which is less than half the weight that the truck is allowed to carry. The poor utilisation of the capacity results not only in high transport costs, but also in extra costs for handling the straw bales and poor utilisation of the storage facilities.

- **Delivery and storage to power plants**
  Upon delivery to power plants, the moisture content of the straw is registered. If the moisture content is above a certain limit, the straw is returned to the farmer.

Generally, the storage capacity of the power plants is only large enough for a few days' consumption at full load, so during the winter months the plants normally receive new supplies on all weekdays. The transport from the storage to the boiler is fully automated, which allows the small plants to run unmanned during nights and weekends.

5.1.2.2 Short rotation coppice

The sourcing of woody biomass from short rotation coppice (SRC) has become more important in recent years. Existing woody biomass sources in the EU are unlikely to be able to meet the future demand for fuel from biomass and there is a need for additional, sustainable resources to fill this gap. Both the amount of established SRC plantation and the expansion rate of new SRC plantation are still comparatively low, so that the share of short rotation coppice in woody biomass supply is still relatively small.

- **Definition**
  Short rotation coppice plantations are perennial plantations of broadleaf trees species that are, in comparison to conventional forests and forestry plantations, harvested on very short rotation cycles. The EC defines biomass from SRC as a conventional agricultural product.

- **Characteristics of short rotation coppice**
  The planting density is very high, between 6,500-10,000 plants/ha. Once established, the rootstock is capable of generating regrowth after the upper woody portions have been harvested. There are generally between 3 and 10 coppice cycles before replanting. In most plantations special energy crop clones are used as the parent material.

- **Tree species**
  A range of different tree species may be used in short rotation coppice. Depending on the soil type, temperature and rainfall, the most common species used are poplar and willow (on land with rather high rainfall) as well as robinia (on rather dry land). For both poplar and willow, a mix of different varieties and/or clones is generally used, to create genetic diversity within the plantation and lower the risk of crop diseases. In recent years, the cultivation of paulownia has became more common, in most cases in very warm locations and in combination with irrigation. Other non-woody species that may be used to produce biomass include annual energy crops, such as Sorghum, which are likely to become more important in the future. In addition, the growing of perennial herbaceous plants like miscanthus or switchgrass is also likely to become more widespread in certain regions under appropriate climatic regimes.

- **Planting**
  Most of the tree species will grow reasonably well on a wide range of soil types, although very wet or very dry soils are best avoided. Soil pH should normally fall between 5 and 7.5, although some species may be suitable for more acidic or alkaline soils. In general, SRC is planted on underutilised agricultural land, on meadows and on fallow land. A large variety of sites may be suitable. The tree species used for SRC can also grow on rather marginal soils, albeit with lower yields. The trees are planted either as cuttings or as seedlings, manually or with a planting machine. Good soil preparation and efficient weed control are necessary for the successful establishment of the plantation.
  In general, land availability in the EU for SRC is quite high. Studies from Germany estimate that up to 1 million ha may be available for this purpose;. Within other EU countries, similar areas are estimated to be available on a proportional basis. However, less than 4,000 ha of SRC have so far been established in Germany; and not more than ca. 50,000 in the entire EU. The estimations of land potential have therefore to be treated with some caution.

- **Harvesting**
  Plants in SRC plantations grow for between 2-5 years and are then harvested, usually with common agricultural machinery like modified forage harvesters. After harvest, the rootstocks sprout again and can be harvested 2-5 year cycles over a total lifetime of ca. 20 years. After that, the plantation is usually uprooted and the area used as agricultural land. Fertilisation and irrigation may be required, but their rate and effectiveness strongly depends on the site type. Under normal circumstances, annual yields of between 8-25 odt/ha/annum can be expected.

5.1.2.3 Agro-industrial residues

Agro-industrial residues exist, to a large degree, outside of the mainstream solid biomass supply chains and trade routes. Their attraction lies in the fact that, where their production is above local needs, the excess residues may be sold at prices that are cheaper, in terms of ú/GJ, than conventional solid biomass materials such as wood chips or wood pellets. However, as they are non-mainstream, more effort may be needed to obtain these residue materials.

Since these materials arise as by-products from the industrial processing of harvested plant materials, the initial sources of the raw materials are generally widely dispersed. Industrial processing leads to a concentration of the harvested materials at the processing centre, with the resultant residues effectively available from a point source. However, residue materials from several of these point sources may need to be grouped to provide an economically viable volume of residues for shipping or other transport purposes.

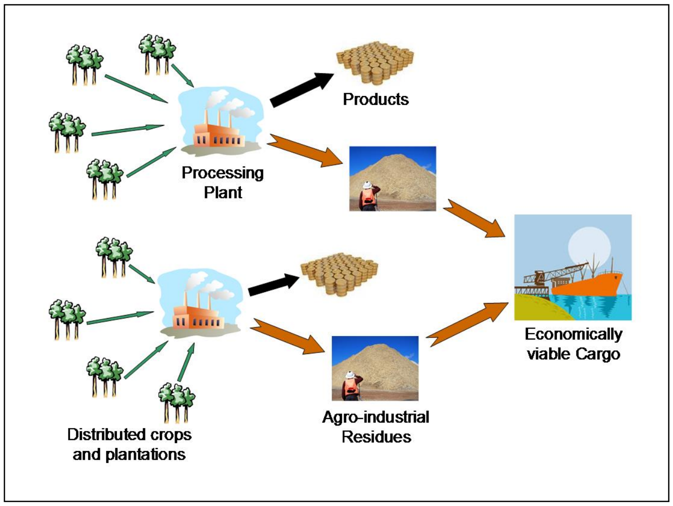

Figure 2: Agro-industrial supply chain [20]

Some of the agro-industrial residues, such as sugar cane bagasse or palm kernel shells, are produced in countries that are a considerable distance from Europe. The most economical supply chains therefore entail the shipping of these residues to European ports in capesize (>150,000 DWT) or panamax (65,000-80,000 DWT) sized vessels. If smaller volumes are required by individual power plants, then utilities have the options of (i) using the remainder of the residues in another plant; (ii) selling on the surplus; or (iii) renting hold space in a large ship carrying other cargos from the country of residue origin.

Other raw materials which give rise to agro-industrial residues, such as soybeans, may be shipped in the raw state from their country of origin and processed in Europe. Trade statistics show that the EU imports approximately 13.5 million tonnes of soybeans each year, mainly from Brazil, the United States and Argentina. These raw soybeans are then pressed in dock-side oil mills to extract the soybean oil. The soya hull pellet residues arising from this processing will therefore be mainly available at European ports.

Where agro-industrial residues arise from plant materials grown within Europe, for example shells from almonds or pellets made from sunflower husks or olive cake, it may be economical to ship the residues in smaller vessels (5,000 - 10,000 DWT), either from port to port around the coast or along Europe's navigable inland waterways. Any onward transport to power plants not located alongside water will have to be by train or by truck. In all instances maximum unit loads and minimum re-handling will deliver the agro-industrial residues at the minimum cost.

5.1.3 Waste feedstock chain

Waste is most commonly, and according to the EU Waste Framework Directive, defined as material which an entity wishes to dispose of. National perception of this varies to a large extent. In the context of biomass, waste will occur in the forestry business as well as in agriculture. As those have already been covered, this section covers only commercial and municipal waste resources.

Waste-to-energy plants burn household and similar waste that remains after waste prevention and recycling. From this waste the plants generate electricity and/or heat. According to EU legislation, only the biodegradable fraction of municipal and industrial waste is considered biomass, thus a renewable energy source. The energy output from waste-to-energy plants is typically about 50% renewable.

For technical reasons the power vs. heat ratio for an incineration plant is lower than for standard fuels. Therefore, having access to a heat market such as a district heating system is a great advantage. The use of commercial and municipal waste for energy production does not typically affect recycling rates, i.e. it does not divert waste that may otherwise be recycled. Indeed, studies show that waste-to-energy has a positive influence on recycling rates. The main alternative for a portion of the biogenic fraction of the waste is composting.

About 40% of municipal waste in Europe is still landfilled, so the potential for increasing production of power and heat is significant. The European Landfill Directive sets strict diversion targets for the landfilling of biodegradable waste. The deadline for reducing landfilling by 50% was in 2009, and European member states that miss this deadline face fines. By 2016 the biodegradable waste being sent to landfills must be reduced by 65% (based on the amount landfilled in 1995). Therefore, a significant increase in energy production from waste may be foreseen from the Landfill Directive in addition to other incentives.

5.2 Bioenergy plant technologies

We can gather an excellent overview of bioenergy plant technologies in use from Plattôs power plant database of existing plants [21]. This database allows us take the overall categories of bioenergy available in the NREAPs, as described in section 2.3, e.g. electricity-only solid biomass, CHP biogas, etc. and consider the actual plant technologies used to generate these bioenergies. For example, technology types include boilers with steam turbines, internal combustion engines and combined cycle gas turbines. The technology types for electricity-only and CHP plant derived from the Plattôs database are set out in tables 9 and 10 below, with table 11 showing heat-only plants (heat-only plants are not in the Plattôs database, but are assumed to be exclusively conventional boiler plants). By calculating the average size of existing plants in the different technology types, we were able to build up a picture of the plant technology mix in each category (e.g. biogas electricity only plants were found to be 86% internal combustion engines, and about 5% of each of CCGTs and OCGTs). This understanding of the plant technology mix was important in the plant efficiency calculations used for the scenarios in this study, as it provides a means for producing a ñweighted averageò plant efficiency according to the technology mix in place. This plant efficiency methodology is set out in section 6.1, with the actual conversion efficiencies set out in section 6.4.2.

Table 9: Current share of plant technologies for electricity [21]

Plant technology distribution ï Electricity only plants				
FUEL (as per NREAP category)	**Plant type**	**Plant type abbreviation**	**% plant in current fleet by capacity**	**Average size today (MW)**
Solid biomass	Boiler with Steam turbine	ST	98 %	24
Biogas	Combined-cycle (unspecified machine configuration)	CC	28 %	112
	Internal combustion (reciprocating diesel) engine	IC	54 %	1
	Boiler with Steam turbine	ST	8 %	11
Bioliquids	Internal combustion (reciprocating diesel) engine	IC	31%	5
	Internal combustion (reciprocating or diesel) engine in combined-cycle	IC/CD	58%	14
	Boiler with Steam turbine	ST	11%	19

Table 10: Current share of plant technologies for CHP [6]

Plant technology distribution ï CHP plants				
FUEL (as per NREAP category)	**Plant type**	**Plant type abbrev.**	**% plant in current fleet by capacity**	**Average size today (MW)**
Solid biomass	Steam turbine with steam sendout (cogen)	ST/S	100 %	18
Biogas	Internal combustion engine with heat recovery (cogen ï CHP)	IC/H	88 %	1
	Steam turbine with steam sendout (cogen)	ST/S	9 %	14
Bioliquids	Internal combustion engine with heat recovery (cogen ï CHP)	IC/H	46 %	6
	Steam turbine with steam sendout (cogen)	ST/S	51 %	34

Table 11: Current share of plant technologies for heat only

Plant technology distribution ï Heat only plants			
FUEL (as per NREAP category)	**Plant type**	**Plant type abbrev.**	**% plant in current fleet by capacity**
Solid biomass	Conventional boiler	N/A	100 %
Biogas	Conventional boiler	N/A	100 %
Bioliquids	Conventional boiler	N/A	100 %

6 Scenario design

6.1 Overall description

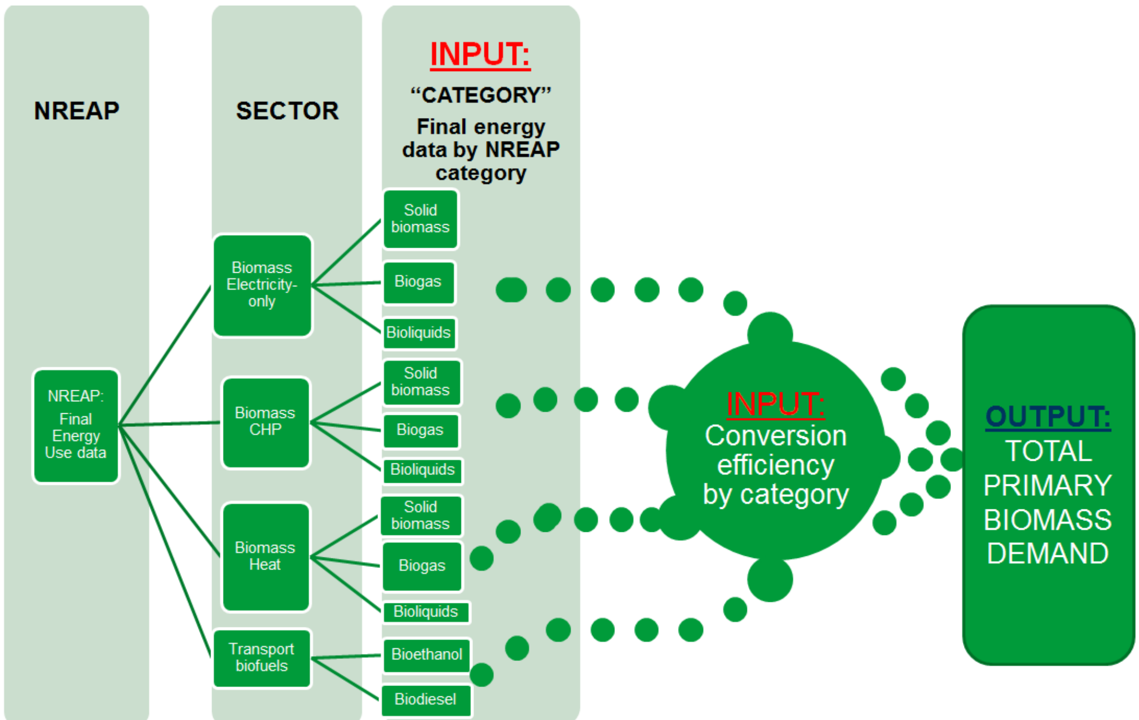

Figure 3: Scenario design (own design)

The diagram above explains the basic scenario design used in this study. The scenarios design can be summarised as follows:

6.1.1 Input: NREAP data

(ñNREAPò,ñSectorò,ñCategoryòin above diagram)

Section 2.3 describes the content of the NREAPs concerning bioenergy. In essence we take the final energy data for bioenergy from tables 10, 11 and 12, for electricity, heating and cooling and transport respectively. The final energy data for these sectors is further split into biomass fuel categories; the categorization used in the NREAPs is solid biomass, biogas and bioliquids (except for transport, where the main types are bioethanol and biodiesel, with very small amount of other liquid fuels and biogas).

We had to make a number of special provisions concerning the biomass electricity and CHP data:

- **Co-firing:** As the NREAPs do not state the share of co-firing of biomass separately, we assume co-firing of biomass plants to have same efficiency than dedicated biomass plants.
- **CHP:** CHP is only referred to in the NREAPs as a part of biomass electricity (table 10), there is no reference in the heating and cooling table (table 11) as to much of the heat is actually produced by CHP rather than heat only plant. Therefore, therefore we calculated the amount of CHP heat by multiplying the electricity produced by CHP by the power to heat ratio of modern CHP plants, allowing us in term to identify which part of total biomass heat was from CHP plant and how much from heat-only plant, and therefore being able to apply the correct plant-specific conversion efficiencies (see below).

The final energy data used as input data from the NREAPs is summarised in section 2.3.

6.1.2 Input data: Conversion efficiency by category

The approach to conversion efficiencies is described below, the actual data is summarised in section 6.3. Two types of conversion efficiency are taken into account; processing efficiency of raw biomass to biomass fuel delivered to the plant and plant efficiency for the electricity or heat plants combusting the biomass fuel.

6.1.2.1 Processing efficiency

Before biomass can be combusted in an electricity or heat plant, it must be processed from raw biomass (see section 5.1). This processing can vary from relatively simple (e.g. collecting, chipping and transport of forest residues) to more complex processing such as pelletization or even the production of torrefied pellets. It is therefore necessary to take into account the energy used in this processing stage by taking into account a processing efficiency figure which takes into account the proportion of energy in the raw biomass required for its processing into final biomass fuel delivered at the plant (even if the processing energy does not come from raw biomass itself but from e.g. fossil fuel sources ï thus this effectively an efficiency "equivalence" figure expressing the percentage of the primary energy in the raw biomass that would be remain if the energy required to conversion into the biomass fuel is deducted. In terms of fuel types, we have adopted processing efficiency figures, as per the fuel categories in the NREAPs, as follows:

- Solid biomass

- Biogas
- Bioliquids

Notably, for transport biofuels we use a global primary to final energy conversion efficiency figure representing the whole process from raw biomass to final fuel; a separate processing and plant efficiency figure is not appropriate (final energy in the transport sector only takes account of the energy content of the fuel and not the useful kinetic energy realized in transport ï unlike electricity and heat final energy calculations based on useful ñpost plantò energy).

6.1.2.2 Plant efficiency

To be able to calculate the demand for biomass-based fuel as delivered to the plant , we need to assume conversion efficiencies for electricity-only, heat-only, and CHP plants, categorizing each of these types by the fuel type (solid biomass, biogas, or bioliquids) ï therefore utilizing the same data categorization used in the NREAPS. As set out in section 5.2, we have analyzed the percentages of different technology types within these categories (e.g. biogas electricity only plants were found to be 86% internal combustion engines, and about 5% of each of CCGTs and OCGTs). Taking conversion efficiencies for each technology type, we then calculated weighted average conversion efficiency for each plant category. We therefore inherently assumed that technology mix of new plants built until 2020 will be similar to existing plants. However, we use a range of conversion efficiencies ï one for current plant, and both a business as usual (BAU) and best available technology (BAT) for plant built 2013-2020 (BAU assumes new plants are built according to current progress in efficiency, BAT assume all new plant are built according to the most efficient technology available).

6.2 Input data ï Final Energy NREAP data

The input data in final energy form contained in the NREAPs is contained in section 2.3.

6.3 Input data: Conversion efficiencies

6.3.1 Processing of biomass

The assumed efficiencies for processing of raw biomass into biomass fuel as delivered to the plant are set out in table 12 below. As referred to above, these figures represent an efficiency ñequivalenceò figure expressing the percentage of the primary energy in the raw biomass that would remain if the energy required for the conversion into the delivered biomass fuel is subtracted. As can be seen in the table, for each of the biomass types (solid, gas, liquid), there are two separate figures ï one ñbusiness as usualò, representing current efficiency levels, and one for best available technology (the latter is used only in the Best available technology scenario). These figures have been derived from previous studies, reviewed with other academics and checked with the industry partners in the BEST project.

Table 12: Assumed processing efficiency for raw biomass to delivered biomass fuel

Heat & Electricity Processing efficiencies			
Fuel	**Business as usual**	**Best available technology**	**Notes**
Solid biomass	95 %	96 %	Chipping, Pelletization
Biogas	70 %	75 %	Biogas reformer
Bioliquids	70 %	75 %	Primary bio oils (e.g. palm oil), Black liquor

For transport biofuels, we use a global conversion figure for the efficiency of conversion from primary energy (raw biomass) to final fuel (fuel at pump). In this case we do not utilise a separate best available technology figure; the study of biofuel production is outside the scope of this study, and given the high degree of uncertainty for these dynamically developing fuels, we have opted to basic efficiency figures suggested in existing literature ï see table 13.

Table 13: Assumed processing efficiency for raw biomass to transport biofuels

Transport processing efficiencies *(global efficiency number, no separate plant efficiency figure)*	
Biodiesel	60 %
Bioethanol / bio-ETBE	40 %
Other biofuels: Of which biofuel (as defined in Article 21(2) of Directive 2009/28/EC)	50 %

6.3.2 Plant efficiencies

In tables 14, 15 and 16 we show the assumed conversion efficiencies for each plant technology type (according to bioenergy plant technology categorization in section 5.2) in different energy sectors (electricity, heat and transport respectively). The methodology behind the conversion efficiencies is set out in section 6.1.2.2 part (ii).

Table 14: Plant efficiencies by technology type ï Electricity-only plants [21]

Plant technology distribution ï Electricity only plants					
	Plant type	Plant type abbrev	Efficiency		
			Current plants	Business as usual 2013-2020	Best Available Technology 2013-2020
Solid biomass	Boiler with Steam turbine	ST	25 %	30 %	38 %
Biogas	Combined-cycle (unspecified machine configuration)	CC	25 %	30 %	33 %
	Internal combustion (reciprocating diesel) engine	IC	25 %	30 %	35 %
	Boiler with Steam turbine	ST	25 %	30 %	33 %
Bioliquids	Internal combustion (reciprocating diesel) engine	IC	26 %	31 %	34 %
	Internal combustion (reciprocating or diesel) engine in combined-cycle	IC/CD	26 %	31 %	34 %
	Boiler with Steam turbine	ST	26 %	31 %	34 %

Table 15: Plant efficiencies by technology type ï Heat-only plants [21]

Plant technology distribution ï Heat only plants					
	Plant type	Plant type abbrev	Efficiency		
			Current plants	Business as usual 2013-2020	Best Available Technology 2013-2020
Solid biomass	Conventional boiler	N/A	85 %	85 %	85 %
Biogas	Conventional boiler	N/A	85 %	85 %	85 %
Bioliquids	Conventional boiler	N/A	85 %	85 %	85 %

Table 16: Plant efficiencies by technology type ï CHP plants [21]

Plant technology distribution ï CHP plants								
			Efficiency					
			Current plants		Business as usual 2013-2020		Best Available Technology 2013-2020	
FUEL	Plant type	Plant type abbrev	Elec.	Heat	Elec.	Heat	Elec.	Heat
Solid biomass	Steam turbine with steam sendout (cogen)	ST/S	22 %	60 %	25 %	60 %	27 %	60 %
Biogas	Internal combustion engine with heat recovery (cogen ï CHP)	IC/H	20 %	60 %	23 %	60 %	25 %	60 %
	Steam turbine with steam sendout (cogen)	ST/S	20 %	60 %	23 %	60 %	25 %	60 %
Bioliquids	Internal combustion engine with heat recovery (cogen ï CHP)	IC/H	20 %	60 %	23 %	60 %	25 %	60 %
	Steam turbine with steam sendout (cogen)	ST/S	20 %	60 %	23 %	60 %	25 %	60 %

The Best Available Technology (BAT) efficiencies require shifting towards larger power plants to increase total average conversion efficiencies in each sector. It is not entirely obvious that this would happen without some distinct changes, since plant size is often restricted by, for example, community structures and preferences in some countries towards distributed generation.

To be able to adjust the conversion efficiencies to fit the categorization in NREAPs, we need to have weighted average efficiencies for the different fuel types in NREAPs (solid biomass, biogas, bioliquids). This methodology is further described in sections 5.2 (plant technology) and section 6.1.2.2 (Input data: Plant efficiency). In table 17 below, we show the weighted conversion efficiencies for each sector. We have differentiated conversion

Table 17: Average plant efficiencies by category (after application of plant technology weightings)

Processed biomass efficiency by sector					
FUEL	Plant category		Current	2010 BaU	2020 BAT
Electricity	Electricity only	Solid biomass	25 %	30 %	38 %
		Biogas	25 %	30 %	34 %
		Bioliquids	26 %	31 %	34 %
	CHP	CHP average	21 %	25 %	30 %
Heat	Electricity only	Solid biomass	85 %	85 %	85 %
		Biogas	85 %	85 %	85 %
		Bioliquids	85 %	85 %	85 %
	CHP	CHP average	60 %	60 %	60 %

6.3.3 Calculations and assumptions for CHP

In NREAPs the member states have set out how much of their total renewable electricity consumption is from combined heat and power (table 10a/10b. We make the assumption that all of this renewable CHP consumption is derived from bioenergy. In theory renewable CHP can also be produced from geothermal or solar thermal energy, but in practice almost no such capacity is planned or in place.

The NREAPs also lack the information of how much heat is produced with CHP. Therefore we calculate the amount of CHP heat by multiplying the electricity produced by CHP by the average power-to-heat ratio of modern CHP plants, 0.5 (in some of the newest CHP plants power-to-heat ratio might be even higher e.g. 0.55).

In the scenarios we calculate separately the electricity-only and CHP electricity consumption and adjust them with respective conversion efficiencies for both technologies. While electricity is produced in CHP plants with a slightly lower conversion efficiency compared to electricity-only plant (table 16), we also acquire significant heat energy for the same biomass input. This generated heat is then considered as ôfreeô heat due to the fact that the primary biomass input is already accounted for under CHP electricity. The amount of CHP heat produced is then deducted from the total biomass heat final energy as stated in the NREAPs (table 11). By this procedure we gain the consumption of heat-only biomass, by which we can further calculate the primary biomass demand for heat-only plant, by using heat-only conversion efficiencies.

Table 18 NREAP.BAU and Zero-CHP scenario calculation example for Finland

Biomass demand calculation: example for Finland								
Energy type	Conversion efficiencies		Final energy consumption (TWh)		Primary biomass fuel demand		Non-processed (raw) biomass demand	
	Combustion	Processing	NREAP BAU	Zero-CHP	NREAP BAU	Zero-CHP	NREAP BAU	Zero-CHP
Electricity-only	30 %	83 %	0,6	13	1,9	42	61	51
Electricity from CHP	25 %		12		49	0		
Heat-only	85 %	83 %	52	77	61	90	74	109
Heat from CHP ("Free heat")	60 %		25		0	0		
Transport		54 %	6,5	6,5	6,5	6,5	12	12
Total demand (TWh)			***96***	***96***	***119***	***139***	***148***	***172***

6.4 Description of scenarios

A brief summary of the scenarios was given in the introduction, section 1.1. Here a more detailed overview is provided, particularly concerning the calculation required in the CHP+ scenario (section 6.4.3). A summary table of the different scenarios is provided in section 6.4.5.

6.4.1 Baseline scenario

In the NREAP Baseline we assume production of heat and electricity according to the mix of electricity-only, heat-only and CHP plants in the NREAPs. For new plants built from 2013 to 2020, we assume the BAU efficiencies set out in table 16, i.e. that average heat and power plant efficiencies will slightly increase from current levels.

6.4.2 BAT scenario

In NREAP BAT (best available technology) we assume the same plant category mix as in baseline scenario, but we assume that there will be a more rapid advance in plant efficiencies, by using the BAT efficiencies set out in table 16 for plants built from 2013 to 2020. Effectively this scenario assumes that new plants will be built with the best available technology; implicit in this assumption is that new plants are built to larger capacities than existing plants to allow for the highest possible conversion efficiencies. The target of the BAT scenario is to reduce primary energy demand by improving the overall efficiency of the plant fleet.

6.4.3 CHP+ scenario

The CHP+ scenario has been developed in order to show the primary energy savings that could result from a higher development of biomass CHP in the period up to 2020 than that foreseen in the NREAPs. Fundamentally this scenario involves reaching the overall final energy consumption from biomass for electricity & heat as in the NREAPs, but using *less* electricity-only biomass and more CHP. In constructing this scenario, we considered it most realistic to take a differentiated approach whereby biomass CHP deployment is adjusted upwards by a higher percentage in countries with a large use of district heating ï and therefore relative ease of utilizing the heat output from new biomass CHP plants. In contrast, in countries with minimal district heating networks, only a small growth in biomass CHP in realistic ï typical application will be small scale, e.g. housing complexes, industrial sites etc, rather than city wide DH networks. Another factor in this differentiated approach is the percentage of Renewables currently used in CHP ï where this is already very high ï for example in Sweden where the share of RES (ie. biomass) in CHP is 75%, we felt that high additional growth of CHP beyond that envisaged in the NREAPs was unrealistic. The so-called differentiated approach is summarised in table 19 below, with the additional ñbeyond NREAPò growth potential categories being named, HIGH, LOW and VERY LOW.

Table 19: Definition of CHP potential categories and respective percentage adjustments for countries in CHP+ scenario

CHP growth potential category name	Criteria for classification of countries to CHP potential levels *(some allowance for flexibility in final categorization, see table 18)*	Percentage increase in CHP applied in CHP+ scenario, by category *(addition to CHP Electricity in NREAPs)*
HIGH	High growth of biomass in CHP = DH >10%, Current share of renewables in CHP <30%	20%
LOW	Low growth of biomass in CHP = DH >10%, Current share of renewables in CHP >30%	12%
VERY LOW	Minor growth of biomass in CHP = DH <10%.	8%

The actual data to fit countries into the different CHP growth potential categories is contained in table 8 in section 4. According to this schedule, countries are classified as shown in table 20. Notably some flexibility was used in categorizing countries, and we did not adhere extremely strictly to the categorization criteria in table 19 ï in some cases complete data was unavailable so best guesses had to be made. In the case of France it was placed in the high growth category, even though its current DH network covers only 7% of citizens, because of the knowledge that France is carrying out a significant expansion of DH networks.

Table 20: Actual categorization of countries for CHP+ scenario

Country categorization in CHP+ scenario		
High growth	**Low growth**	**Very low growth**
Belgium	Austria	Cyprus
Bulgaria	Finland	Greece
Czech Republic	Sweden	Ireland
Denmark		Luxembourg
Estonia		Malta
France		Portugal
Germany		Spain
Hungary		United Kingdom
Italy		
Latvia		
Lithuania		
Netherlands		
Poland		
Romania		
Slovakia		
Slovenia		

Having adopted the different CHP growth potential percentages, it was necessary to apply these percentages to the CHP development already foreseen in the NREAPs. The percentages were used to increase the amount of CHP ï which is only shown as part of the RES Electricity table in the NREAPs, table 10. It was then necessary to find a methodology by which the CHP level could be increased but the final energy output of heat and electricity be kept constant. Figure 2 explains this approach. In the example set out in figure 2, CHP generation is expanded by 10%, from its original electricity output of 30GWh. This implies that there is an additional 3GWh of electricity generation from CHP, and an additional 6GWh of CHP derived heat (assuming electricity ot heat ratio of plant is a typical value of 0.5). Therefore, in total there is 9GWh of additional final energy. This additional 9GWh is then deducted from the total final energy from electricity only plants, which is reduced from 60GWh to 51GWh in the example bellows. This decrease in final energy from electricity only plants leads to a significant reduction in the primary biomass requirement as a current typical electricity-only biomass plant is only 25% efficient (see table 14), compared to 80% plus for current CHP plants.

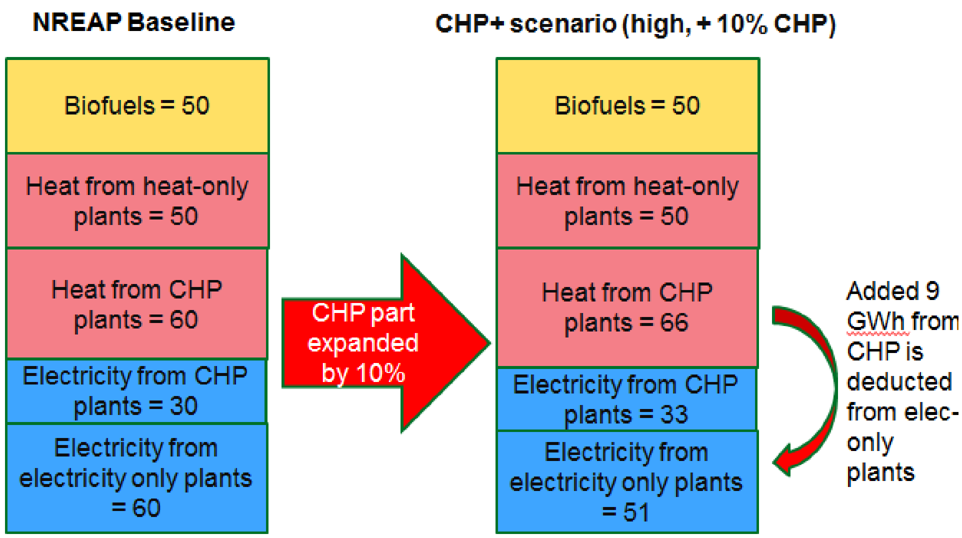

Figure 2: Explanation of calculations for CHP+ scenario

The above methodology where the additional CHP derived final energy is deducted from final energy from electricity only plants operates fine where there is sufficient electricity-only generation for the additional CHP energy to be deducted from. This approach is also logical since we would expect additional CHP plant to supplant development of electricity-only biomass plant. However, some countries have very little existing or planned electricity-only biomass generation. This leads to a problem; one alternative would be to deduct the additional CHP energy from the final energy from heat only plants ï however this would have little or no primary energy effect since heat-only plants are often as efficient as CHP plants. We have developed an alternative approach, based on the consideration that in reality, additional biomass CHP is actually likely to be replacing existing coal plants, rather than substituting biomass heat-only plants, as the latter suggested approach could imply. Therefore we have adopted an approach based on primary energy savings of coal from additional energy from biomass CHP plant. This approach operates as follows:

(i) At first, additional CHP final energy is deducted from final energy from electricity-only biomass plant until this reaches zero
(ii) The additional CHP final energy is then taken to calculate the approximate final energy savings of coal that it could account for
(iii) CHP final energy is assumed to replace CHP coal plant with an efficiency of 87%, therefore the remaining additional CHP final energy after part (i) of the calculation is multiplied by a factor of 1/0.87 to calculate the primary coal energy saving from the biomass CHP.
(iv) Furthermore, we also calculate the CO_2 emission saving arising from the reduced coal use, using a coal CO_2 emission factor of 97.0 tonnes of

CO_2/TJ. In this phase we are not considering biomass sustainability issues, thus we assume biomass to be carbon-neutral.

A worked example of this coal energy saving is provided here (using same stage number (i)-(iv) as above:

EXAMPLE CALCULATION FOR CHP+ SCENARIO: Biomass, Coal & CO2 savings

For this example calculation we use following two countries:

Country	Biomass CHP in electricity (GWh) - 2020	Additional biomass CHP in CHP+ scenario	Biomass CHP increase (GWh) - 2020	Electricity-only biomass (GWh) - 2020
Belgium	2980	20 %	596	8058
Finland	12340	12 %	1481	570

i) Deducting increased biomass CHP from biomass electricity-only

Electricity-only biomass left after deduction of increased CHP:
Belgium: 8058GWh ï (1+1/0.5) * 596GWh = 6270GWh
Finland: 570 - (1+1/0.5) * 1481GWh = - 3872GWh

(0.5 = typical electricity : heat ratio in CHP plant)

Belgium is able to replace all increased biomass CHP in CHP+ scenario with biomass electricity-only → no further calculations needed.

Finland is not able to replace increased CHP with biomass electricity-only → advances to calculation phase ii.

ii) Additional biomass CHP to be replaced with coal CHP
Finland: 3872GWh

iii) Coal primary energy savings:
Finland: 3872GWh * 1/0.87 = 4451GWh
4451GWh * 3.6 TJ/GWh = 16024TJ

(0.87 = coal CHP plant efficiency assumption)

iv) CO_2 emission savings:
Finland: 16024TJ * 97.0 tonnes of CO_2 / TJ = 1.55 Mt of CO_2

We can also add this coal primary energy saving to the biomass primary energy saving for the CHP+ scenario, to calculate an overall total primary energy saving figure in comparison to the baseline scenario. In practice, it could be argued that this figure is a ñtotal equivalent biomass saving figureò since all additional final energy from CHP ï even that which supplants coal - may imply that governments are more in surplus vis-a-vis their RES objectives - and can therefore reduce other efforts to develop renewable energies. Such efforts may or may not involve biomass (some countries could e.g. reduce ambitions for transport biofuels ï although only a few countries plan to exceed the mandatory 10% RES transport target ï a target primarily fulfilled through biofuels).

6.4.4 Zero-CHP scenario

To evaluate the effect of CHP in NREAPs, we have built a Zero-CHP scenario. In the Zero-CHP scenario we utilize the same heat and electricity data from the NREAPs in final energy terms, but assume that it is produced without the use of CHP. This implies that all the heat and electricity are produced by dedicated heat-only and electricity-only plants respectively. The results of Zero-CHP scenario are compared with results of NREAP BAU scenario to analyse how much more biomass would be needed in order to fulfil the same amounts of electricity and heat without CHP.

6.4.5 Scenario variations: Processing energy requirements

As mentioned in the scenario design description in sections 6.1 and 6.3, we have distinguished between conversion efficiency figures for biomass processing (raw biomass to fuel) and for the electricity and heat production plants using the fuel. As mentioned in the introductory scenario description in section 1.1, we have actually run two versions of all scenarios, with primary energy demand calculate including and excluding the initial biomass processing to fuel, as follows:

(i) **Processing efficiency included** - Scenario variation taking account of primary energy efficiency of raw biomass processing into biomass fuel as delivered to plant i.e. representing demand for raw biomass from forestry, agriculture or waste. As described in section 6.3.1, processing efficiency assumptions are distinguished only according the overall biomass fuel types set out in the NREAPs ï solid, gas, liquid. Of course, in reality there would be significant variations in the processing efficiency of e.g. different types of forestry and agricultural biomass.

(ii) **Processing efficiency not included** - Scenario variation not including primary energy efficiency of raw biomass ï i.e. only representing the primary energy demand of biomass fuel as delivered to plant. As referred to previously, we felt it important to include this scenario to give comparability with other studies ï many of which do not make mention of processing efficiency, and to give equivalence with data on primary demand of fossil fuels in the energy sector, which also typically take no account of pre-plant processing energy demand e.g. in coal mining, gas production, etc.

(iii)

6.4.6 Summary table of scenarios

The table below summarises the scenarios described in the section above.

Table 21: Summary of scenarios

<table>
<tr><th>Scenario code</th><th>Scenario name</th><th>NREAP Final Energy input
(same total final energy for all scenarios)</th><th>Processing efficiency input</th><th>Plant efficiency input</th></tr>
<tr><td>Base.Ex</td><td>Baseline excluding biomass processing</td><td rowspan="2">Basic ï as per NREAPs</td><td>Not taken in account</td><td rowspan="2">BAU - Business as usual</td></tr>
<tr><td>Base.In</td><td>Baseline including biomass processing</td><td>BAU</td></tr>
<tr><td>BAT.Ex</td><td>Best available technology exc. biomass processing</td><td rowspan="2">Basic ï as per NREAPs</td><td>Not taken in account</td><td rowspan="2">BAT ï Best available technology</td></tr>
<tr><td>BAT.In</td><td>Best available technology inc. biomass processing</td><td>BAT</td></tr>
<tr><td>CHP+.Ex</td><td>CHP exc. biomass processing</td><td rowspan="2">NREAP + additional CHP (8/12/20% added depending on country)</td><td>Not taken in account</td><td rowspan="2">BAU</td></tr>
<tr><td>CHP+.In</td><td>CHP inc. biomass processing</td><td>BAU</td></tr>
</table>

CHP0.Ex	Zero-CHP exc. biomass processing	NREAP without CHP (exclusively electricity-only and heat-only plant)	Not taken in account	BAU
CHP0.In	Zero-CHP inc. biomass processing		BAU	

6.4.7 Extension of scenarios to 2030

For the 2030 scenarios for primary biomass demand we have developed two scenarios as follows:

- First scenario based on the EC's proposal for a 2030 Climate & Energy package[8], as elaborated in section 3.
- The second scenario is based on a continuation of member state progress in bioenergy development in accordance with their NREAPs to 2030; simply their trend in bioenergy development from 2012-2020 is extended on a linear basis to 2030.

In these 2030 scenarios we do not include a country-level approach in the different sectors, but we focus on overall growth in total biomass final energy consumption at EU-level. In the NREAPs countries have typically assumed that share of biomass in FEC (in all sectors combined) will grow almost linearly between 2010 2020. In the Linear Extension scenario we assume that the FEC of biomass will keep increasing at the same ratio (approximately 60TWh annually) until 2030.

In table 22 below, we present our assumptions in EC 2030 climate package scenario. In this scenario we use a relatively sophisticated approach according to the forecast of final energy consumption in 2030 and the share of renewable energy proposed for 2030 in EC's 2030 proposal (26.5% share of RES in FEC. In addition we use the the trend in the share of biomass in total RES in the NREAPs to calculate the share of biomass as proportion of increase in RES final energy consumption for the period 2020 to 2030. This leads to an assumption that the share of biomass of total RES will slowly decrease over the years due to higher comparative growth in wind and solar power. This is explained illustratively in the tables below.

Table 22 Biomass final energy consumption calculations in EC 2030 scenario

CODE	Biomass FEC calculations	2005	2020	2030
A	RES as percentage of FEC	8,5%	20,0%	26,5%
B	Forecast FEC total all energy (Mtoe)			1073
C	FEC RES (to reach target) (Mtoe)	99,6	236,7	284,3
D	Stated FEC Biomass for 2005 and 2020 (to reach target) (Mtoe)	61,7	139,0	
E	Biomass as proportion of increase in RES FEC 2005-2020 (%)		56,4%	
F	Additional RES developed 2020-2030 (mtoe)			48
G	Calculated additional biomass developed 2020-2030 (mtoe)			27
H	Calculated FEC biomass for 2030			**165,9**
I	Biomass as a proportion of total RES (%)	61,9%	58,7%	58,3%

EXPLANATION OF THE CODES AND CALCULATIONS IN TABLE 22

A) European commissionCommissionCommission proposal in 2009 and 2030 for share of renewable energy in final energy consumption

B) EC 2030 CLIMATE PACKAGE

C) A * B

D) A * B (Final energy consumption of renewable energy sources for 2005 and 2020 are calculated according to NREAPs)

E) From the NREAPs

F) [illegible] / [illegible]

G) C(2030) ï C(2020)

H) F(2030) * E(2020)

I) G(2030) + D(2020)

J) H / C (D / C for 2005 and 2020)

Table 23 Share of different bioenergy sectors in 2030 scenarios (including comparison to NREAP 2020 baseline)

Bioenergy sector	2020 (NREAPs)	2030 - (EC 2030 Energy Climate package)	2030 ï (Linear increase from

					NREAPs)	
	Absolute biomass, final energy (Mtoe)	Relative share	Absolute biomass, final energy (Mtoe)	Relative share	Absolute biomass, final energy (Mtoe)	Relative share
Electricity	20,0	14 % (of total bionergy)	23,9	14 %	29,7	NA
Electricity-only	9,2	46,1 % (of total biomass elec)	11,0	46,1 %	13,7	46,1 %
CHP	10,8	53,9 %	12,9	53,9 %	16,0	53,9 %
Heat	90,0	65 % (of total bionergy)	107,7	65 %	116,0	NA
Heat- only	68,5	76,1 % (of total biomass heat)	81,9	76,1 %	88,2	76,1 %
CHP	21,5	23,9 %	25,8	23,9 %	27,8	23,9 %
Transport	28,6	21 % (of total bionergy)	34,2	21 %	41,0	
Biodiesel	20,9	72,9 % (of total biomass transport)	25,0	72,9 %	29,9	72,9 %
Bioethanol / BIO-ETBE	7,3	25,5 %	8,7	25,5 %	10,5	25,5 %
Others	0,5	1,6 %	0,5	1,6 %	0,7	1,6 %
Total (Mtoe)	***138,6***		***165,9***		***186,6***	

7 Prospects for 2020

7.1 NREAP Baseline scenario results

7.1.1 NREAP Baseline Excluding Processing ï Base.Ex

Table 24: Primary biomass fuel demand in Base.Ex scenario

Primary Biomass (fuel) Demand: NREAP Baseline Excluding Processing ï Base.Ex - 2020 (TWh)				
Country	**Total electricity demand**	**Total heat demand**	**Total transport demand**	**Total biomass demand**
Austria	20	41	6	66
Belgium	39	21	9	69
Bulgaria	3	13	3	19
Cyprus	0	0	0	1
Czech Republic	18	22	8	47
Denmark	35	15	3	54
Estonia	1	7	1	10
Finland	51	61	7	119
France	69	185	41	295
Germany	179	106	63	348
Greece	4	16	7	28
Hungary	13	10	6	30
Ireland	4	5	6	15
Italy	66	64	29	159
Latvia	5	17	1	22
Lithuania	5	11	2	18
Luxembourg	1	0	3	4
Malta	0	0	0	1
Netherlands	61	1	10	72
Poland	51	58	23	131
Portugal	13	27	6	46
Romania	12	46	6	64
Slovakia	7	5	2	14
Slovenia	3	6	2	11
Spain	42	58	32	132
Sweden	67	90	9	167
United Kingdom	88	49	49	186
EU-27	***858***	***937***	***333***	***2128***

7.1.2 NREAP Baseline Including Processing ï Base.In

Table 25: Primary raw biomass demand in Base.In scenario

Primary Biomass (raw) Demand: NREAP Baseline Excluding Processing ï Base.In - 2020 (TWh)				
Country	Total electricity demand	Total heat demand	Total transport demand	Total biomass demand
Austria	21	43	10	75
Belgium	43	22	16	81
Bulgaria	4	13	6	24
Cyprus	1	0	1	2
Czech Republic	23	24	14	61
Denmark	41	17	6	64
Estonia	1	8	2	11
Finland	61	74	12	148
France	78	197	75	350
Germany	222	121	114	456
Greece	6	17	16	39
Hungary	15	11	13	39
Ireland	4	6	11	21
Italy	84	69	55	208
Latvia	6	18	1	25
Lithuania	6	12	4	21
Luxembourg	2	0	4	6
Malta	1	0	0	1
Netherlands	71	2	19	91
Poland	59	63	43	164
Portugal	16	32	10	58
Romania	14	49	11	74
Slovakia	8	6	4	19
Slovenia	3	6	4	13
Spain	48	61	56	166
Sweden	71	95	21	187
United Kingdom	100	53	98	252
EU-27	*1008*	*1019*	*627*	*2655*

7.2 NREAP BAT scenario results

7.2.1 NREAP BAT Excluding Processing ï BAT.Ex

Table 26: Primary biomass fuel demand in BAT.Ex scenario

Primary Biomass (fuel) Demand: NREAP BAT Excluding Processing ï BAT.Ex - 2020 (TWh)				
Country	**Total electricity demand**	**Total heat demand**	**Total transport demand**	**Total biomass demand**
Austria	16	41	6	63
Belgium	31	21	9	61
Bulgaria	3	13	3	19
Cyprus	0	0	0	1
Czech Republic	15	22	8	44
Denmark	29	15	3	48
Estonia	1	7	1	10
Finland	43	61	7	111
France	57	185	41	283
Germany	149	106	63	318
Greece	4	16	7	27
Hungary	11	10	6	27
Ireland	3	5	6	14
Italy	56	64	29	149
Latvia	4	17	1	21
Lithuania	4	11	2	17
Luxembourg	1	0	3	4
Malta	0	0	0	1
Netherlands	50	1	10	61
Poland	42	58	23	122
Portugal	11	27	6	44
Romania	10	46	6	62
Slovakia	6	5	2	13
Slovenia	2	6	2	10
Spain	34	58	32	124
Sweden	56	90	9	156
United Kingdom	72	49	49	170
EU-27	***711***	***937***	***333***	***1981***

7.2.2 NREAP BAT Including Processing ï BAT.In

Table 27: Primary raw biomass demand in BAT.In scenario

Primary Biomass (raw) Demand: NREAP BAT Including Processing ï BAT.In - 2020 (TWh)				
Country	**Total electricity demand**	**Total heat demand**	**Total transport demand**	**Total biomass demand**
Austria	17	43	10	70
Belgium	34	22	16	72
Bulgaria	3	13	6	23
Cyprus	1	0	1	2
Czech Republic	18	23	14	56
Denmark	33	16	6	55
Estonia	1	8	2	11
Finland	49	71	12	133
France	63	194	75	333
Germany	177	117	114	408
Greece	5	17	16	38
Hungary	12	11	13	36
Ireland	3	6	11	20
Italy	68	68	55	190
Latvia	5	18	1	24
Lithuania	5	12	4	20
Luxembourg	1	0	4	6
Malta	0	0	0	1
Netherlands	56	2	19	77
Poland	47	62	43	151
Portugal	13	31	10	54
Romania	11	48	11	70
Slovakia	7	6	4	17
Slovenia	3	6	4	13
Spain	38	60	56	155
Sweden	58	94	21	173
United Kingdom	79	52	98	230
EU-27	***808***	***1001***	***627***	***2437***

7.3 CHP+ scenario results

7.3.1 CHP+ Excluding Processing ï CHP+.Ex

Table 28: Primary biomass fuel demand in CHP+.Ex scenario

Primary Biomass (fuel) Demand: CHP+ Excluding Processing ï CHP+.Ex - 2020 (TWh)				
Country	**Total electricity demand**	**Total heat demand**	**Total transport demand**	**Total biomass demand**
Austria	17	41	6	64
Belgium	35	21	9	65
Bulgaria	4	13	3	20
Cyprus	0	0	0	1
Czech Republic	22	22	8	51
Denmark	42	15	3	61
Estonia	2	7	1	10
Finland	55	61	7	123
France	82	185	41	308
Germany	154	106	63	323
Greece	4	16	7	28
Hungary	14	10	6	31
Ireland	3	5	6	14
Italy	59	64	29	152
Latvia	4	17	1	22
Lithuania	6	11	2	19
Luxembourg	1	0	3	4
Malta	0	0	0	1
Netherlands	51	1	10	62
Poland	45	58	23	125
Portugal	12	27	6	45
Romania	14	46	6	66
Slovakia	8	5	2	16
Slovenia	3	6	2	11
Spain	41	58	32	130
Sweden	75	90	9	175
United Kingdom	88	49	49	186
EU-27	***844***	***937***	***333***	***2114***
Coal savings				**40**

7.3.2 CHP+ Including Processing ï CHP+.In

Table 29: Primary raw biomass demand in CHP+.In scenario

Primary Biomass (raw) Demand: CHP+ Including Processing ï CHP+.In - 2020 (TWh)				
Country	**Total electricity demand**	**Total heat demand**	**Total transport demand**	**Total biomass demand**
Austria	19	43	10	72
Belgium	39	22	16	77
Bulgaria	5	13	6	25
Cyprus	1	0	1	2
Czech Republic	27	24	14	65
Denmark	49	17	6	72
Estonia	2	8	2	12
Finland	66	74	12	152
France	93	197	75	366
Germany	191	121	114	425
Greece	6	17	16	39
Hungary	16	11	13	40
Ireland	4	6	11	20
Italy	75	69	55	199
Latvia	5	18	1	25
Lithuania	7	12	4	22
Luxembourg	2	0	4	7
Malta	1	0	0	1
Netherlands	59	2	19	80
Poland	52	63	43	157
Portugal	15	32	10	57
Romania	16	49	11	76
Slovakia	10	6	4	21
Slovenia	4	6	4	14
Spain	47	61	56	164
Sweden	79	95	21	195
United Kingdom	99	53	98	251
EU-27	***989***	***1019***	***627***	***2636***
Coal savings				**40**

7.4 Zero-CHP scenario results

7.4.1 Zero-CHP Excluding Processing ï CHP0.Ex

Table 30: Primary biomass fuel demand in CHP0.Ex scenario

Primary Biomass (fuel) Demand: Zero-CHP Excluding Processing ï CHP0.Ex - 2020 (TWh)				
Country	**Total electricity demand**	**Total heat demand**	**Total transport demand**	**Total biomass demand**
Austria	17	49	6	72
Belgium	37	28	9	74
Bulgaria	3	15	3	21
Cyprus	0	0	0	1
Czech Republic	15	32	8	55
Denmark	29	36	3	69
Estonia	1	8	1	10
Finland	43	90	7	139
France	57	225	41	324
Germany	165	155	63	383
Greece	4	17	7	28
Hungary	11	18	6	35
Ireland	3	7	6	16
Italy	62	78	29	169
Latvia	4	19	1	24
Lithuania	4	14	2	20
Luxembourg	1	1	3	5
Malta	0	0	0	1
Netherlands	55	21	10	86
Poland	47	70	23	140
Portugal	12	32	6	49
Romania	10	53	6	68
Slovakia	6	9	2	17
Slovenia	2	7	2	12
Spain	41	64	32	136
Sweden	56	130	9	195
United Kingdom	87	54	49	190
EU-27	***774***	***1232***	***333***	***2338***

7.4.2 Zero-CHP Including Processing ï CHP0.In

Table 31: Primary raw biomass demand in CHP0.In scenario

Primary Biomass (raw) Demand: Zero-CHP Including Processing ï CHP0.In - 2020 (TWh)				
Country	Total electricity demand	Total heat demand	Total transport demand	Total biomass demand
Austria	19	52	10	81
Belgium	41	30	16	86
Bulgaria	3	16	6	25
Cyprus	1	0	1	2
Czech Republic	19	35	14	68
Denmark	34	39	6	79
Estonia	1	9	2	12
Finland	51	109	12	172
France	65	240	75	380
Germany	205	176	114	494
Greece	6	18	16	39
Hungary	12	19	13	44
Ireland	4	7	11	22
Italy	79	84	55	218
Latvia	5	20	1	27
Lithuania	5	15	4	23
Luxembourg	1	1	4	7
Malta	1	0	0	1
Netherlands	64	26	19	109
Poland	55	76	43	173
Portugal	15	38	10	62
Romania	11	56	11	79
Slovakia	7	10	4	22
Slovenia	3	8	4	14
Spain	46	68	56	170
Sweden	59	137	21	217
United Kingdom	99	58	98	255
EU-27	*910*	*1345*	*627*	*2882*

7.5 Summary of scenario results by country

Table 32: Primary biomass fuel demand across scenarios excluding processing

Primary biomass (fuel) demand across scenarios ï excluding processing - 2020 (TWh)				
COUNTRY	NREAP Baseline *Base.Ex*	NREAP BAT *BAT.Ex*	CHP+ *CHP+.Ex*	Zero-CHP *CHP0.Ex*
Austria	66	63	47	72
Belgium	69	61	65	74
Bulgaria	19	19	20	21
Cyprus	1	1	1	1
Czech Republic	47	44	51	55
Denmark	54	48	61	69
Estonia	10	10	10	10
Finland	119	111	123	139
France	295	283	308	324
Germany	348	318	323	383
Greece	28	27	28	28
Hungary	30	27	31	35
Ireland	15	14	14	16
Italy	159	149	152	169
Latvia	22	21	22	24
Lithuania	18	17	19	20
Luxembourg	4	4	4	5
Malta	1	1	1	1
Netherlands	72	61	62	86
Poland	131	122	125	140
Portugal	46	44	45	49
Romania	64	62	66	68
Slovakia	14	13	16	17
Slovenia	11	10	11	12
Spain	132	124	130	136
Sweden	167	156	175	195
United Kingdom	186	170	186	190
EU-27	***2128***	***1981***	***2097***	***2338***
Coal Savings	-	-	**40**	-

Table 33: Primary raw biomass demand across scenarios including processing

Primary biomass (raw) demand across scenarios ï including processing - 2020 (TWh)				
COUNTRY	**NREAP Baseline** ***Base.In***	**NREAP BAT** ***BAT.In***	**CHP+** ***CHP+.In***	**Zero-CHP** ***CHP0.In***
Austria	75	70	72	81
Belgium	81	72	77	86
Bulgaria	24	23	25	25
Cyprus	2	2	2	2
Czech Republic	61	56	65	68
Denmark	64	55	72	79
Estonia	11	11	12	12
Finland	148	133	152	172
France	350	333	366	380
Germany	456	408	425	494
Greece	39	38	39	39
Hungary	39	36	40	44
Ireland	21	20	20	22
Italy	208	190	199	218
Latvia	25	24	25	27
Lithuania	21	20	22	23
Luxembourg	6	6	7	7
Malta	1	1	1	1
Netherlands	91	77	80	109
Poland	164	151	157	173
Portugal	58	54	57	62
Romania	74	70	76	79
Slovakia	19	17	21	22
Slovenia	13	13	14	14
Spain	166	155	164	170
Sweden	187	173	195	217
United Kingdom	252	230	251	255
EU-27	***2655***	***2437***	***2636***	***2882***
Coal Savings			**40**	

7.6 Overall summary of scenarios for EU-27 in 2020

In this section we make an overview of the results in the different scenarios, and in particular, discuss the effect of CHP on primary energy demand for biomass. We exclude here the results concerning the primary energy demand derived from transport biofuels, since this is constant across all scenarios and in this summary, it can distract from the overall focus in this report on the electricity and heat sectors. The scenario results in terms of primary energy demand (including Coal & CO_2 savings for the CHP+ scenario) are summarised in table 34. A comparison of the scenarios in terms of biomass savings is given in table 35. Overall observations are made as follows:

- A first observation is that primary energy demand in all scenarios is increased by around 13% when the energy required in the processing of the raw biomass before delivery to plant is taken into account. For the BAT scenarios the difference is only 10% because of the more efficient processing assumed.
- The BAT scenarios show a saving of 8% of primary biomass for BAT.Ex (excluding processing) and 11% for BAT.In (including processing), showing that the benefits of using more efficient plant can be taken even further when opportunities to improve biomass fuel processing are also implemented. The results of this scenario clearly show the benefits of incentivising and building the most efficient plant available.
- The CHP+ scenarios show significant primary energy savings even for the relatively modest increases in CHP set out in this scenario. The primary energy savings in terms of biomass are however, rather small ï of the order of 1% - because of the limited amount of biomass electricity-only plants from which to deduct the additional CHP final energy from ï especially in the countries in the ñHIGHòCHP growth potential group (see scenario methodology section 6.4.3). However, these biomass savings do not take account of the true role of the additional final energy from biomass CHP plant, which according to our methodology, we have used to substitute coal CHP. In this respect, we see significant savings in primary coal ï of 40TWh, and a 14Mt reduction in CO_2 emissions. If we add the primary biomass and coal savings figures together to produce an ñequivalent biomassò primary energy saving, we see a more significant reduction of 3% against the baseline scenario (as mentioned in section 6.4.3, we argue that this ñequivalentò approach is valid since the additional biomass final energy from CHP could also substitute for transport biofuels ï in which case the primary savings would actually be rather larger)
- The theoretical Zero-CHP scenario clearly shows the primary energy benefits of existing and planned CHP; if all final energy from biomass CHP planned in 2020 was to be produced from separate electricity-only and heat-only plants, the result would be 11% higher primary biomass demand for CHP0.In (including processing) and 12% higher for CHP0.Ex (excluding processing).

Table 34 Summary table showing EU-27 results and primary energy savings against baseline between all different scenarios (not showing sectors) including coal primary saving and CO_2 in CHP+ scenario

Total biomass demand in EU-27 without transport - 2020 (TWh)								
	NREAP Baseline		NREAP BAT		CHP+		Zero-CHP	
Processing included/ excluded	Inc. proc	Exc. proc	Inc. proc	Exc. proc	Inc. proc	Exc. proc	Inc. proc	Exc. proc
Scenario code:	*Base. Inc*	*Base. Exc*	*BAT. Inc*	*BAT. Exc*	*CHP+. Inc*	*CHP+. Exc*	*CHP0. Inc*	*CHP0. Exc*
Total primary biomass demand	2027	1795	1810	1648	2008	1781	2255	2005
Coal savings					*40*	*40*		
CO_2 Savings (Mt of CO_2)					*14*	*14*		

Table 35: Biomass savings across the different scenarios vs NREAP baseline

Biomass savings in electricity and heat compared to baseline scenario in 2020								
Scenarios	NREAP BAT		CHP+				ZERO-CHP	
			Biomass only		*Biomass eq. (Coal savings included)*			
	BAT. Inc	*BAT. Exc*	*CHP+. Inc*	*CHP+. Exc*	*CHP+. Inc*	*CHP+. Exc*	*CHP0. Inc*	*CHP0. Exc*
Absolute (TWh)	-218	-147	-18.8	-13.6	-58.6	-53.5	+228	+210
Relative (%)	-11 %	-8 %	-0,9 %	-0,8 %	-2,9 %	-3,0 %	+11%	+12%

Overall the BAT scenario shows the most primary energy saving benefits, though the optimum scenario in terms of minimising biomass demand would clearly be a combination of the BAT and CHP+ scenarios. The primary energy savings from the CHP+ scenario could have been furthered if higher growth percentages of CHP were applied to the different countries studied, especially for the countries in the ñVERY LOWò CHP growth potential group who are also planning to develop large capacities of electricity-only biomass for which the CHP could substitute. This group of countries - such as the UK and Spain could arguably implement biomass CHP without significant DH networks if small scale biomass CHP was heavily promoted for e.g. industrial sites, hospitals, schools and new residential complexes (in Spainôs case small scale biomass tri-generation could be appropriate ï power, heating and cooling).

The results clearly show the benefits of implementing best available technology where possible and maximising the use of CHP ï the policy implications of these conclusions are discussed in the next section.

8 Prospects for 2030

8.1 Linear Extension scenario

Table 37 Final energy consumption in Linear Extension scenario

Final energy consumption of biomass in Linear Extension scenario (TWh)						
Sector	**2010**	**2013**	**2015**	**2020**	**2025**	**2030**
Electricity	114	149	169	232	287	345
Heat & Cooling	720	794	850	1047	1187	1349
Transport	158	201	226	333	396	476
Total	***993***	***1144***	***1245***	***1612***	***1871***	***2170***

Table 38 Final energy consumption between sectors and weighted average conversion efficiencies in Linear Extension scenario for 2030

FEC Biomass: Linear Extension scenario in 2030				
	Absolute biomass (TWh)	Relative share	Weighted conversion efficiencies by sector	
			Processing efficiency	Combustion efficiency
Electricity	345,1		88 %	
Electricity- only	159,1	46,1 %		37 %
CHP	186,0	53,9 %		30 %
Heat	1348,9		94 %	
Heat- only	1026,1	76,1 %		85 %
CHP	322,8	23,9 %		60 %
Transport	476,4		53 %	
Biodiesel	347,2	72,9 %	60 %	
Bioethanol / BIO-ETBE	121,6	25,5 %	40 %	
Others	7,6	1,6 %	50 %	
Total	***2170***			

Table 39 Biomass fuel and raw biomass demand in Linear Extension scenario

Biomass demand in Linear Extension scenario ï 2030		
	Processed (TWh)	**Non-Processed (TWh)**
Electricity	1055	1200
Heat & Cooling	1207	1290
Transport	476	898
Total	***2739***	***3388***

8.2 EC 2030 climate package scenario

Table 40 Final energy consumption between sectors and weighted average conversion efficiencies in EC 2030 climate package for 2030

FEC Biomass: EC 2030 climate package scenario in 2030				
	Absolute biomass (TWh)	Relative share	Weighted conversion efficiencies by sector	
			Processing efficiency	Combustion efficiency
Electricity	278,1	14 %	88 %	
Electricity- only	128,3	46,1 %		37 %
CHP	149,9	53,9 %		30 %
Heat	1252,5	65 %	94 %	
Heat- only	952,8	76,1 %		85 %
CHP	299,8	23,9 %		60 %
Transport	398,3	21 %	53 %	
Biodiesel	290,3	72,9 %	60 %	
Bioethanol / BIO-ETBE	101,7	25,5 %	40 %	
Others	6,3	1,6 %	50 %	
Total	***1929***			

Table 41 Biomass fuel and raw biomass demand in EC 2030 climate package scenario

Biomass demand in EC 2030 climate package scenario - 2030		
	Processed (TWh)	**Non-Processed (TWh)**
Electricity	850	967
Heat & Cooling	1121	1198
Transport	398	751
Total	***2370***	***2916***

8.3 Overall summary of scenarios for EU-27 in 2030

In this section we make an overview of the results in the 2030 scenarios contained in the above section 8.1 and 8.2. A comparison of the 2030 scenarios in terms of biomass increase, is given in table 42; this table also presents the 2020 NREAP baseline results for illustrative purposes.

Table 42 Biomass savings across 2030 scenarios vs NREAP baseline 2020

Biomass increase in 2030 scenarios compared to baseline scenario in 2020 (including transport in all scenarios)							
Increased biomass	**NREAP BAU 2020**	**EC 2030 climate package**			**Linear extension**		
	Demand (TWh)	Demand (TWh)	Absolute increase (TWh)	Relative increase (%)	Demand (TWh)	Absolute increase (TWh)	Relative increase (%)
Processed biomass	2128	2370	242	11 %	2739	611	29 %
Non-processed biomass	2655	2916	261	10 %	3388	734	28 %

In discussing these results, it must be kept in mind that these results are very approximate; there is a great deal of uncertainty concerning the policy and market environment in the 2030 timeframe. In this regard, it has to be remembered that even the assumptions for achieving the bioenergy development in the 2020 scenarios is under scrutiny, thus furthering the difficulty in estimating biomass demand in 2030. The 2030 EC package makes this level of uncertainty even higher by not presenting any national targets for RES, but rather relying on an EU-level target, the legally binding nature of which is in itself highly questionable (see discussion on the 2030 package in section 3). Furthermore, the EC 2030 climate package is currently only a proposal from the Commission and is yet to be agreed by member states.

As considered in more detail in section 6.4.7 on 2030 scenario methodology, the scenarios for 2030 are based on overall projections of RES growth, from which highly approximate forecasts of bioenergy growth are derived. In total we would point out 3 principal sources of uncertainty in these scenarios:

- How much RES will grow to 2030 presented in the two scenarios, Linear extension scenario in section 8.1 and EC Package in section 8.2.
- Secondly, there is the uncertainty of what proportion of this total RES growth will be fulfilled by bioenergy. We assume in the EC 2030 Scenario that the trend of bioenergy as a proportion of total RES continues along the same trajectory as to 2020 (i.e., that the proportion of total RES being bioenergy continues to decline slightly, to 58.3% of total RES in 2030, compared to 58.7% in 2020).
- A further source of uncertainty concerns whether the share between biomass electricity, heat and transport in 2030 will remain the same in 2030 as in 2020. With ECọs 2030 climate package we can currently calculate assumptions for total biomass in final energy consumption but it is far harder to try to evaluate the shares between different sectors (electricity, heat and transport) in the future. Our assumptions are based on the fact that the majority of biomass in final energy consumption is in heat sector (table 23). In truth, according to current progress it seems that the share of biomass FEC in transport will grow more than in the heat thus meaning that the actual demand of raw biomass will increase because the overall conversion and processing efficiencies for transport biofuels are lower than for the heat sector.

Given these uncertainties, it is impossible to present any meaningful projections on country level, and even the EU-level scenario results for 2030 should only be taken as very general indications of the future of the bioenergy sector. Keeping this in mind, we can make the following general observations of the 2030 results presented in summary in table 42:

- The results of EC 2030 package scenario analysis clearly show that the EC is effectively intending to decrease the growth rate of renewable energies to 2030 in comparison to the period up until 2020, and by extension, therefore decreasing the foreseen growth rate in bioenergy utilization. We can illustrate this by comparing the EC 2030 package and linear extension scenarios, since the latter scenario represents simply an extension of the growth levels required to reach the 2020 RES target:
  - In the EC 2030 climate package scenario the primary energy demand is increased by 10 %-11% over the 2020 NREAP baseline scenario
  - If the bioenergy utilization would continue to grow at same annual rate to 2030 as between 2010-2020, i.e. as per our Linear extension scenario, we would need almost 30% more biomass, as is shown in table 42.

- The assumption of improving conversion efficiencies should also be considered. Conversion efficiencies are likely to increase from 2020 point of view. In these scenarios we predict a rather moderate increase in conversion efficiencies (same conversion efficiencies in 2030 as in the 2020 BAT scenario).

In the following section we discuss the 2020 and 2030 scenarios in context against forecasts of future biomass availability.

9 Discussion & Conclusions

9.1 Context: Demand vs Availability

In putting the results of the scenarios in context, is important to discuss the demand scenarios derived for 2020 and 2030 in comparison to the availability of biomass within the EU. There are various estimations of the available ĩEU domesticò primary biomass resource, but for the 2020 period, the availability in all estimates it is much less than the total 2000TWh (172 Mtoe) of raw biomass required in the 2020 NREAP baseline scenario ï even 2600TWh (224 Mtoe) when biofuels are included. Typical availability estimates for 2020 are as follows:

- 138 Mtoe (1605 TWh) according to member state estimates in the NREAPs themselves [22]
- 122Mtoe (1419TWh) according a study made by Pöyry Energy Consulting for EURELECTRIC [20]

This summary data can be elaborated further as per the table below:

Table 43: Projections of Biomass availability to 2020 (in Mtoe) [20][22]

Primary bioenergy type	Pöyry Projection 2010 (Mtoe)	Pöyry Projection 2020 (Mtoe)	NREAP Projection 2020 (Mtoe) *(member state estimates in NREAPs)*
Forestry	63.7	71.4	68.1
Agriculture	12.8	36.3	44.1
Waste	5.7	13.9	25.8
TOTAL	82.2 (956 TWh)	121.7 (1415 TWh)	137.8 (1603 TWh)

As shown in the table above and discussed in section 5, according to the Pöyry study, the growth in availability to 2020 is foreseen to be greatest in the agriculture and waste sectors, for which the growth in availability 2010-2020 is foreseen to be a tripling of available for agricultural biomass and a more than doubling in biomass from the biodegradeable fraction of waste. Notably, the growth foreseen in the forestry sector is rather modest; only an additional of around 15% from 2010 supply. The member state estimates in the NREAPs present even greater ambitions for the agriculture and waste sectors ï and yet are even more pessimistic about further potential in the forestry sector. However, even if the growth in availability predicted by either of these availability forecasts is achieved, the scenarios for demand we present in this study imply that the need for bioenergy imports from outside the EU will be very significant indeed.

For 2030, there is even greater uncertainty about biomass availability, but with forecasted demand running from 2900TWh (in our scenario based on EC Climate and Energy Package) up to 3400TWh is bioenergy development is extended linearly from 2020 to 2030. Nonetheless, it is clear that EU bioenergy availability will be an even more intractable problem in 2030, and indeed will likely make it difficult to progress with bioenergy development after 2020 and indeed may have wider implications for reaching overall renewable energy and climate objectives.

9.2 Policy recommendations

Without doubt, fulfilling the objectives for bioenergy inherent in EU's 2020 Renewable Energy Policy will require large imports of biomass from outside the EU – indeed significant imports to central western Europe are already in place. These import needs are likely to further accelerate after 2020 if the EU's 2030 Climate and Energy objectives are to be reached. The question of Biomass sustainability – which has already provoked much debate concerning transport biofuels – is particular prescient when considering imported biomass, the origins of which are often difficult and administratively complex to ascertain. Increased reliance on imported biomass for the electricity and heat sector is likely to raise significant attention from NGOs and the general public, and will generate pressure for sustainability criteria to be put in place, similar to those already in place for transport biofuels. Indeed, in the circumstances of increased import, such criteria could arguably be rather desirable to promote market stability and investor certainty. Nonetheless, becoming too reliant on imported biomass from outside the EU will inherently make utilities vulnerable to changes in public policy on biomass sustainability, restrictions on imports, and changes in the global biomass energy market (which is currently a very immature market, the future dynamics and stability of which cannot be easily forecast). However, this study shows that need for import could be significantly reduced – and therefore the problems inherent in imports ameliorated - if primary biomass demand was reduced by all new biomass plants being built to BAT standards and if the role of biomass CHP is fully maximized. Therefore, we would make a number of tentative recommendations to policymakers in the short to medium term, as follows:

- There should be clear incentives – e.g. through subsidy conditions - to build all new biomass plant to the best available technology. This may also imply focussing as much as possible on more efficient, larger scale plant - in the case of CHP this most relevant for those countries with existing DH networks. Technical efforts will be needed to improve the efficiency of smaller scale technologies – especially for CHP in countries without large DH networks.

- Electricity-only biomass plants should be avoided where possible since it represents the most inefficient use of the primary biomass resource.
- Biomass CHP plants should be heavily promoted ï to replace fossil fuel plant in existing DH systems, and where DH is absent, smaller scale CHP plants for industrial sites, hospitals and residential complexes could be promoted.
- Member state governments should develop a clear understanding of the primary energy implications of the biomass plant development foreseen in their NREAPs and where possible, put measures in place to ensure this primary resource is available ï e.g. through promoting forestry, agricultural biomass and collection of energy waste, as well as appropriate processing and transport infrastructure.

10 Suggestions for further research

This study gives rise to a number of ideas for further research, as follows:

A. General scenario development:

More detailed scenarios could be developed in consultation with Energy Utilities and European policymakers and stakeholders concerning the ñrealismòthe scenarios presented in this study. These more sophisticated scenarios could particularly focus on the following issues:

- Role of large European Energy Utilities existing investment plans on biomass use. Including:
  - Effect of current energy market situation on plant investments and development
  - Wider plant development issues such as conversion of existing coal plant and related use of torrefied biomass (e.g. analysis of how much existing capacity could be converted)
  - Possible impact of EU-level sustainability criteria and questions concerning market-compatible design of such criteria; whether such criteria could be beneficial is providing greater fuel supply certainty and facilitating stable biomass market development, or whether more negative effects are foreseeable e.g. in restricting biomass availability and imposing administrative barriers
- More advanced CHP plus scenario with individual country analysis of realistic/feasible possibilities and adjust each country upwards by a unique percentage. The CHP potential of countries could be based on an analysis of existing DH systems and heat markets and could, for example, be carried out in collaboration with utilities operating such plant.

B. Specific issues for an improved 2030 analysis:

Developing a more detailed, sophisticated 2030 analysis:

- Considering reaction of member states to EC proposal for 2030 Climate and Energy package and indications this provides on intention on national RES development to 2030 and the role of biomass within this (e.g. a number of members states are vehemently opposed to 2030 national level RES targets whereas others actively lobbied the Commission to introduce national level targets in the 2030 proposal, albeit unsuccessfully)
- Use of other national level policies and plans towards 2030 and beyond; e.g. UK 2050 climate objectives.

C. Realistic NREAP progress scenario to 2020:

A scenario to 2020 and beyond which is based on the progress of member states thus far towards reaching the target; a number of member states are already deviating significantly from their intended NREAP pathway.

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