Potential and implications of using biomass for energy in the European Union

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Executive Summary

This study conducted by the Building Research Establishment Ltd (trading as BRE) is presented against proposal number 136379 issued in response to the NGO steering group, consisting of EEB, Transport & Environment and BirdLife Europe, invitation to tender received by email on 17 July 2014 from BirdLife Europe on behalf of the group.

In Europe, there is increasing demand for biomass for energy, alongside existing (construction, pulp and paper) and more novel uses of biomass (chemicals) to produce a broad range of materials. More than half of EU's renewable energy target for 2020 is expected to be made out of bioenergy. Even though the policy framework for renewable energy until 2030 still is largely unclear, bioenergy is assumed to play an equally important role. This has led to several studies, including ones commissioned by the European Commission as well as by NGOs, already indicating increasing competition over biomass and conflicts with sustainable domestic supplies of biomass and the expected demand in 2020 and 2030.

This study aimed at improving our knowledge and understanding on the potential of sustainable biomass for energy. The main objective of the study is to facilitate progressive and robust policy to ensure the sustainable use of biomass for energy in Europe. Europe has committed itself to reduce its GHG emissions by 80-95 % by 2050 and in the shorter term, by 2020, to reduce GHG by 20%, increase the share of renewables to 20%, and save 20% energy.

Renewable energy in general is vital for our sustainable future in Europe. The fundamental big picture must ensure the greenhouse gas impacts of renewable energy are accounted for and low impact choices are made in policy initiatives. In addition, there are four key issues that are prominent when considering availability of feedstocks and the extent of using biomass as renewable energy.

1. There is an expectation both now and in all generic forecasts for renewable energy sources of business as usual and that biomass feedstocks will be the source of approximately 50% of the total renewable energy for Europe;
2. Biomass feedstocks are finite;
3. Non-energy sectors are 'competing' for biomass feedstocks;
4. Biomass as a natural and renewable resource is in most cases an intrinsic component of European ecosystems.

European Directives and Strategies indicate reductions in certain biomass feedstock availability. They also provide boundaries and limitations on the extent that energy crops could fulfil energy needs and limitations

on forest and agricultural land crop extraction and management that reduce biodiversity. These strategies are priority and must remain robust.

A series of boundaries and limitations have been applied when considering potential in this study of the availability of biomass feedstocks and thus their potential for energy in order to determine the sustainability potential for biomass feedstocks in Europe.

The boundaries are:

Europe should limit the ecological footprint of its consumption, and not deliberately increase it through policies. It should focus on becoming more aligned towards consuming no more than Europe can produce (albeit that this may comprise of European sourced biomass and imported material).

Conservation as a competing demand for land and for the quality of the managed land (agricultural and forestry) must also be considered. For the final outcome the sustainable potential, additional environmental, economic and social criteria have been integrated which include:

- Increase of 5% in strictly protected forests
- 5% increase in retained trees on harvest sites
- Constraints on residue removal from unproductive poor soils and a maximum of 70% residue removal allowed on other soils.
- No stump extraction[1]
- 33% of all agricultural residue left on land to maintain soil condition[2]
- Land for energy crops should not displace food production within the current agricultural area, or do so only minimum negative impacts and risk to the environment (including ILUC)
- Any crop production must satisfy as a minimum the conditions set out under Article 17 (3) –(6) of Renewable Energy Directive[3]
- Reduce food waste generation by 30% by 2025;

Information has been taken forward from the three foundation studies (IINAS 2014; IEEP 2014; ICCT 2014) on availability of wood, land for energy crops and lingo-cellulosic waste. The study has used energy demand estimations from the various European Commission scenarios including the Roadmap 2050. New information has been gathered on forecasts of competing demands placed on those biomass feedstocks from non-energy demands such as pulp and paper or construction timber and removal of these from the total technical potential gives the technical potential available for energy.

[1] All environmental constraints for woody biomass are as in IINAS study 2014
[2] ICCT study 2014
[3] These include protection of land with high biodiversity value, high carbon stock land; land that was formerly peatland; and must respect rules governing the receipt of support through the Common Agricultural Policy

The sustainable potential of biomass feedstocks for energy in 2030 is calculated to be 152.2 Mtoe which is 29.2% of the total technical potential (Table 1). In all cases with the European Commission scenarios the forecast share of renewable energy that is met by biomass and waste derived under 'business as usual' scenarios is greater than the sustainable volume of biomass feedstocks calculated to be available for energy in this study.

Mtoe	2020	2030
Technical potential	527.3	521.8
Technical energy potential	354.1	335.5
Sustainable potential	171.9	152.2

Table 1. The sustainable potential is approximately 32.6% of the 2020 technical potential; 29.2% of the 2030 technical potential.

The sustainable potential derived could yield a theoretical 8% final energy consumption met by biomass in 2030, or 4.8% of consumption if converted to heat, with the total share of renewable energy that is met by biomass as 30%. In 2012 65.5% of all RES was biomass and waste and whilst this figure is expected to be lower in 2015 it is significantly higher from the sustainable potential proportions highlighted here as 30% for 2030 (Figure 1).

Even with continuing growth trends for other renewable energy sources, there is a gap between the RES targets and the sustainable amount of biomass available for energy plus the other available energy from renewables, assuming trends develop as expected in the NREAPs of EU member states. In addition the material use demands are assumed to develop according to forest sector model projections, which are in part disputed as they do not take account of structural changes in the sector and in consumption; an example being the shift from print media to electronic media. This gap is 36% of all renewable energy for 2020 and 50% for 2030. If the 27% RES 2030 target is to be met than this will require a huge upshift in deployment of wind, solar and other renewable energy sources across Europe.

Biomass feedstocks have a role to play in current and future RES for Europe as it decarbonises energy. The study assumed import of biomass for energy, expanding Europe's global land footprint above current levels (1.3ha per capita), is not desired and that annual harvest increments in Europe's forests do not increase significantly. This study concludes the contribution made by sustainable biomass to European renewable energy will be relatively modest.

To challenge the conflicts with sustainable domestic supplies of biomass and the expected demand for energy in 2020 and 2030 this study recommends to:

1. Establish strict sustainability criteria for biomass feedstock

2. Prioritise the use of resources by facilitating the use of biomass feedstocks that have not competing demands such as wastes and residues
3. Ensure biomass feedstocks go to the most energy efficient means of conversion
4. Avoid use of biomass that can be a driver for loss of biodiversity, linked to intensity of land use, direct and ILUC to ensure
5. Maintain a requirement for 33% of agricultural residue being left on the land to maintain soil condition.
6. Encourage management of forests and woodlands to be positive for carbon stocks such as systems that promote regeneration to enhance forest growth.
7. Strengthen Energy Efficiency policies and measures and deep pan-European implementation should be accelerated.
8. Unlock the deployment of solar and wind RES to begin to “live within our means” for energy.

Cutting energy consumption, limiting policy incentives, and balancing the demand and supply of biomass will allow a smooth transition to a low-carbon economy. Future energy systems need to rely on efficient and smart use of energy mostly generated from solar, wind and other renewables that don’t emit carbon. Wood and biomass waste and residues can play a limited role, but require strict environmental safeguards.

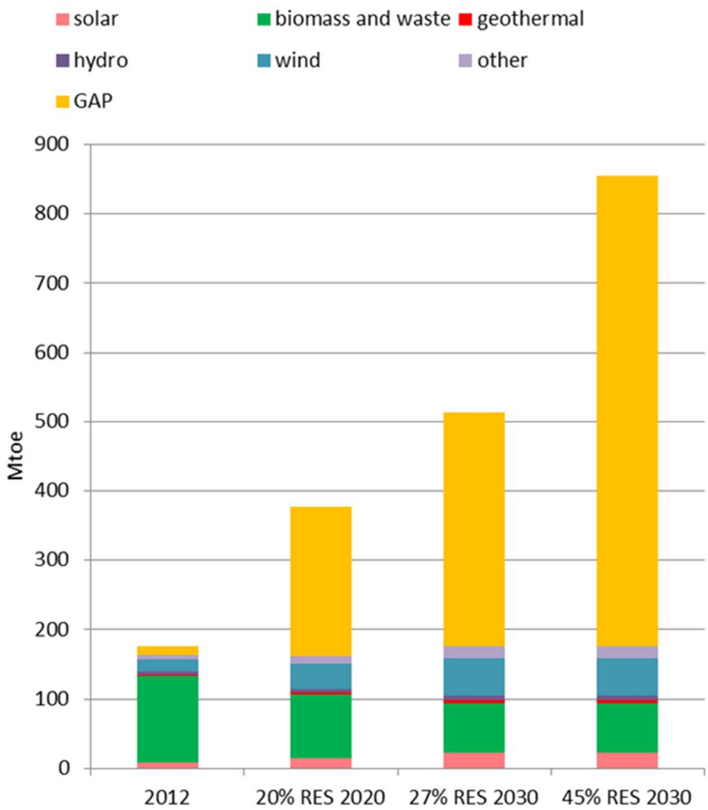

Figure 1. Scenarios presented as total Mtoe from RES sources. NOTE in 2020 it is likely that 20% overall European RES target will be met with heavier reliance on biomass than illustrated.

Contents

List of figures 7
List of tables 9
Abbreviations 10

1 Introduction and Scope of Work 12
2 Biomass feedstock identification 15
2.1 Methodology 15
2.2 Rationale for biomass classifications 15
3 Data on biomass feedstock availability 18
3.1 Methodology 18
3.2 The foundation studies 19
4 Potentials 27
4.1 Technical potential 29
4.2 Competing uses for biomass feedstocks 34
4.3 Technical potential for energy 45
5 European Directives and Strategies 47
5.1 Biodiversity strategy 47
5.2 High nature value farmland 48
5.3 Landscape and Green Infrastructure 49
5.4 Land use change 50
5.5 Invasive alien species 50
5.6 Circular economy 51
5.7 Climate change 53
5.8 Carbon debt 54
6 Sustainable potential 56
6.1 Sustainable potential 56
7 Renewable Energy Sources 63
7.1 Renewable energy - total RES and biomass waste contribution 65
7.2 SUST RES scenario biomass for energy pegged to sustainable potentials 70
7.3 HIGH RES scenario for EU 72
8 Conversion of biomass potential to energy 76
8.1 Energy Efficiency 76
8.2 Processing losses 77
9 Summary & Recommendations **Error! Bookmark not defined.**
Appendix A: Hierarchy of use for biomass feedstocks 84
Appendix B: Literature review reports of biomass feedstock potentials 88
Appendix C: Calculations 99

List of Figures

Figure 1. Scenarios presented as total Mtoe from RES sources. 5

Figure 2. Ranking of biomass feedstock classifications indicating which are reported in the three foundation reports. 16

Figure 3. Reference Potentials of forest biomass from final harvest, thinning and pre-commercial (PC) thinning. Totals 152.4 Mtoe (2010) and 53.0 Mtoe (20230) 20

Figure 4. Secondary woody residue (IINAS 2014 Figure 3 converted to Mtoe). 20

Figure 5. Summation of available harvested softwood, primary forest residues and secondary woody residues. 21

Figure 6. Reference (REF) and low mobilisation (LOW) potentials of total forest biomass 21

Figure 7. European agricultural land available for energy crops 22

Figure 8. Categories of land considered in the IEEP 2014 study for energy crop production. 23

Figure 9. Summary of energy crop agronomics, impacts, yields and distribution. 24

Figure 10. Total biomass production (Mdt) and final energy produced (PJ) from dedicated biomass utilisation (upper and lower values). 24

Figure 11. Waste available Mt for bioenergy production in 2030 25

Figure 12. The technical potential of biomass feedstocks in Europe 33

Figure 13. EU forest product consumption forecasts in RWE Mm3 per year 35

Figure 14. EU forest product consumption forecasts in RWE Mm3 per year adjusted for import and export 36

Figure 15. Proportion of wood based product demand in 2011 that is satisfied by EU27 supply 36

Figure 16. EU28 forest product consumption forecasts in RWE Mm^3 per year adjusted for import and export to yield EU28 consumption 37

Figure 17. Competing demands from other non-energy uses and industries 44

Figure 18. Technical potential for energy use is 287.5 Mtoe (2010); 317.6 Mtoe (2020) and 297.2 Mtoe (2030). 46

Figure 19. Circular economy approaches ‘design out’ waste and typically involve innovation throughout the value chain, rather than relying solely on solutions at the end of life of a product. 51

Figure 20. The sustainable potential available for energy on implementation of stricter forest environmental controls (IINAS 2014), 50% agricultural residue left on land, less land used for energy crop. 58

Figure 21. The sustainable potential is 32.6% of the 2020 technical potential; 29.2% of the 2030 technical potential. 59

Figure 22. Summary chart of technical, technical energy and sustainable potential for biomass feedstocks in 2030. 62

Figure 23. Historical and forecast trends of decreasing Gross Inland Consumption and increasing primary production of renewable energy in Europe. 63

Figure 24. Approximately 50% of primary production of renewable energy has been from solid biofuels EUROSTAT. Total RES energy and individual RES sources EUROSTAT 2012 data. 64

Figure 25. The share of renewable energies in gross final energy consumption by country EUROSTAT 2012 64

Figure 26. Roadmap 2050 REF and Roadmap 2050 HIGH RES scenarios showing total RES production and the biomass and waste proportion PJ for EU28 67

Figure 27. Potentials and forecast demands for biomass feedstock Mtoe - for 2020 and 2030. 69

Figure 28. A snapshot of total RES primary energy production in 2012 in the EU28 by renewable energy source EUROSTAT data 70

Figure 29. 2030 sustainable biomass feedstock scenario total RES primary energy 71

Figure 30. 2020 GAP in RES at forecast energy demand when using sustainable potential of biomass 71

Figure 31. 2030 GAP in RES at forecast energy demand when using sustainable potential of biomass 71

Figure 32. 2030 sustainable biomass feedstock energy demand when using sustainable potential of biomass 73

Figure 33. 2030 GAP in RES at forecast energy demand 73

Figure 34. Scenarios presented as total Mtoe from RES sources 75

Figure 35. European energy flow in 2011 76

Figure 36. Sustainable potential is approximately 32.6% of the 2020 technical potential; 29.2% of the 2030 technical potential 81

Figure 37. Scenarios presented as percentages of RES sources 82

List of Tables

Table 1. The sustainable potential is approximately 32.6% of the 2020 technical potential; 29.2% of the 2030 potential 4

Table 2. Wood resource conversion factors 18

Table 3. Waste availability 25

Table 4. Technical potential for biomass feedstocks 29

Table 5. Summary of competing demand for forest product reductions on potentials biomass feedstocks 38

Table 6. Summary of competing demand reductions from biopolymers on potentials for biomass feedstocks 39

Table 7. Summary of competing demand reductions from compost production on potentials for biomass feedstocks 39

Table 8. Summary of competing demand reductions from bark mulch on potentials for biomass feedstocks 40

Table 9. Summary of competing demand reductions from animal bedding on potentials for biomass feedstocks 42

Table 10. Competing demands totals from other non-energy uses and industries 43

Table 11. The technical potential for energy use from in Europe. 45

Table 12. The sustainable potential for biomass feedstocks 57

Table 13. Summary of competing uses and sustainability constraints imposed on potential calculations 60

Table 14. Summary feedstock Mtoe for technical (T), technical energy (TE) and sustainable (S) biomass potentials. 61

Table 15. Summary of scenarios used for comparison of this study's potentials 66

Table 16. Summary of Mtoe potentials and demand scenarios for 2020 and 2030 68

Table 17. A comparison of total primary energy consumption met by biomass for different study scenarios compared to RES targets for 2020 and 2030. 69

Table 18. Non-biomass RES required to meet RES targets 70

Table 19. A comparison of total primary energy consumption met by biomass for different study scenarios compared to RES targets for 2020 and 2030. 72

Table 20. Non-biomass RES required to meet 45% RES target 72

Table 21. Energy conversion pathway efficiencies expressed as secondary energy output per unit of primary energy needed to convert biomass feedstock 78

Table 22. Sustainable biomass energy conversion efficiency for 2030 feedstock availability 78

Abbreviations

AD	Anaerobic digestion
CAP	Common Agricultural Policy
CCS	Carbon capture and storage
CHP	Combined Heat and Power
CSPP	concentrating solar power plant
DS	Domestic sludge
EC	European Commission
ECCP	European Climate Change Programme
EE	Energy efficiency
EED	Energy Efficiency Directive
EPBD	Energy performance of buildings Directive
ETS	The EU Emission Trading Scheme
EU27	European Union member states prior to Croatia's accession 2013
EU28	European Union member states 2015
GHG	Greenhouse Gas emissions
HNV	High nature value
IAS	Invasive alien species
ICCT	International Council on Clean Transport
IEEP	Institute for European Environmental Policy
IINAS	International Institute for Sustainability Analysis and Strategy
ILUC	Impacts of land use change
IPCC	International Panel on Climate Change
Mha	Million hectares
Mm^3	Million cubic metres
Modt	Million oven dry tonnes
MSW	Municipal solid waste
Mtoe	Million tonnes oil equivalent
NNL	No net loss

PJ	petajoule (J x 10^{12})
PV	photovoltaic
RES	Renewable energy source
RWE	Round wood equivalent
RWP	Recycled wood pallets
S	Sustainable potential (Table 14)
SFM	Sustainable forest management
SRC	Short rotation coppice
SRF	Short rotation forestry
T	Technical potential (Table 14)
TE	Technical energy potential (Table 14)
UCO	Used cooking oil

1 Introduction and Scope of Work

This study conducted by the Building Research Establishment Ltd (trading as BRE) is presented against proposal number 136379 issued in response to the NGO steering group, consisting of EEB, Transport & Environment and BirdLife Europe, invitation to tender received by email on 17 July 2014 from BirdLife Europe on behalf of the group.

In Europe, there is increasing demand for biomass for energy, alongside existing (construction, pulp and paper) and novel uses of biomass (chemicals) to produce a broad range of materials. The catalyst for this increase in demand is the climate change agenda; the key issue underlying the use of biomass resources in economic sectors to minimise impacts, reduce carbon emissions and increase resource efficiency.

Europe has committed itself to reduce its GHG emissions by 80-95% by 2050 and in the shorter term, by 2020, to reduce GHG by 20%, increase the share of renewables to 20%, and save 20% energy through efficiency. More than half of EU's renewable energy target for 2020 is expected to be made out of bioenergy. Even though the policy framework for renewable energy until 2030 is largely unclear, bioenergy is assumed to play an equally important role. This has led to several studies, including ones commissioned by the European Commission as well as by NGOs, already indicating increasing competition over biomass and conflicts with sustainable domestic supplies of biomass and the expected demand in 2020 and 2030.

Existing studies have shown that European policies have not yet addressed these conflicts and are not yet sufficient to ensure a sustainable development of the bioenergy sector. The NGOs behind this study want to improve their knowledge and understanding on the potential of sustainable biomass for energy. This will support the work to make well informed policy recommendations for the EU's 2030 climate and energy framework and the role of bioenergy in comparison to other renewable energies as well as to understand the role bioenergy could play in efforts to improve energy security.

The main objective of the study is to facilitate progressive and robust policy to ensure the sustainable use of biomass for energy in Europe. This ensures that significant GHG savings are delivered within a timeframe relevant to EU climate policy objectives, that negative impacts on the environment are minimized, that other uses of the same biomass resources are not displaced causing for example indirect land use change and that the overall demand of biomass doesn't further significantly increase the EU's global land footprint.

Comparison between supply and demand data for biomass feedstocks needs to be approached with caution as variable conversion factors used in multiple data sources as well as differences in actual supply and volume of stock vary within calendar years[4]. The availability and quality of data is typically good for forestry

[4] IIASA (2014) Resource efficiency impacts of future EU bioenergy demand (ReceBio) Background Paper for 6 October 2014 - http://www.iiasa.ac.at/web/home/research/researchPrograms/EcosystemsServicesandManagement/Background_Paper_-_6_October_-_Workshop_on_the_Impacts_on_Re.pdf

and traditional wood based commodities such as sawn wood, wood based panels, pulp and paper. Forest residue data is fragmented and not as comprehensive and a similar picture is found for agricultural biomass and biogenic waste.

Key sustainability issues concerning the impact of biomass use for energy on natural resources and the environment include:

1. Sustainable availability of biomass without displacing other uses
2. Demand being a driver for loss of biodiversity
3. Stress on soils which require respective conservation measures.
4. Water demand
5. Potentially significant direct and indirect impacts on greenhouse gas emissions from biomass production and use

This introduces the need for a European analysis of the sustainable potential of biomass feedstocks and their availability for energy.

A core principle of the study is to limit EU land consumption and ensure it happens in a sustainable way. The average European land footprint per capita is 1.3 hectares which equates to a total land footprint of 654 Mha. Thus Europe's global land footprint exceeds the land area of Europe (422 Mha) and we consume more than we can produce, living beyond our means in terms of food, consumable goods and energy. For bioenergy it is assumed Europe must live within its means and this study looked only at EU28 land and available feedstocks to define the potentials.

Some key biomass feedstocks are delivered by forests. The biodiversity of forests and woodlands is declining and even though efforts are being made to address this it is not enough to reverse this trend. Invariably this is linked to the management of the forest and woodland – in some cases the inappropriate management system for the forest conditions and in others the fact that there is no management at all and single species dominance encroaches. By way of example a study[5] in 2012 concluded that Finnish forests were capable of meeting national 2020 RES targets but it was difficult to see that beyond 2020 national needs could be met *and* the possible needs for other EU28 countries as the expectation was for such a forest rich country.

An absolute fundamental when considering energy potential of a feedstock is the conversion efficiency to a useable form of energy - heat, electricity or fuel for transport. Even with renewability as a cornerstone of biomass the feedstocks are still finite and the inefficient use of biomass must be avoided especially where limitations on feedstock availability and future potential exist.

[5] Erajaa S. (2012) Felling the Golden Goose: The sustainable limits of Finland's biomass ambitions *A report produced by FERN and the Finnish Association for Nature Conservation.*

This study collates data to present the technical potential of biomass feedstocks, the competing demands for these feedstocks for non-energy uses, the technical potential available for energy and finally the sustainable potential available for energy.

This sustainable potential is then considered in terms of overall renewable energy sources and ambitions within the EU. An illustrative piece of work is then done to look at the conversion of the sustainable potential into heat energy.

2 Biomass feedstock identification

The biomass feedstock classification definitions are fundamental to the clear expression of the findings from this study and any policy focussed outcomes from the work. This task identified biomass feedstocks with potential for energy use until 2030 within the European Union. This includes biomass from forests, energy crops from available land (without causing ILUC) and ligno-cellulosic waste (as identified in the previous NGO studies carried out).

2.1 Methodology

The study has reviewed the literature focussing initially on the three foundation studies (see section 3.2 IINAS 2014[6]; IEEP 2014[7]; ICCT 2014[8]) and extending this to wider studies and research papers on biogenic feedstocks for energy across Europe. The scope of types of biomass feedstock was articulated initially as a first sift to capture all forms and then analysed alongside the three foundation study classifications to identify gaps. Rationalisation of the classifications took place with external experts, the NGO Steering Group and three members of the Consultation Group.

The boundary is the European Union member states (EU28) which is critical to understand in the light of earlier studies and subsequent expansion of the European Union, or in some cases the inclusion of Norway, Switzerland and the Ukraine in study scopes of Europe.

2.2 Rationale for biomass classifications

Step 1: Feedstock classifications were collated from literature based on existing groupings around waste types, woody biomass origins and energy crops specifically grown for energy or by-product/co-product for energy. Definitions of feedstocks were collated which enabled first stage rationalisation based on groupings of feedstocks and likely available data sources.

Step 2: A first sift assessment of the feedstocks was conducted to indicate generic feedstock groupings:

(i) Post consumer or post-processing wastes and by-products that are not readily utilised for other products e.g. used cooking oil

(ii) Post consumer or post-processing wastes and by-products that are readily utilised in other products e.g. industrial wood residues used in panel board manufacture

[6] IINAS 2014 Forest biomass for energy in the EU: current trends, carbon balance and sustainable potential.

[7] IEEP 2014 Space for energy crops – assessing the potential contribution to Europe's energy future.

[8] ICCT study 2014 Wasted Europe's untapped resource: An assessment of advanced biofuels from wastes and residues

(iii) Primary growth e.g. forest stemwood

Consideration of a hierarchy of use is presented in Appendix A.

Step 3: A final analysis of classifications utilised in the three foundation studies and robust data limitations prompted a final review of the classifications. For example it was confirmed that the accumulation of separate harvest softwood and harvest hardwood stemwood data was not possible in a clear and robust way across Europe and the combined category of harvested stemwood was used. The confirmed and final classifications used in this study are presented in Figure 2 indicating what they comprise.

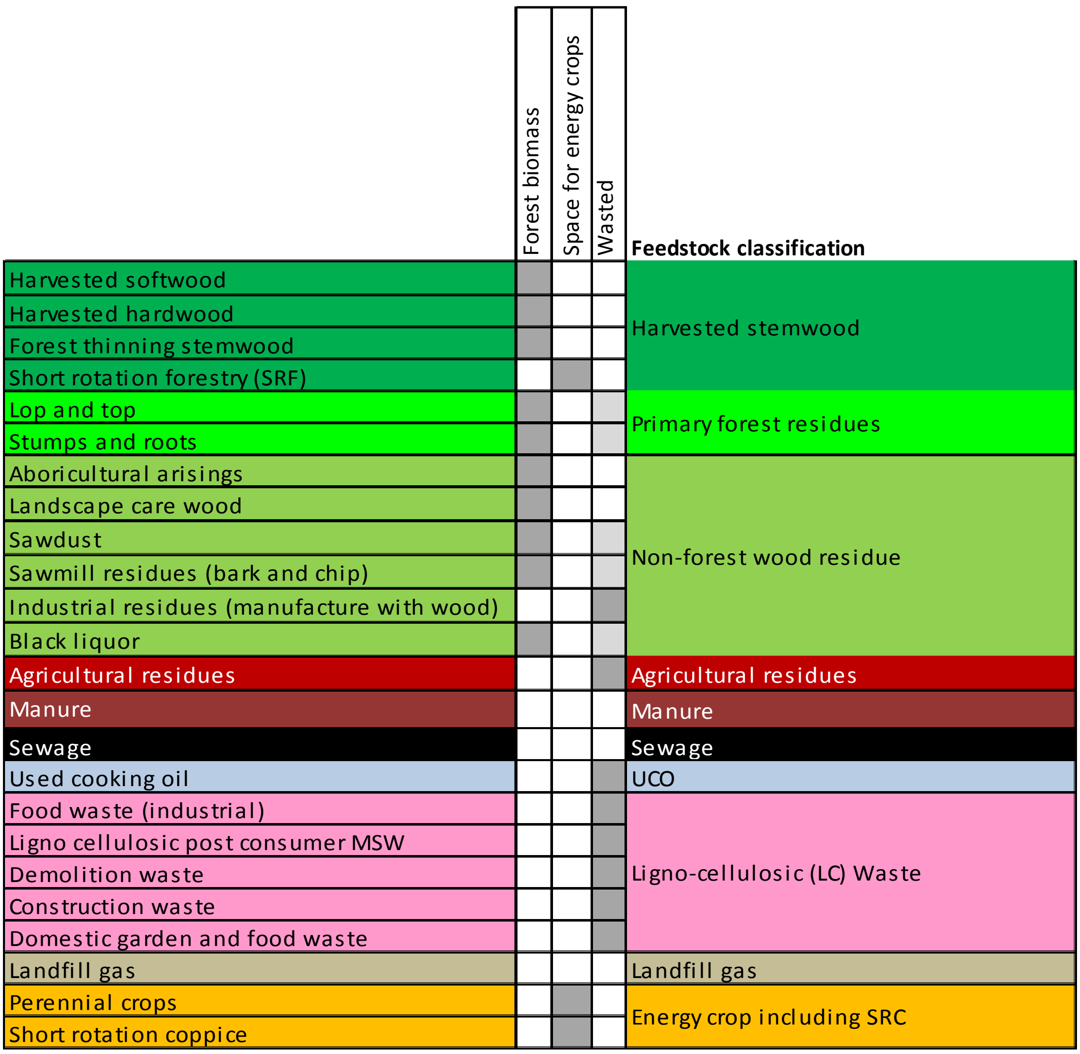

Figure 2. A collation of biomass feedstocks is presented. A shaded grey square indicate feedstocks reported in the three foundation studies. Where two studies report the same feedstock the dark grey is the primary data source used. The right hand column shows the final feedstock classifications that are taken forward into the study; with the colour key as they appear in the charts presented later in this report.

The biomass feedstock classifications in Figure 2 are further defined:

1. Harvested stemwood - final forest harvest and thinning stemwood

2. Primary forest residues - biomass comprising harvest stump, harvest residues, thinning stump, thinning residues, pre-commercial thinning biomass

3. Non-forest woody residue - woody biomass generated outside the forest. A summation of prunings, aboricultural arisings (landscape care wood) and secondary processing wood waste (sawmill residues, chip, sawdust, industrial wood residue from manufacturing, black liquor).

4. Agricultural waste – production of food a direct by-product of growing non-energy crops (food, fodder and fibre crops) upon harvesting creates ligno-cellulosic straw or leaf based biomass

5. Manure – animal derived waste from sheep, cows, horses, chickens etc.

7. Sewage – solid and liquid waste from water processing works and treatment plants

8. UCO – used cooking oil

9. Ligno-cellulosic (LC) waste – the ligno-cellulosic component of municipal solid waste (post-consumer wood, paper, cardboard, mixed food, vegetation).

10. Landfill gas – biogas tapped from existing landfill sites

11. Energy crop including short rotation coppice (SRC) and short rotation forestry (SRF) – land available for production of energy crops for direct biomass use or for production of biofuels for transport. This includes perennial crops which are harvested on average once a year over several years without the need for ploughing up and new planting and SRC which refers to plants and trees that are harvested by cutting the growing stem to its base, allowing the growth of new stems.

3 Data on biomass feedstock availability

This section compiles available data on the potential of the identified biomass feedstocks in the EU. The target is to gather data for the potentials presented in a comparable format for 2010, 2020 and 2030. The potential estimates from the previous foundation studies have been used, combined with other existing studies[9] making sure there are no overlaps or gaps in the estimates.

3.1 Methodology

Following the literature review a 'project library' was assembled and the literature sources were scrutinised for data on availability for each biomass feedstock classification Appendix B. Particular attention was taken to record the method of calculation, assumptions, units and uncertainties. Literature sources were catalogued for ease of reference and extraction of pertinent information against this study's criteria.

This process included an expert judgement of the quality of data based on an assessment of the uncertainties and assumptions in the stated method of collation and recording. In addition variance between published sources of data for the same feedstock classification has been scrutinised and is presented in this report. The units and agreed conversion techniques (especially relating to information on moisture content) and their assumptions are attached to data sources and converted to a comparable unit million tonnes of oil equivalent (Mtoe). An example for woody biomass is presented in Table 2 in other cases moisture content has been used to calculate dry matter biomass prior to conversion. Calculations are referenced in the text with workings cited in Appendix C.

From/to	Mm^3	Modt	PJ	Mtoe
Mm^3	1	0.50	8.72	0.21
Modt	2.00	1	18.18	0.44
PJ	0.11	0.055	1	0.024
Mtoe	4.76	2.26	41.87	1

Table 2. Wood resource conversion factors[10]

Initially the study reviewed the existing data from foundation studies and then the existing data from other sources were scrutinised and peer reviewed. In the context of the reports and studies the data gaps and overlaps were identified and a process for managing them was established. This was based on a data quality metric and whether the approach, measures and analysis are more relevant or up-to-date compared with the other study that overlaps. In all cases the best quality data source judged by the team and the NGO Steering Group was used.

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[9] For example Biomass Futures project (2012), Biomass Energy Europe project (2010), EUwood – Mantau (2010)

[10] EUwood – Mantau U et al. 2010: EUwood - Real potential for changes in growth and use of EU forests. Final report; Hamburg. BEE Project report 2012.

3.2 The foundation studies

"The three foundation studies"

This term refers to the two studies commissioned by the NGOs assessing the sustainable potential of energy crops on unused land (IEEP, 2014) and the sustainable potential of woody biomass (IINAS, 2014). The third study, commissioned by the European Climate Foundation looked at the sustainable potential of waste for biofuels (ICCT, 2014).

Each study is considered with an overview of key findings indicating which data are taken forward in this study highlighted.

3.2.1 Forest biomass for energy in the EU: current trends, carbon balance and sustainable potential.

The study (referred to as the **IINAS study 2014**) was conducted by the International Institute for Sustainability Analysis and Strategy (IINAS), European Forest Institute (EFI) and Joanneum Research (JR) in May 2014. The study aimed to clarify possibilities and implications of woody bioenergy supply for the natural environment and climate for the EU for 2020 and 2030. The amounts of forest derived and woody biomass were estimated that could be sustainably supplied for material and energy. Particular attention was given to GHG emissions and biodiversity of woody bioenergy supply. For the estimation of technical potential of biomass (Chapter 4.1) the so called reference potential for wood availability without additional sustainability constrains from this study was used. The reference potentials from this study are presented in Figures 3 and 4. They are summed in Figure 5 as this studies feedstock classification of **harvested stemwood**, **primary forest residues** and **secondary woody residues** (non-forest wood residues) availability to take forward into the technical potential section 4.1.

The IINAS 2014 study also estimated wood availability under various environmental and socio-economic constrains. The greenhouse gas (GHG) emissions scenario consider C stock changes in forest bioenergy and implemented cascading use of wood. The sustainable bioenergy scenario (SUS) assumes reduced forest bioenergy to avoid associated risks to biodiversity and from imports. A summary of these concluding sustainable potentials are presented in Figure 6.

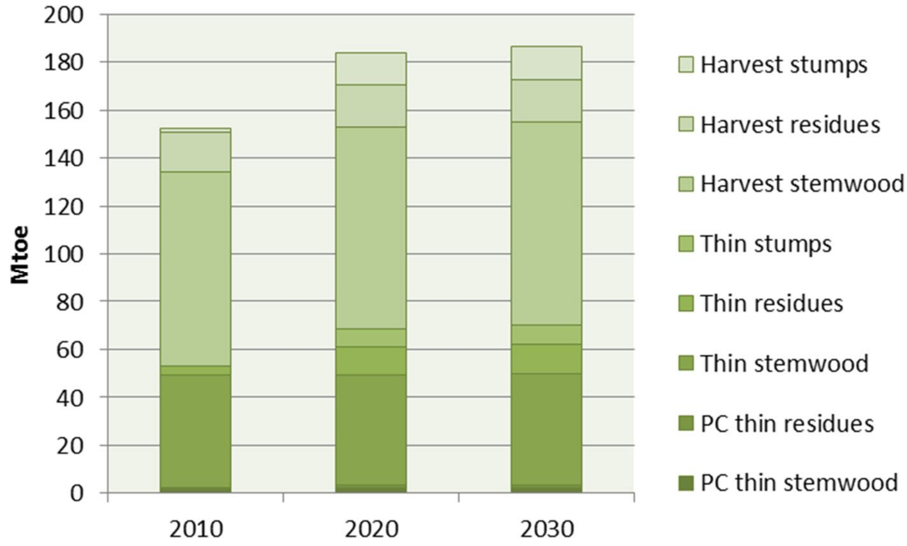

Figure 3. Reference (REF) potentials of forest biomass from final harvest, thinning and pre-commercial (PC) thinning. Totals 152.4 Mtoe (2010), 184.0 Mtoe (2020) and 186.6 Mtoe (2030).

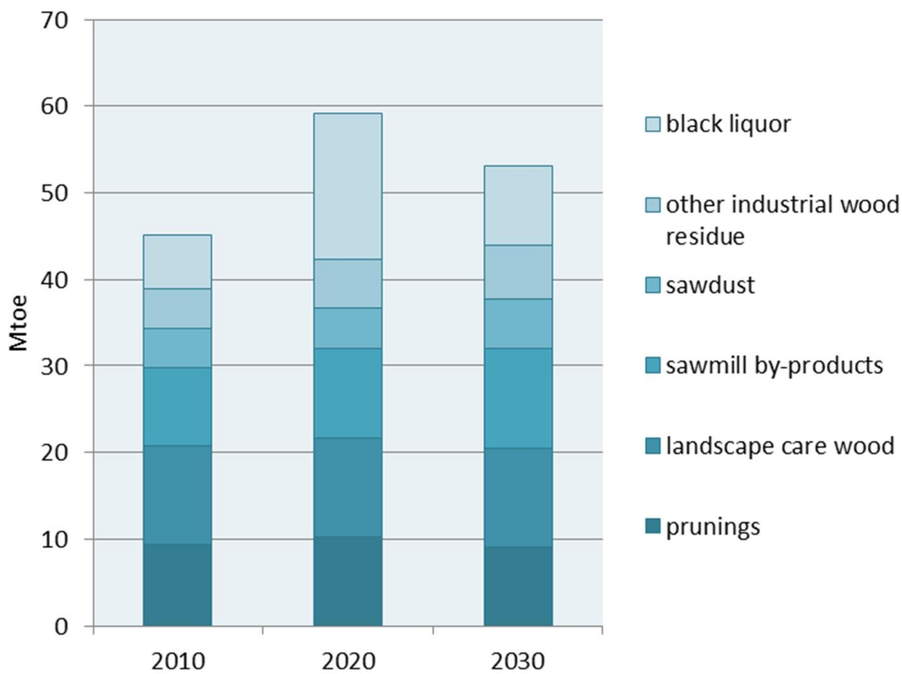

Figure 4. Secondary woody residues (Non-forest wood residues IINAS study 2014 Figure 3 and Table 12 Annex converted to Mtoe) totals 59.2 Mtoe (2020) and 53.0 Mtoe (2030).

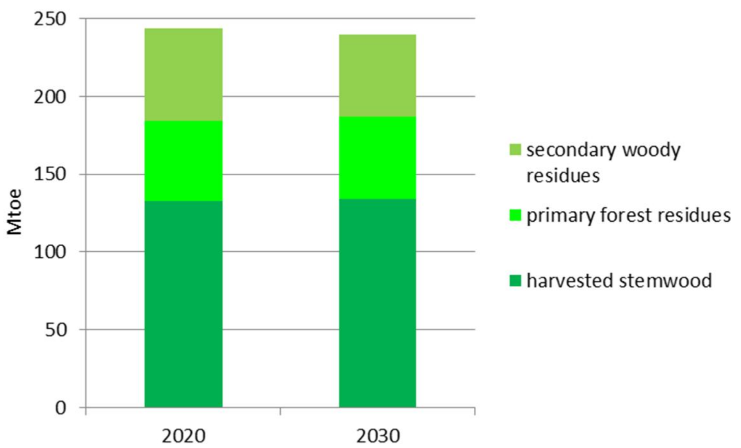

Figure 5. Summation of available harvested softwood, primary forest residues and secondary woody residues. Total 243.2 Mtoe (2020) and 239.6 Mtoe (2030).

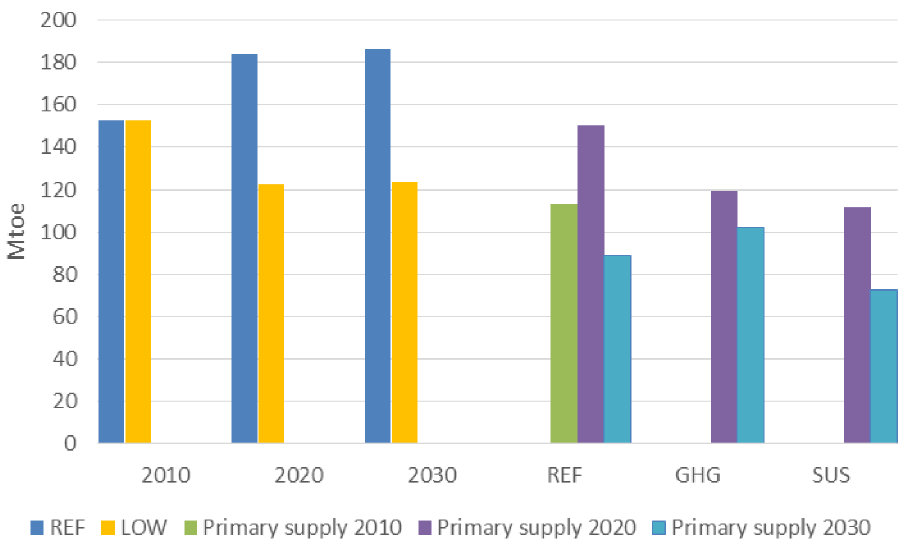

Figure 6. Reference (REF) and low mobilisation (LOW) potentials of total forest biomass alongside primary total woody bioenergy supply and use of sustainable potentials in the EU27 under the REF, GHG and SUS scenarios.

<u>3.2.2 Space for energy crops – assessing the potential contribution to Europe's energy future.</u>

This study (referred to as the **IEEP study 2014**) was conducted in May 2014 and looked at potential land use in Europe for energy production. This subject has been the topic of considerable debate and many conclude that there is considerable underutilised land on European farms that could be mobilised rapidly to produce biomass by planting energy crops. However these conclusions lack robustness. The IEEP study applies real world conditions that show where water supplies are limited, conditions unfavourable, distance to processing facilities too far then it is often not cost-effective to establish commercial energy crops. It focusses on understanding the scope for additional production of energy crops in Europe, the nature of any spare available land for use and the sustainability issues of increasing output from these land volumes. The report concentrates on land for further energy crop production not already used for food production, forestry, or other social values uses including nature conservation. The IEEP study findings are taken forward into this study.

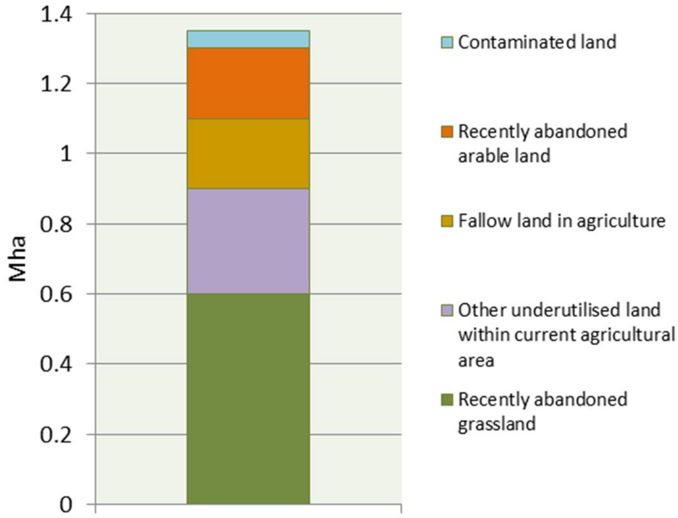

Figure 7. European agricultural land (non-food production) available for energy crops

Of the total 442 Mha of EU land area the 95% is classed as rural. Land that is currently in food production was not considered in this study and the land estimated under fallow land in agriculture was 7.4 Mha.

The potential land available for energy crops was determined by applying cost-effectiveness, land use and sustainability criteria and economic measures of distance to processing capacity to the land not in food production and shown in Figure 7 and Figure 8 giving a total of 1.35 Mha land that's potentially available and feasible to cultivate. The summary of energy crop agronomics, impacts and yields from the study is presented in Figure 9.

	Category of land	Area	Exclusion rationale or data source
Natural and forest land			
A	Existing woodland and forest	Excluded	Covered in IINAS *et al*, 2014
B	Existing non-forest semi-natural habitats (including abandoned grazing land)	Excluded (unless C or D)	Excluded on the basis of its environmental importance
Agricultural land			
C	Recently abandoned cropland (<5 years old)	**~200,000ha**	Data highly limited, estimates based on Corine land use changes ***Corine land cover change (2000 – 2006)*****
D	(Recently abandoned) Grassland moving out of agricultural use since 2009, most likely out of production, includes transitions to urban land	**600,000ha**	Some areas excluded on the basis of environmental importance; transition areas unknown, assume most going to urban/forest ***LUCAS land cover data (2009 – 2012)***
E	Current arable land in rotation (including oilseed rape and other industrial crops being utilised as biofuel or other bioenergy feedstocks) excluding fallow (see F)	Excluded	Excluded on the basis of competition with food and feed production
F	Fallow land in agricultural rotation – most of which is needed for agronomic purposes	**200,000ha**	Some areas excluded on the basis of agronomic or environmental importance. ***Farm Structure Survey - Eurostat (2000 – 2012)***
G	Uncropped land within arable farms under environmental agreements or similar eg field corners, buffer strips etc	Excluded	Excluded on the basis of environmental importance. ***No area information***
H	Current grassland under agricultural management (non-arable)	Excluded	Excluded on the basis of competition with food and feed production
I	Other underutilised land within the current UAA but not permanent grassland***	**300,000ha**	n/a
Non-agricultural land			
J	Suitable contaminated sites (excluding areas suited only for afforestation)	**50,000ha**	Excludes areas in use or unsuitable for production or with high biodiversity value. ***JRC 2001 – 2011****
Total			
	Total potentially available land based on optimistic assessments of area		**1,350,000ha**

Source: Own compilation. **Notes:** *= Between 2001 and 2011, Member States have been asked to report the overall extent of contaminated land, as part of several data collection organised by EEA before 2007, and thereafter, by the JRC European Soil Data Centre (ESDAC), in cooperation with the National Reference Centres for Soil belonging to the European Environment Information and Observation Network (EIO-NET). **= no further updated Corine data is available, trends in land use change were estimated to continue at the same rate and distribution between 2006 and 2012; ***= there are likely to be some areas of land that are genuinely unused land ranging from small patches to larger parcels. No data or information is available on which to base this assessment.

Figure 8. Categories of land considered in the IEEP study 2014 for energy crop production.

Energy crop	Yield	Growing conditions	Nutrient requirements	Main EU cropping areas*	Environmental implications
Eucalyptus	**4 to 24** t/ha (Searle and Malins, 2014)	Well adapted in mild temperate climates, in Europe mostly in the Mediterranean; north-western coast of ES and PT particularly suitable (high precipitation levels, short dry season, minimum temperature >-7° C). Best on sandy clay soils, can be grown on marginal and poor soil and on deep soils with available moisture (ie South-western Spain).	N fertilisation rate varies from 60-125 kg/ha	Portugal and Spain	Drought-tolerant; high water requirements; native to Australia, New Guinea, Indonesia; has been categorised as invasive in several countries
Giant reed	**6-7 t/ha** (Scordia *et al*, 2009)	Mainly growing in warm temperate or subtropical climatic zones, but can survive in areas with short period of frost. Prefers soils with moisture abundance	N fertilisation from 50-100 kg/ha	Mediterranean area	Impacts uncertain. High resistant to drought (can grow without irrigation); Originated in Asia but considered a native in the countries surrounding the Mediterranean sea,; pest resistant.
Miscanthus	**5-13t/ha** on poor marginal land, **7-44t/ha** on sufficient irrigated arable land; **13-44t/ha** in warm temperate regions (Greece); **7-9t/ha** at field scale (Searle and Malins, 2014). Low yields after establishment, progressive increase after the 3rd year.	Very adaptable to all climatic zones in Europe; sensitive to extremely cold weather conditions and when supplementary irrigation is needed (Nemoral and Mediterr. South, respectively). Easier to establish on lighter soils, but higher yields on heavy soils (higher water availability)	High nitrogen-use efficiency; nitrogen and nutrient requirements very low	UK, France, Ireland	High water requirements, risks to groundwater; however high water use efficiency. Biodiversity impacts uncertain. Potential increase in SOM and limited water retention, potential erosion risk in first year, increase soil carbon. Poor performance again weed; Native to Asia and Africa
Poplar	Mostly between **5-10** t/ha; **2.2-11.4** t/ha in a former landfill site in Belgium, **3.6** t/ha in a former mining site (Searle and Malins, 2014)	Suitable for temperate regions, requiring abundant irrigation/precipitation. Tolerates poor soil conditions	Low fertiliser needs	Italy, Germany, Denmark	Some genotypes are drought tolerant; High water requirements.
Reed canary grass	**4-7t/ha** (Alexopoulou *et al*, 2012)	Well adapted in cool temperate climate. Good winter hardiness and survives well in North Scandinavia. Most soil types suitable, particularly suitable for poorly drained soils with good tolerance to flooding		Finland; Sweden; Denmark	Drought-tolerant; high water requirements; native to the temperate regions of Europe, Asia, and North America.
Switchgrass	**5-10 t/ha** (temperate areas, arable and moderate quality soils); **10.9 t/ha** grown in monoculture vs. **4.4 t/ha** grown in mixtures, unless legumes part of mixture (Searle and Malins, 2014). At least 3 years to reach full yield potential	Many varieties, adaptable to many climatic zones, less so to far north latitudes	In general no nitrogen (N) is needed the establishment year; afterwards low N need of 0-70 kg/ha	Negligible at present, apart from high estimate for Romania	Little experience hence impacts rather uncertain; reduced nutrients run-off losses, limited gully erosion, increase soil carbon; biodiversity unclear (higher yields in monoculture); native to North America
Willow	**5-10 t/ha** (Searle and Malins, 2014); **5** (Ireland), **8-10** (Sweden), **8-20** (UK), **15-20** (Italy) t/ha (all in odt).	Mainly in continental climate zones, best in Northern Europe; can be grown on a wide range of soil types, light as well as loamy soils; not suitable for cold climates or dry locations	Sweden: no N applied in the 1st year of establishment; 45kg/ha applied in 2nd year, 100-150 kg/ha in 3rd year	UK, Poland, Denmark	Water demanding (irrigation not viable); Provides an habitats for animals and plants (for example, butterflies, invertebrates and birds); Increased SOC, low soil erosion; Potential negative visual impacts; Native to Europe (particular, the UK)

Figure 9. Summary of energy crop agronomics, impacts, yields and distribution - IEEP study 2014.

Estimates of the biomass and energy volumes that could be produced if the 1.35 Mha were all cultivated for energy crops was analysed. Figure 10 shows the total Mdt of biomass from energy crops that could be available was between 7.7 and 16.7 Mdt with an embedded energy content of 139 to 300 PJ of energy or 3.3 to 7.2 Mtoe.

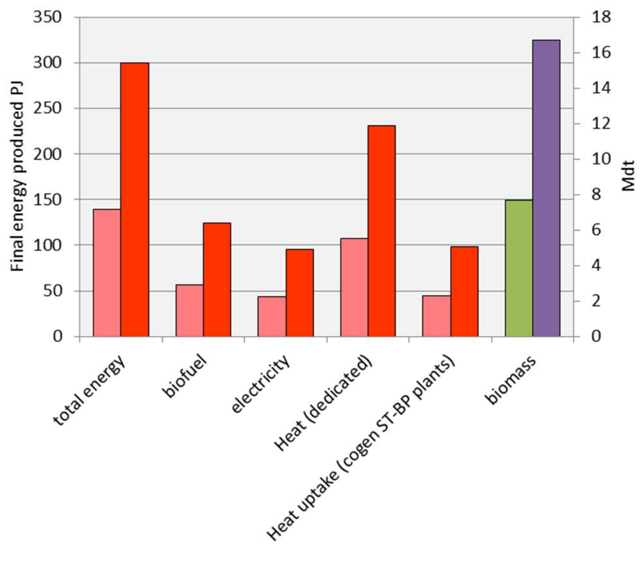

Figure 10. Total biomass production (Mdt) and final energy produced (PJ) from dedicated biomass utilisation in 2020 (upper and lower values are shown in each case) IEEP study 2014.

3.2.3 Wasted Europe's untapped resource: An assessment of advanced biofuels from wastes and residues

This study (referred to as the **ICCT study 2014**) was conducted by the International Council for Clean Transportation (ICCT), the National Non-Food Crops Centre (NNFCC) and the Institute for European Environmental Policy (IEEP). The study analysed the potential for Europe to cut the carbon intensity of transport fuels, reduce spending on oil imports and boost the rural economy by developing sustainable advanced biofuels from wastes and residues. It concluded that advanced biofuels from wastes if mobilized in a sustainable manner can make a moderate contribution to reducing European dependence on imported oil.

The conversion of all sustainably available ligno-cellulosic fractions of wastes and residues (having factored in environmental concerns and other uses) to road transport fuels could in theory deliver a potential of 16% of demand in 2030 if a rapid and large scale investment plan were put in place. This total availability of around 220 Mt per year between now and 2030 allows for cascading and other uses. Whilst the total amount remains roughly constant between now and 2030 the fraction of each source changes; an example of the fraction for 2030 is shown in Figure 11. NOTE the term forest slash used here is the same as harvest residues in the IINAS 2014 study. Forest residues are accounted for under "Primary forest residues" not as part of lingo-cellulosic waste.

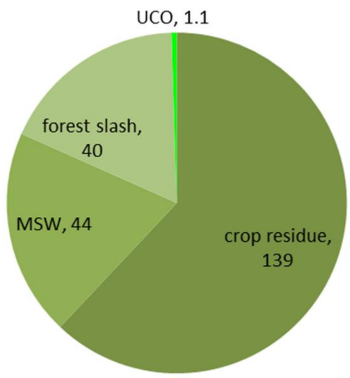

Figure 11. Waste available (Mt) for bioenergy production per year in 2030. MSW = municipal solid waste

The main findings on municipal waste availability are presented in Table 3.

Technical (and Sustainable) potentials Mt	2010	2030
Paper waste	23.2 (17.6)	16.3 (12.3)
Solid wood	62.2 (8.0)	43.5 (5.6)
Food and garden waste	74.6 (37.6)	52.2 (26.3)

Table 3. Waste availability in Mt expressed as a technical potential (and Sustainable potential)

This study's feedstock classification of ligno-cellulosic waste has been created from the sum of these availabilities and is taken forward into the technical potential section 4.1.

NOTE: Total wood waste incinerated for energy is 62.2 Mt but this includes a proportion of wastes from forest product processing (chips, sawdust, black liquor etc.). These are already accounted for in the IINAS study 2014 and any overlap in the technical potential assessment has been avoided. The secondary woody residues are accounted for under non-forest wood residues in this study. The ICCT study 2014 suggests there are 39.4 Mt in total included and that is split 59% incinerated and 31% recycled.

4 Potentials

Biomass potential has been calculated under three different categories:

- Technical
- Technical for energy use
- Sustainable

Theoretical potentials of biomass feedstock availability have not been considered in this study as they can be highly speculative, and therefore widely variable, and overlook core sustainability principles. The theoretical potential is the maximum amount of biomass that could be produced in the EU28 expressed in Mtoe primary energy, i.e. the energy contained in the raw, unprocessed biomass. In the case of biomass from crops and forests, the theoretical potential represents maximum productivity under optimal management.

Resource based potentials

Resource based potentials (forest stemwood, forest residue, non-forest woody residue, agricultural waste, manure, sewage, UCO, ligno-cellulosic waste and landfill gas) are generated on the basis of data available for resource volumes and then narrowing it down by removing non-energy uses from those resources and deriving a sustainable potential having applied sustainability criteria.

Land availability based potentials

Potential for biomass resources that require additional land for their production, such as (energy) crops, short rotation coppice and short rotation forestry has been estimated differently in this study than the resources based potentials. The limiting resource for these biomass feedstocks is availability and suitability of land which is already intensively used in Europe for food and feed production and forestry, and further encroached by soil sealing (the covering of the ground by an impermeable material for housing, roads etc.). The potential for energy crops provides various challenges compared with other assessments of volumes of biomass feedstocks and has as a result in the literature a wide range of speculative potentials (50-300 Mtoe) reported.

This study does not consider agricultural land already in use for food or feed production or existing forest areas as land available for energy production but focuses only on the potential of additional land, which is not yet in use but could potentially be used for energy production. Careful evaluation of land that could be available for energy production, without causing displacement of other land uses or negative environmental impacts was already carried out in the IEEP study 2014 (Figure 8). This study uses the current availability of land (1.35 Mha) identified in the foundation study and the estimated yields from that land (7.7 and 16.7 million dry tonnes of biomass) as a sustainable, maximum potential of biomass from energy crops, SRC or

SRF. An indicative estimate for technical potential has been made based on land availability and remains unchanged for the technical potential for energy.

Land itself is a stable resource while current uses of it can change due to markets, demand and policies. The land use in Europe for food and feed production, forestry and settlements is not assumed to decrease under any assumptions or scenarios by 2020 and 2030, even if social and economic reasons might cause e.g. food and feed production to move outside of Europe in practice, causing land to be released from a 'local perspective'. Therefore no speculations of "land release" in Europe by 2020 or 2030 have been included in this study.

Significant amount of agricultural land in Europe has been taken for energy production already since the introduction of renewable energy policies, particularly the 10% for renewable energy in the transport sector by 2020 which is being largely met with food and feed crops. There are an estimated 5.5 Mha land in production for biofuels in 2012[11] producing an estimated 29.3 Mtoe as the potential for energy crop biomass for 2020. As a result of future changes in EU and national policies if parts of this land were released from energy production, it is assumed that food and feed production, ecosystem restoration or biodiversity conservation would be priority uses for these areas, many of which have likely been in these uses before prior to being 'displaced' by energy production.

[11] Biomass Futures project report D3.3 page 18

4.1 Technical potential

The technical potential is that available for all uses under normal current framework conditions with the current technological possibilities including existing harvesting techniques, infrastructure and accessibility and processing techniques (Table 4). The technical potential includes the following criteria:

- Phase out of waste to landfill by 2025, leading to almost complete phase out of GHG from landfills by 2030
- Increase of recycling of municipal solid waste to 70% by 2030[12]
- Increase packaging waste recycling/re-use to 80% in 2030

Mtoe	2010	2020	2030
Forest stemwood[13,14]	130.5	132.8	134.2
Forest residue[15]	21.9	51.2	52.4
Non-forest wood residue[16]	45.1	59.2	53.0
Agricultural waste[17]	138.4	148.2	157.2
Manure[18]	30.8	27.7	24.9
Sewage[19]	4.5	4.7	4.9
UCO[20]	2.1	2.1	2.2
Ligno-cellulosic waste [21]	36.5	27.4	17.8
Landfill gas[22]	2.9	2.9	0.5
Energy crop including SRC[23]	33.0	34.7	36.4

Table 4. Technical potential for biomass feedstocks. The energy crop values are indicative only as it is driven by land availability.

12 Sustainability constraints on waste availability follow the direction of the Commission July 2014 proposal for the Review of Waste Policy and Legislation which had been withdrawn at the moment of writing of this study
13 Reference from forests IINAS foundation study 2014
14 Conversion see Appendix C workings #1
15 Reference from forests IINAS foundation study 2014
16 IINAS study 2014 Annex and Biomass Futures project 2012 Table 3.3
17 ICCT (2013) Availability of cellulosic residues and wastes in the EU see Appendix C workings #2
18 Technical Report No. I to the European Commission, Directorate-General Environment concerning Manure Processing Activities in Europe - Project reference: ENV.B.1/ETU/2010/0007 (2014) http://agro-technology-atlas.eu/docs/21010_technical_report_I_inventory.pdf
19 Milieu Ltd, WRc and RPA for the European Commission, DG Environment Study (2010) http://ec.europa.eu/environment/waste/sludge/pdf/part_iii_report.pdf
20 Biomass Futures Project 2012 http://www.biomassfutures.eu/work_packages/WP3%20Supply/D_3_3__Atlas_of_technical_and_economic_biomass_potential_FINAL_Feb_2012.pdf
21 ICCT study 2014 foundation study (woody, paper, board, food, garden waste summed)
22 European Bioenergy Outlook (2012) AEBIOM http://www.aebiom.org/wp-content/uploads/file/AEBIOM%20Statistical%20Report/AEBIOM_European%20Bioenergy%20Outlook%202012sv.pdf
23 Indicative estimate. There is no estimate for technical potential in the IEEP study 2014 see Appendix C workings #3

The **forest stemwood** is the sum of harvested stemwood, thinning stemwood and pre-commercial thinning stemwood. This data is collated from the IINAS study 2014.

The **forest residue** is the sum of harvesting stumps, harvesting residues, thinning stumps, thinning residues and pre-commercial thinning biomass for forestry operations. This data is collated from the IINAS study 2014.

The **non-forest wood residue** is the sum of biomass material from pruning, landscape care wood, sawmills residues, sawdust, industrial wood residues from processing and manufacture with wood and black liquor. This data is collated from the IINAS study 2014.

The **agricultural waste** defined as crop residues data in the ICCT (2013) study is all residues generated during harvesting and crop processing of barley, maize, oats, olives, rapeseed, rice, rye, soybeans, sunflower, triticale, wheat and sugar beet. The data is presented as million tonnes of residue which is converted to Mtoe using the 1Mt = 0.377 Mtoe conversion from the Biomass Energy Centre[24].

The entire **manure** production in the EU that is theoretically available for processing is estimated to be 1.4 billion tonnes in 2010[25]. This study assumes that 50% of this manure is unavailable as technical potential due to dispersion based on scale of the herd or livestock farm. For example, dairy herds in numbers are dropping and the average size increasing. Of the total European dairy herd (23 million cows) 42% in 2013 were in farms of less than 150 cows[26], it is assumed that at a scale of less than 150 cows the manure is dispersed and therefore unavailable. Some ambitious member states have targets for 50% of all manures processed for energy purposes by 2020. The 153 million pigs, 88 million cattle and 1.3 billion poultry (2009) make up the vast majority of the livestock manure in relation to manure processing. The 1.4billion tonnes is halved to give available to 700 Mt and then multiplied by dry solids content (10%[27]) to yield 70 Modt. Any decline in cattle numbers[28] for example due to shifts in food consumption patterns as higher welfare standards increase price of meat and moves to less intense production leads to less manure production.

In a study by Milieu Ltd (2010)[29] total production of **sewage** was estimated in the EU in 2006 as 10.13 Mt dry solids (DS) and it is assumed to all be available as technical potential. The production of DS in absolute

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[24] See Appendix C Workings #2

[25] Technical Report No. I to the European Commission, Directorate-General Environment concerning Manure Processing Activities in Europe - Project reference: ENV.B.1/ETU/2010/0007 (2014) http://agro-technology-atlas.eu/docs/21010_technical_report_I_inventory.pdf

[26] DairyCo data http://www.dairyco.org.uk/resources-library/market-information/farming-data/eu-cow-numbers/#.VTou4mhwbcs

[27] Dry solids content chicken litter 60%, manures 25% and slurries 6% http://www.rothamsted.ac.uk/sites/default/files/Booklet1ManuresArableLand.pdf

[28] European Market study (2012): Declining EU cattle numbers 12/14 published by www.ahdb.org.uk http://www.thefarmsite.com/reports/contents/EuropeanMarketSurvey13April2012.pdf

[29] Milieu Ltd, WRc and Risk & Policy Analysts Ltd (2010) Environmental, economic and social impacts of the use of sewage sludge on land Final Report Part I: Overview Report DG Environment under Study Contract DG ENV.G.4/ETU/2008/0076r

terms was noted to be increasing due to population growth across Europe. We have assumed a 5% increase from 2020 to 2030 in line with the past 10 years.

Data for **used cooking oil** (used fats and oils) in the Biomass Futures project were derived from the REFUEL report[30] which provides estimates for the potential in 2020. The potentials in the Biomass Futures project for 2020 were back-calculated to 2010 and forecasted to 2030 by using country specific population and income growth projections towards 2020 and 2030. These are higher than the figures quoted in the ICCT study 2014 of 1.1 million tonnes of UCO consumed in the EU in 2013 with 0.7 million tonnes EU sourced which noted potential to expand. The Biomass Futures project figures are used as the technical potential and the ICCT study 2014 figures as the sustainable potential. It is sustainable as it can be readily collected from sources unlike the Biomass Futures figures which include disperse cooking oil uses in the home. In addition USDA sources[31] quoted consumption of UCO in Europe as 1.225 million tonnes in 2013.

Generation of MSW is increasing but rates of recycling are increasing at a faster rate, leading to an overall decrease in available volumes between now and 2030. For the **lingo-cellulosic waste** (post-consumer wood, paper, board, food, garden waste) the ICCT study 2014 technical potential assumes rate of change of non-recycled waste (from 60% in 2010 to 51% in 2020) and extrapolated this to 2030 (42%), based on EEA projections for recycling. In this study we have applied a more ambitious non-recycled waste limit of 30% i.e. 70% recycled in 2030 compared with 58% above. In addition the increase in packaging waste recycling/re-use target to 80% in 2030 is included. Current EU Waste Framework Directive sets the target that roughly 50% of all MSW should be recycled by 2020.

In addition, it should be noted that the fraction of this bio-waste pool that is non-cellulosic (i.e. animal waste, plant oils, etc.) is unknown[32]. The non-ligno-cellulosic bio-waste of MSW has been assumed to be a small fraction of MSW and too small to be considered in the scale of the above table. In sub-section 4.2.2 biopolymer demand was estimated to peak at around 5 Mt in 2020. The calculations[33] are based on assumed moisture content of 60% for food and garden waste, of 20% for waste wood and of 6% for paper waste[34].

NOTE: Total wood waste incinerated for energy is 62.2 Mt but this includes a proportion of wastes from forestry processing (chips, sawdust, black liquor etc.). These non-forest residues are accounted for in the IINAS study 2014 and presented in the non-forest wood residue.

[30] Deurwaarder, E.P., S.M. Lensink, H.M. Londo (2007). BioTrans biofuels data. Annex to 'Use of BioTrans in Refuel'; functional and technical description. Refuel deliverable D10b. IEE programme.

[31] USDA GAIN Report – EU Biofuels annual

[32] S. Searle and C Malins (2013) Availability of cellulosic residues and wastes in the EU. ICCT

[33] See Appendix C Workings #4

[34] http://msw.cecs.ucf.edu/Exercise-EstimationoftheMoistureContentinTypicalMSW.pdf

The technical potential for **landfill gas** of 2.9 Mtoe in 2010 and 2020[35] then assumes a reduction in availability due to phase out of landfill to 2030 as Waste Directive legislation effectively phases out new landfill in Europe by 2030.

Energy crops including SRC is calculated for 2020 as the existing 5.5 Mha in energy crop production plus the 1.35 Mha sustainable fraction from the IEEP study 2014, totalling 6.85 Mha in 2020. The yield is taken as 11.5 dry t/ha[36] which gives 78.7 Modt of biomass converted to **34.7** Mtoe. A 5% growth between 2010 and 2030 was assumed to estimate the 2010 and 2030 position. A 2012 fallow land availability of 7.4 Mha was recorded in EU statistics (see IEEP study); this in part (0.2 Mha) overlaps with the 1.35 Mha (IEEP study). In addition, there is uncertainty as to whether the 2010 biofuel production data and 2012 data on fallow land actually overlap and if so to what extent. As a precaution to avoid double counting we have excluded any fallow land from the energy crops total.

The technical potential is presented in Figure 12.

[35] European Bioenergy Outlook (2012) AEBIOM http://www.aebiom.org/wp-content/uploads/file/AEBIOM%20Statistical%20Report/AEBIOM_European%20Bioenergy%20Outlook%202012sv.pdf

[36] IEEP study 2014 Space for energy crops – assessing the potential contribution to Europe's energy future page 24

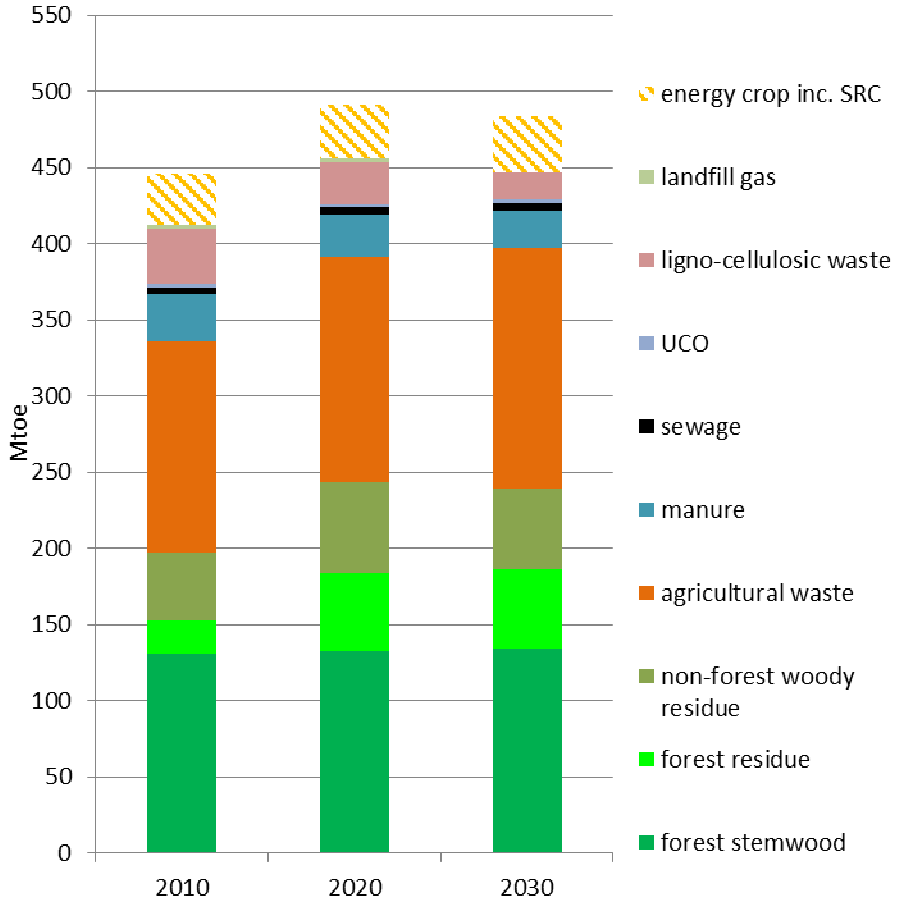


Figure 12. The technical potential of biomass feedstocks in Europe 480.2 Mtoe (2010), 527.3 Mtoe (2020) and 521.8 Mtoe (2030). NOTE the energy crop potential is an indicative estimate only.

4.2 Competing uses for biomass feedstocks

The competing uses for biomass feedstocks are non-energy uses of biomass. Examples are existing uses for feedstocks such as spreading manure on land to fertilise the soil and the use of stemwood to produce construction timber, paper, pulp and packaging.

In addition to these existing and foreseen competing uses, efforts to move to a ‘bioeconomy’ have led to several additional claims on biomass resources by new sectors and industries. Given that these estimates are highly speculative, especially in the timeframe until 2030, they have not been quantified for the purpose of this study. It is never the less important to note that realization of these visions would further add to the competing uses for the identified biomass feedstocks.

Total competing uses information is sourced from numerous studies and industry sources.

4.2.1 Forest product

In evaluating the competing uses for forest product the study has considered the round-wood equivalent (RWE) volumes which are a measure of the volume of stemwood (round wood) used in the manufacture of wood-based products (including wood pulp, paper, furniture, joinery and plywood). The RWE includes the primary wood product plus the co-products from production (sawdust, industrial residue, black liquor etc.), which are accounted for under the non-forest wood residues. The co-products (which get used for bioenergy and other competing uses) get subtracted from the stemwood volume to yield the stemwood volume as product. This provides a consistent approach to estimating the total volume for competing uses of forest product. In addition the following boundaries have been set:

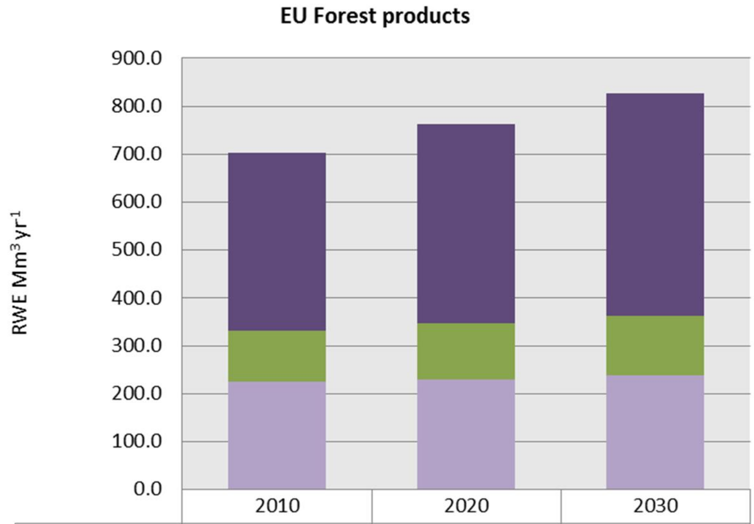
- All consumption of forest products should be met by European resource
- All recycled content of forest products should be met by European resource
- Trade follows that modelled by UNECE and FAO

Industrial roundwood for non-energy uses (total predicted demand for sawnwood, panel, pulp and paper production) is 739 RWE Mm^3 in 2020 and 853 RWE Mm^3 in 2030 (Figure 13) according to the UNECE and FAO European Forest Sector Outlook Study II 2010-2030. The *Reference scenario* of the EFSOS II study is projected by the European Forest Institute’s Global Forest Sector Model EFI-GTM[37] which is a partial equilibrium model that makes assumptions on global trade, production and consumption of forest products. Projections show a steady rise in prices of forest products and wood over the whole period, driven by expanding global demand and increasing scarcity in several regions.

The net trade of the EU with the rest of the world needs to be considered. Net imports of wood raw material are projected to decrease from 12.6 Mm^3 in 2010 to 1.3 Mm^3 in 2030 and net import of wood-based panels

[37] EFI-GTM makes projections of global consumption, production and trade of forest products, in response to assumed changes in external factors such as economic growth, energy prices, trade regulations, transport costs, exchange rates, availability of forest resources and consumer preferences.

decrease slightly from 6.3 to 5 Mm³ RWE. Net exports of sawnwood are decreasing from 7 to 2.5 Mm³ RWE. Net exports of paper and paperboard are projected to double, reaching 61 Mm³ RWE in 2030. Overall, the EU region is projected to increase its net exports from 19 Mm³ RWE in 2010 to 58 Mm³ RWE in 2030.



	2010	2020	2030
pulp and paper	371.5	417.0	463.3
panel product	106.7	116.0	124.9
sawnwood	224.9	230.0	237.9

Figure 13. EU28 forest product forecasts[38] in RWE Mm³ per year

These adjustments for import and export have been summarised in Figure 14.

UNECE 2011 statistics show a snapshot for the timber trade in the EU27 (EU28 less Croatia) and the percentage of consumption of product volumes that is satisfied by internal EU27 production (Figure 15). For stemwood 85-87% of EU27 consumption was satisfied by wood produced in the EU whilst at the other end of the scale only 38% of paper and board product consumed is satisfied by EU27 produced paper and board.

Mantau (2015)[39] demonstrates the method of sectoral mass flow analysis using the example of the raw material wood. And shows where there are limited resources, market analysis methods must consider an interactive flow analysis in a closed system. The wood flow analysis represents a total resource assessment including all wood products in all process steps from forest to disposal. In this study we consider that RWE (stemwood) includes the primary product (e.g. sawnwood) plus the co-products from production (sawdust, industrial residue, black liquor), which are accounted for under the non-forest wood residues. RWE totals are 664.0 (2010), 710.0 (2020) and 759.4 (2030) Mm³ as shown in Figure 16. These are converted to Mtoe

[38] UNECE and FAO. The European Forest Sector Outlook Study II 2010-2030 http://www.unece.org/fileadmin/DAM/timber/publications/sp-28.pdf

[39] Mantau, U., 2015. Wood flow analysis: Quantification of resource potentials, cascades and carbon effects. Biomass and Bioenergy 79, 28-38.

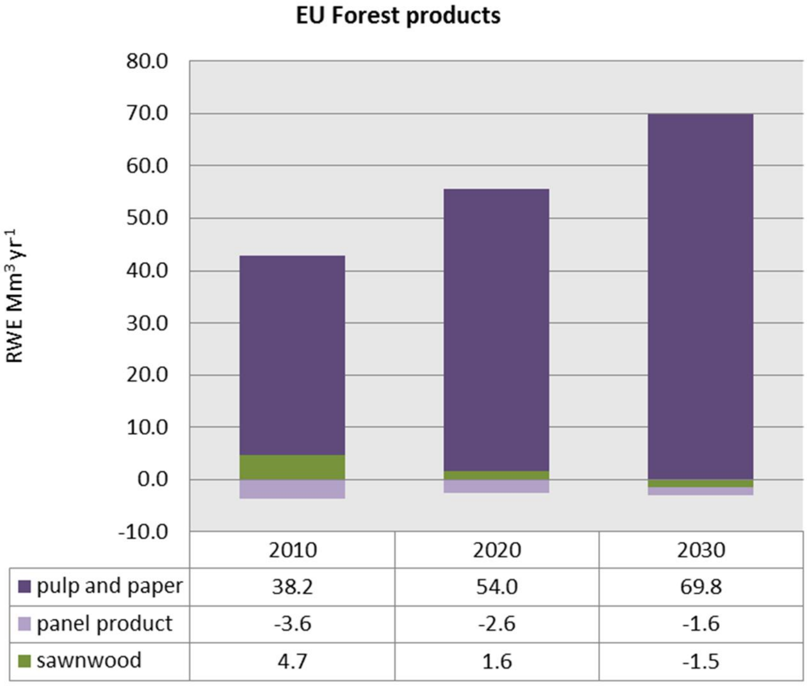


Figure 14. EU28 forest net trade forecasts in RWE Mm3 per year (+ = export - = import) NOTE this does not account for the trade balance between EU28 and EFSOS countries

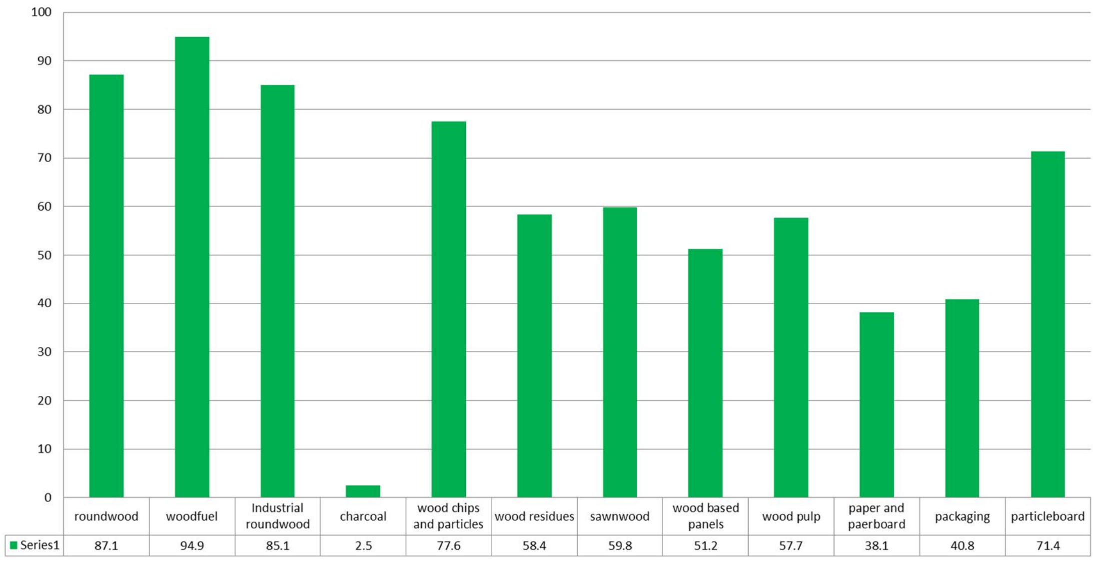
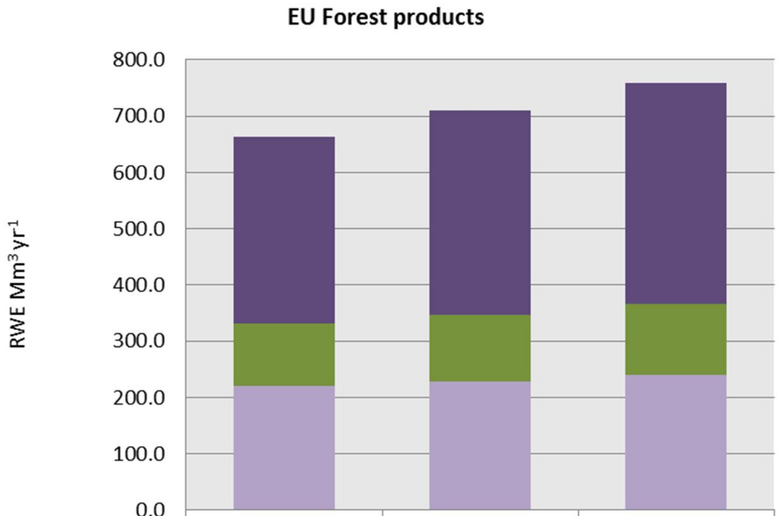


Figure 15. Proportion of wood based product demand in 2011 that is satisfied by EU27 supply[40]

[40] http://www.unece.org/fileadmin/DAM/timber/statsdata/fps07-11.pdf

and to avoid double counting have the total of the 'co-products' (sawmill, sawdust, industrial residue, black liquor etc.) subtracted which yields primary product only as 119.0 (2010), 127.5 (2020) and 139.1 (2030) Mtoe[41]. It is recognised that there are fundamental questions as to whether the partial equilibrium models are really able to project realistic future wood demand. For example forest sector model projections do not account for structural change in the sector such as the shift from print media to electronic media which challenges model assumptions that newsprint demand increases with GDP growth as observed in the past[42]. These questions require research and analysis that is beyond the scope of this study.



	2010	2020	2030
pulp and paper	333.3	363.0	393.5
panel product	110.3	118.6	126.5
sawnwood	220.2	228.4	239.4

Figure 16. EU28 forest product consumption forecasts[43] in RWE Mm^3 per year adjusted for import and export to yield EU28 consumption.

The proportion of stemwood not needed for product manufacture because recycled (ligno-cellulosic waste) fibre or non-forest woody residue is used to make the product is then subtracted. Wood-based panel products are on average 50%[44] recovered wood so the proportion of stemwood not needed for wood-based panel manufacture is 55.1 (2010), 59.3 (2020) and 63.3 (2030) RWE Mm^3 per year. This needs to be taken from non-forest woody residues and waste wood ligno-cellulosic waste which is equivalent to 8.8 (2010), 9.2 (2020) and 9.6 (2030) Mtoe non-forest woody residues and 2.8 (2010), 3.2 (2020) and 3.6 (2030) Mtoe ligno-cellulosic waste. Pulp and paper products are 25% recycled content[45] so the proportion of stemwood

41 See Appendix C Workings #5

42 Hurmekoski, E., Hetemäki, L., 2013. Studying the Future of the Forest Sector: Review and Implications for Long-Term Outlook Studies. Forest Policy and Economics 34, 17-29.

43 The European Forest Sector Outlook Study II 2010-2030 http://www.unece.org/fileadmin/DAM/timber/publications/sp-28.pdf

44 http://www.greenspec.co.uk/building-design/wood-panel-types-1/ WPIF

45 CEPI statistics 2013

not needed for pulp and paper manufacture 83.3 (2010), 90.8 (2020) and 98.4 (2030) RWE Mm^3 per year. This does not need to be supplied by EU forests it is assumed that the recycled content of pulp and paper products is satisfied by the closed loop of existing recycled paper.

Consequently 138.5 (2010), 150.1 (2020) and 161.6 (2030) RWE Mm^3 per year need to be removed from the total industrial stemwood predicted demand for non-energy as these proportions of stemwood do not get used in paper, pulp and panel product production and are thus technically available for energy. These in total are 29.1 (2010) 31.5 (2020) and 33.9 (2030) Mtoe not required from stemwood. Subtracting also the proportion of RWE that is co-product then this yields a final competing demand for stemwood of 89.9 (2010), 96.0 (2020) and 105.1 (2030) Mtoe (Table 5).

Mtoe	2010	2020	2030
Forest stemwood	89.9	96.0	105.1
Non-forest woody residue	8.8	9.2	9.6
Ligno-cellulosic waste	2.8	3.2	3.6

Table 5. Summary of competing demand for forest product on biomass feedstock technical potentials

4.2.2 Biopolymers

Examples of biopolymers from renewable resources are: plastics from cellulose, polylactides, plastics based on starch and plastics from soya. Polymers synthesised by microorganisms - polyhydroxyalkanoates (PHA) are also growing in production[46]. Biopolymers from renewable resources represent a new generation of plastics that are stated as reducing the impact on the environment, both in terms of energy consumption and the amount of greenhouse gas emissions. The manufacture of biopolymers from natural product monomers such as starch is increasing as demand for biodegradable packaging increases in food retailing. The data for consumption is not available so a production forecast has been used to estimate likely consumption of EU biomass in production in biopolymers.

The production forecast for biopolymers in Europe in 2011 is around 0.36 Mt rising in 2020 to an estimated 1.30 Mt[47]. Biopolymers are principally made from starch (from maize, wheat, potatoes and others), polyesters from fermentation and cellulose (from plant material). Starch blends and fermentation producing polylactic acid (PLA) dominates. It is assumed that 3 tonnes of biomass are required to produce 1 tonne of biopolymer[48]. Biopolymer production in the EU is therefore estimated to use around 1.0 Mt/yr of biomass from agricultural sources in 2011 and is forecast to expand to 3.9 Mt/yr by 2020. It has been assumed in this study that production grows at a similar rate to a total of 10 Mt/yr by 2030.

[46] Babu et al. Progress in Biomaterials 2013, 2:8 http://www.progressbiomaterials.com/content/pdf/2194-0517-2-8.pdf
[47] Nova Institute (2013) http://www.bio-based.eu/market_study/media/files/13-07-24PRMarketStudynova.pdf
[48] Communication from BASF http://www.rsc.org/chemistryworld/News/2007/May/14050701.asp

The majority of agricultural sources used for biopolymers are feedstocks that are specifically grown for biopolymer production, especially maize. Considering the range of polymers produced, the dominance of starch blends and PLA, it is assumed that only 20% of the total production capacity could be made from agricultural residues or wood crops (biomass feedstocks classified in this report). Thus 0.2 Mt/yr of biomass from agricultural residues is used in 2011, 0.8 Mt/yr in 2020 and 2.0 Mt/yr by 2030. Assuming a 15% moisture content (and using the Modt to Mtoe conversion of biomass of 0.44) then this is equivalent to an estimated 0.075 Mtoe of biomass from the 2011 agricultural residue biomass energy total, 0.30 Mtoe from the 2020 agricultural residue biomass energy total and 0.75 Mtoe of biomass from the 2030 agricultural residue biomass energy total (Table 6).

Mtoe	2010	2020	2030
Agricultural waste	0.08	0.30	0.75

Table 6. Summary of competing demand from biopolymers on biomass feedstock technical potentials

4.2.3 Compost

Data sources for compost volumes and markets are complicated by the summations of types of compost based on the different source materials. Data for 2008 in the EU27 showed 80.1 Mt of bio- and green waste potential and the study summarised compost production as 13.2 Mt of which 10.5 Mt was green and bio-waste compost, 1.4 Mt sewage sludge compost and 1.4 Mt mixed waste compost[49]. This is before significant uptake of European-wide domestic kerbside recycling of segregated compostable waste (food and garden). At this time 2006-2008 in the UK 2.1 Mt of compost were produced[50] representing around 10-15% of EU27 production.

In the UK one study reported 5.8 Mt of biomass going in to compost per annum in 2012[51]. It is estimated based on population that in 2012 54.2 Mt of compost at the EU level was used for landscaping based on the UK market being typical of the pan-European market and needs to come out of non-forest woody residue classification. This is equivalent to 11.4 Mtoe (2012) and increasing 2% per annum to 60 Mt per year 2020 (12.6 Mtoe) and 65 Mt per year 2030 (13.7 Mtoe) from the ligno-cellulosic waste and agricultural waste (Table 7). Additional data broadly supports this scale of compost market.

Mtoe	2010	2020	2030
Agricultural waste	10.4 assumed	11.0	11.0
Lingo-cellulosic waste	1.0 assumed	1.6	2.7

Table 7. Summary of competing demand from compost on biomass feedstock technical potentials

49 http://susproc.jrc.ec.europa.eu/activities/waste/documents/080229_EoW_final-report_v1.0.pdf

50 http://www2.wrap.org.uk/downloads/Compost_market_assessment_report_-_volume_2.9301b78e.6140.pdf

51 ECONOMIC ANALYSIS OF OPTIONS FOR MANAGING BIODEGRADABLE MUNICIPAL WASTE http://ec.europa.eu/environment/waste/compost/pdf/econanalysis_finalreport.pdf

4.2.4 Bark

Bark chip is an extensively deployed mulch material in horticulture and in children play area soft landing surfaces. The IINAS study includes bark in what is described as "Secondary biomass sources" - *solid forest and wood industry by-products (sawmill residues, bark, wood industry wastes).* This straddles the categories of forest residues and non-forest wood residues and ultimately it is not clear where bark is accounted for in the IINAS study. A total resource assessment by Mantau (2015)[52] shows 51.1 Mm^3 SWE of bark as overall wood resource from trees (WRT) of 577.1 Mm^3 SWE. The bark then gets distributed as part of the WRT into WRT associated with pulp, wood production and energy.

The global wood harvest utilized for industrial purposes as roughly 1.6 billion solid m^3 and represents only 43% of total cut as the majority is directly burned[53]. Considering that the average bark content of a tree is approximately 10%, utilization of bark would result in approximately 160 Mm^3 of raw material in the world[54] and about 31 Mm^3 bark in EU[55]. Bark is a component of the non-forest woody residue as it is removed in the mill. If we take the density of bark[56] as 160-320 kg/m^3 then 31 Mm^3 converts to 5-10 Mt and if we assume a 40% moisture content[57] it is 3.5-7.0 Modt bark = 1.3-2.6 Mtoe.

Mtoe	2010	2020	2030
Forest stemwood	0.85	0.85	0.85
Non-forest woody residue	0.85	0.85	0.85

Table 8. Summary of competing demand from bark mulch on biomass feedstock technical potentials

Data sources for bark volumes and markets are limited. In the UK one study[58] reports that landscaping uses dominate with a total of 667 kgt (kgt = thousand green tonnes) of bark available in UK and 100kgt being used for woodfuel the remainder for landscaping. If we assume 40% moisture content then this calculates as 0.40 Modt of bark in total of which 0.06 Modt goes for fuel. This converts to an energy potential of 0.18 Mtoe and 0.03 Mtoe respectively[59]. Based on the UK market being typical of the pan-European market it is estimated based on population that an energy potential of 1.7 Mtoe of bark at the EU level is used for landscaping and this is also assumed to apply historically to 2010. This is in the range (1.3-2.6 Mtoe) calculated from total EU bark estimates. Bark is part of the stemwood potential and the non-forest woody

52 Mantau, U., 2015. Wood flow analysis: Quantification of resource potentials, cascades and carbon effects. Biomass and Bioenergy 79, 28-38.
53 Kain G., Heinzman B., Barbu M.C. and Petutschnigg A. (2013) Softwood bark for modern composites PRO LIGNO 9 (4) :460-468
54 Xing C, Zhang SY, Deng S, Wang S (2007) Investigation of the effect of bark fiber as core material and its resin content on three-layer MDF performance by response surface methodology. Wood Science and Technology 41:585-595
55 Barbu MC (2011) Current developments in the forestry and wood industry. PRO LIGNO 7(4):111-124
56 Bark is 10-20 lbs/ft3 in this catalogue http://www.tapcoinc.com/content/product_data/Tapco_Catalog_09_p88-94.pdf
57 Bark and its possible uses – Forest Products Laboratory http://www.fpl.fs.fed.us/documnts/fplrn/fplrn091.pdf
58 Hogan G. (2013) The British Bark Industry An assessment in the context of *Phytophthora ramorum*. Forest Research report
59 Forestry Commission (2012) The British Bark Industry An assessment in the context of *Phytophthora ramorum* http://www.forestry.gov.uk/pdf/BritishBarkIndustryReport.pdf/$file/BritishBarkIndustryReport.pdf

residues potential as it is part of the cascaded resource. The 1.7 Mtoe energy potential needs to be allocated and removed from the stemwood and the non-forest woody residue classification (Table 8).

4.2.5 Animal husbandry

Market data for animal bedding is very limited. We have investigated a number of ways of determining market volumes and thus competing uses for biomass feedstocks.

In the UK one study reports that animal bedding uses of wood shavings 150,000odt for horses[60] 150,000 odt for chickens 20,000 odt other pets with the source material ratio of 1:2 for recycled wood pallets (RWP) and virgin wood shavings. This equates to 107,000 odt RWPs and 213,000 odt virgin wood. Based on population and the UK market being typical of the pan-European market it is estimated for the EU28 a total of 1 Modt RWPs and 2 Modt virgin wood shavings which is equivalent to 0.44 Mtoe and 0.88 Mtoe[61]. However, it is unlikely that the UK market for animal bedding is typical of Europe so high uncertainty is attached to this approach. The conversion of UK data to Europe also seems unreasonable in the light of Northern periphery project findings[62] which estimated Icelandic markets for animal bedding as 4,900-5,400 odt per year whereas if converted on a population pro rata basis would yield 10,000 odt[63], double the market evaluation.

Scarlat et al (2010)[64] estimates lower livestock needs for the EU as a whole and speculate that the UK's structure of many small farms allows greater residue use in that country, compared to e.g. France where there are fewer, very large livestock farms and where it is logistically more difficult to get residues to the animals. They estimated that 11% of residues are used in animal husbandry over the whole of the EU.

In much the same way that a significant proportion of the agricultural residue consumption for livestock feed is thought to occur on site similarly it is thought that the majority of animal bedding for agricultural residue (straw) is used directly on the farm. The farmer who harvests cereals and collects the straw feeds it to his or her livestock or uses it in animal husbandry; this type of consumption is difficult to quantify as data collection does not occur. There are also many other materials used in animal husbandry across the EU such as sand, rubber mattresses, gypsum, dried manure and data for volumes of use could not be sourced.

The use of straw (wheat, rapeseed, barley) and agricultural residue for animal husbandry and bedding is estimated to be 5-10 times greater than the use of wood shavings. As for manure it is assumed that numbers of livestock and thus animal bedding declines in 2020 by around 10% from 2009 data and in 2030 by 20% from 2009 data due to shifts in food consumption patterns as higher welfare standards increase price of meat and moves to less intense production (Table 9) as well as more imports.

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60 http://www2.wrap.org.uk/downloads/WOO0055_Recyced_Wood_in_Equine_Bedding_ExecSummaryJan071.64b34c08.3770.pdf

61 See Appendix C workings #6

62 http://www.northernperiphery.eu/files/archive/Downloads/Project_Publications/10/Study_Reports/Wood_shavings_as_animal_bedding_in_stables_2009.pdf

63 See Appendix C workings #7

64 Scarlat, N., Martinov, M., & Dallemand, J.F. (2010). Assessment of the availability of agricultural crop residues in the European Union: Potential and limitations for bioenergy use. Waste Management 30: 1889-1897.

Straw is also fed to livestock as a source of long fibre, which is essential as part of a ruminant's diet and such roughage (which could be straw, hay or silage) should comprise a minimum of 10% of the feed ration. Although this is well known within the livestock sector, it is virtually impossible to calculate the exact quantities used due to the different feeding systems and feed rations adopted by individual farmers. Of the 11.9 Mt of straw produced in the UK in 2007, 6.2 Mt were used in livestock rearing (bedding and feed) and 0.04 Mt in mushroom growing[65].

Mtoe	2010	2020	2030
Non-forest woody residue	0.88	0.88	0.88
Agricultural waste	5.9	5.0	4.8
Ligno-cellulosic waste	0.44	0.44	0.44

Table 9. Summary of competing demand from animal husbandry on biomass feedstock technical potential

Based on the above competing uses information this study (the sum of compost, biopolymers, animal husbandry) removes 10% of total agricultural residue in 2020 from the technical potential for 'non-energy uses' (excluding land care and soil conditioning) in section 4.3. This is significantly different from the ICCT study 2014. A more recent ICCT study[66] indicates much less than 33% in many EU countries has other uses. It suggests our rough attempt to build up agricultural wastes using piece by piece may be comparable.

In the ICCT study 2014 33% of agricultural residue was removed this is assumed to include uses for animal husbandry, animal bedding, compost, biopolymers, straw bale housing. This has been adopted in this study and is recognised as a cautious approach for estimating the available resource for energy.

4.2.6 Land care

The manure technical potential is 50% of the theoretical potential as that generated on smaller farms is considered to be dispersed or used directly for land care purposes. From farms >150 head of cattle there is a proportion that is used directly on the land for soil condition and fertilisation, we have estimated this to be 3.7 Mtoe in 2010 and 6.0 Mtoe in 2020 and 2030[67]. There is noted large variation across the EU28 concerning the availability of manure.

In a study by Milieu Ltd (2010)[68] total production of **sewage** was estimated in the EU in 2006 showed that on average 36% of domestic sludge (DS) was recycled to land for agriculture purposes of land care. The rest is incinerated, landfilled or treated otherwise. There is never the less large variation across Member States,

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65 Straw availability in Great Britain http://www.northwoods.org.uk/northwoods/files/2012/12/StrawAvailabilityinGreatBritain.pdf

66 http://theicct.org/sites/default/files/ICCT_EU-national-wastes-residues_Feb2015.pdf)

67 Technical Report No. I to the European Commission, Directorate-General Environment concerning Manure Processing Activities in Europe - Project reference: ENV.B.1/ETU/2010/0007 (2014) http://agro-technology-atlas.eu/docs/21010_technical_report_I_inventory.pdf

68 Milieu Ltd, WRc and Risk & Policy Analysts Ltd (2010) Environmental, economic and social impacts of the use of sewage sludge on land Final Report Part I: Overview Report DG Environment under Study Contract DG ENV.G.4/ETU/2008/0076r

such as France, Portugal, Spain and the UK where quantities recycled to agriculture have continued to increase, whilst agricultural application has effectively been banned in some countries, e.g. the Netherlands and regions of Belgium (Flanders), Austria and Germany.

Mtoe (% of technical potential)	2010	2020	2030
Forest stemwood	90.8 (70%)	96.9 (73%)	106.0 (79%)
Forest residue	-	-	-
Non-forest woody residue	10.6 (24%)	11.0 (19%)	10.4 (20%)
Agricultural waste	16.4 (12%)	14.3 (10%)	14.6 (9%)
Agricultural waste[69]	46.1 (33%)	49.4 (33%)	52.4 (33%)
Manure	3.7 (12%)	6.0 (22%)	6.0 (24%)
Sewage	1.6 (36%)	1.6 (36%)	1.7 (37%)
UCO	-	-	-
Ligno-cellulosic waste	4.2 (12%)	7.2 (26%)	8.7 (49%)
Landfill gas	-	-	-
Energy crop including SRC[70]	-	-	-

Table 10. Competing demands totals from non-energy use industries expressed as Mtoe and percentage of technical potential. The data highlighted in yellow is not taken forward in this study.

Table 10 and Figure 17 shows that the main competing demands are from the wood industry for construction products and fibre for paper, pulp and packing. For manure, sewage and agricultural waste the existing competing uses for land care and animal care account for significant shares of the technical potentials.

[69] ICCT study 2014 presents rationale for using the figure of 33% going for competing uses including animal husbandry

[70] Competing uses are not applied here – as primary one with land use is for conservation

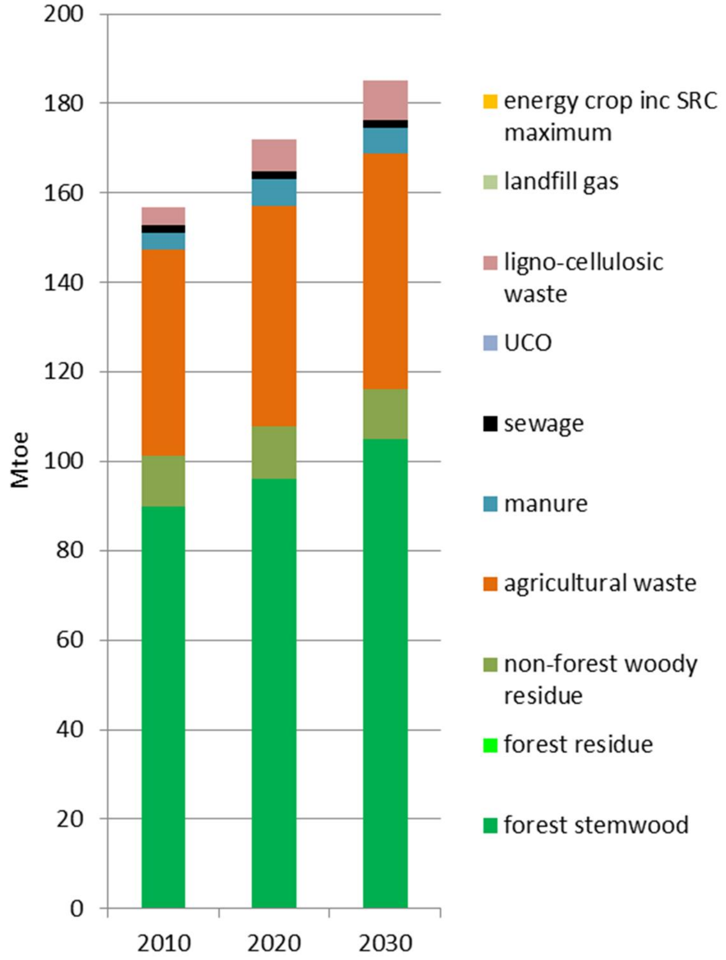

Figure 17. Competing demands from other non-energy uses and industries 157.0 Mtoe (2010), 172.1 Mtoe (2020) and 185.2 Mtoe (2030)

4.3 Technical potential for energy use

The technical potential for energy is the proportion of the technical potential that can be implemented following satisfaction of competing uses which are assumed to take priority over energy. For this study it is the non-energy uses of the biomass feedstocks are subtracted from the technical potential; the technical potential that is available for biomass energy remains (Table 11 and Figure 18).

Mtoe	2010	2020	2030
Forest stemwood	39.7	35.9	28.2
Forest residue	21.9	51.2	52.4
Non-forest woody residue	34.5	48.2	42.6
Agricultural waste[71]	92.3	98.8	104.8
Manure	27.1	21.7	18.9
Sewage	2.7	2.9	3.0
UCO	1.1	1.1	1.2
Ligno-cellulosic waste	32.3	20.2	9.1
Landfill gas	2.9	2.9	0.5
Energy crop including SRC	33.0	34.7	36.4

Table 11. The technical potential for energy use from biomass in Europe is calculated by subtracting the competing demands from non-energy sectors from the total technical potential yields. NOTE this technical potential is before applying any sustainability criteria.

[71] ICCT study 2014 Wasted 33% other uses assumed

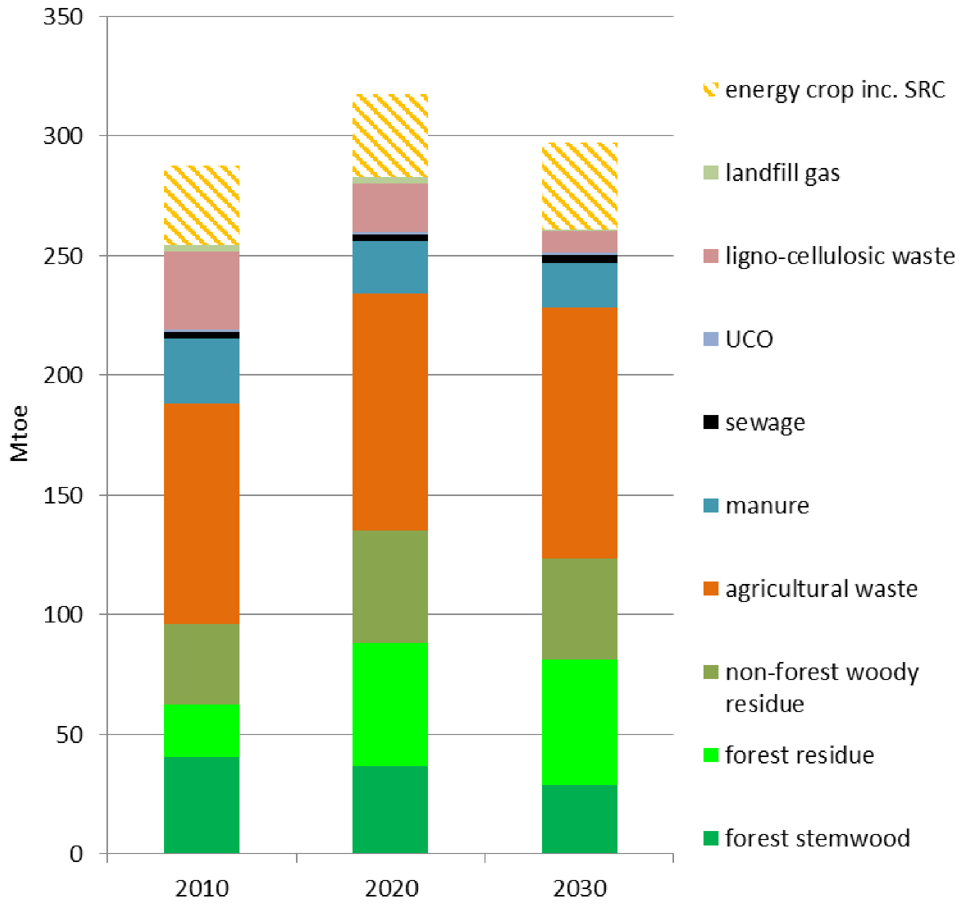

Figure 18. Technical potential for energy use is 287.5 Mtoe (2010), 317.6 Mtoe (2020) and 297.2 Mtoe (2030). NOTE Energy crop potential is indicative only.

5 European Directives and Strategies

This study is focussed on identifying the sustainable biomass feedstocks available for energy in Europe. As part of the definition of sustainability issues concerning land use and protection, soil fertility and conservation of land are considered. This section evaluates the competing demands for biomass feedstocks, or the land that may produce them, for conservation demands. Conservation is defined as uses that enhance biodiversity and contribute to the restoration targets of the EU Biodiversity Strategy. In addition there are European Directives and Strategies that impact on this technical area of energy, land use and conservation. These are considered briefly here.

5.1 Biodiversity Strategy

Biodiversity loss is the most critical global environmental threat alongside climate change[72]. Principle instruments are:

(i) The resolution on the **EU 2020 Biodiversity Strategy**[73]

(ii) An EU-wide strategy on **Green Infrastructure**: Enhancing Europe's Natural Capital

(iii) **The Habitats Directive** (together with the **Birds Directive**) forms the cornerstone of Europe's nature conservation policy.

(iv) Management of **Natura sites**

Of specific relevance are:

Target 2. By 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and **restoring at least 15% of degraded ecosystems**.

Target 3. Agriculture and Forestry

> B) Forests: By 2020, Forest Management Plans or equivalent instruments, in line with Sustainable Forest Management (SFM), are in place for all forests that are publicly owned and for forest holdings above a certain size so as to bring about **a measurable improvement in the conservation status of**

[72] Our life insurance, our natural capital: an EU biodiversity strategy to 2020 [COM(2011)244 final 3/5/2011]

[73] http://ec.europa.eu/environment/nature/info/pubs/docs/brochures/2020%20Biod%20brochure%20final%20lowres.pdf

species and habitats that depend on or are affected by forestry and in the provision of related ecosystem services.[74]

How the study has incorporated the 'demand for conservation and biodiversity' as part of the non-energy demands for EU biomass is summarised as:

- Transfer the biodiversity safeguards from the woody biomass study (IINAS 2014) to this study.
- Transfer the biodiversity safeguards from the energy crops study (ICCT 2014; IEEP 2014) to this study.
- In translating these safeguards into the 2030 context, this study concluded there is nothing missing.
- This study concludes there are no additional biomass feedstocks that require biodiversity safeguards.

Protected areas – woodland and forest set aside for conservation purposes. For agriculture it is assumed what is being harvested will continue to be cultivated and that change of land use in protected areas will not be allowed. This ensures no reduction in European land in conservation status. The land use question for energy crops has been simplified such that the use of fallow land and change of use between agriculture types is minimised (see Table 14).

Restoration targets should not be built into the biodiversity safeguards due to lack of clarity around the baseline and how to measure 15% restoration of degraded ecosystems. Those such as restoration of forests (set aside a proportion for conservation; noting biodiversity gains from types of woodland management) and grassland restoration (scale back productivity and intensification) are included in this studies analysis as part of the sustainability definition. For example the study excludes land for energy crop and have increased the proportion of protected forest and remaining standing forest during harvest in the sustainable potential figures.

Restoration targets (note there is uncertainty with the definition) such as recreating wetlands that would take productive land out of use would be part of a more aggressive policy – so the impact of these actions should be applied as part of the main sustainable biomass volume calculations.

5.2 High Nature Value (HNV) farmland

As farmland biodiversity is rich within High Nature Value (HNV) farming systems, the continuation of these systems is crucial for the EU's goals on nature conservation and biodiversity. In total 32% of EU28 agricultural land is HNV which is 74.7Mha of a total 233.7Mha[75]. Large-scale abandonment may provide

[74] Implementation of 2020 EU Biodiversity Strategy: Priorities for the restoration of ecosystems and their services in the EU ENV.B.2/SER/201/0029 Arcadis Final report Jan 2014.

[75] http://www.ieep.eu/assets/215/highnaturefarming.pdf

opportunities for beneficial restoration of non-agricultural habitats and re-wilding, but it is clear that larger areas of semi-natural habitats of high conservation concern are likely to be at risk.

The application of this conservation demand is part of the reduction of land available for energy crops moving to the sustainable potential. In addition, the possible demands for a 15% restoration target of habitat for agricultural land is part of the land that's exclude for use for energy crops on moving to the sustainable potential. The available land must avoid all HNV land and concentrate on abandoned or fallow land where prospects for HNV are low.

5.3 Landscape and Green Infrastructure

Green Infrastructure is addressing the spatial structure of natural and semi-natural areas but also other environmental features which enable citizens to benefit from its multiple services[76]. The underlying principle of Green Infrastructure is that the same area of land can frequently offer multiple benefits if its ecosystems are in a healthy state. The Commission brochure[77] explaining the main issues of Green Infrastructure shows it is a key step in implementing the EU 2020 Biodiversity Strategy and specifically Target 2 that requires that 'by 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15% of degraded ecosystems'.

The EEA report[78] 'Spatial analysis of green infrastructure in Europe' maps a network of natural and semi-natural spaces and other environmental features in Europe with a good capacity to deliver 'ecosystem services'. These include air filtration, erosion protection, regulating water flow, coastal protection, pollination, maintaining soil structure, water purification, and carbon storage. The report also identifies key habitats for large forest-dwelling mammals and the analysis of connectivity among them.

This experimental methodology, applicable at different scales, indicates that healthy areas of green infrastructure cover approximately a quarter of Europe's land. In many cases, these areas are also home to Europe's large wild animals, including the brown bear, wolf, reindeer and lynx. This underscores the need for effective conservation and restoration, the report says. Roads, towns and other developments continue to fragment habitats, splitting wildlife populations into smaller groups, reducing the gene pool and making species more vulnerable to pressures such as climate change. The report authors map several corridors where the environment could be restored in order to reconnect habitat fragments.

There is some uncertainty in this analysis, the report notes. However, it provides a useful starting point for identifying priority areas for conservation and potential restoration. The multiple benefits of green infrastructure were highlighted in EU Green Infrastructure Strategy, published last year. For example, in cities trees and green areas can prevent flooding, reduce air pollution and reduce noise levels. In addition, using natural systems in this way can often be cheaper and more robust than the typical 'grey' infrastructure

[76] Communication from the Commission: Green Infrastructure (GI) – Enhancing Europe's natural capital, Com (2013) 249 final

[77] Building Green Infrastructure for Europe http://ec.europa.eu/environment/nature/ecosystems/docs/green_infrastructure_broc.pdf

[78] EEA (2014) Spatial analysis of green infrastructure in Europe Technical report No 2/2014

such as concrete flood barriers. In addition there are significant citizen wellbeing benefits potentially associated with natural systems, such as the amenity value of woodlands.

5.4 Land use change

While biofuels are important in helping the EU meet its greenhouse gas reductions targets, biofuel production typically takes place on cropland which was previously used for other agriculture such as growing food or feed. Since this agricultural production is still necessary, it may be partly displaced to previously non-cropland such as grasslands and forests. Indirect land use change (ILUC) risks negating the greenhouse gas savings that result from increased biofuels because grasslands and forests typically absorb high levels of CO_2. By converting these land types to cropland, atmospheric CO_2 levels may increase[79].

To reduce the risk of indirect land use change, the EU has amended the current legislation on biofuels, specifically the Renewable Energy Directive and the Fuel Quality Directive. The new rules seek to ensure that:

- biofuels from new installations emit at least 60% less greenhouse gases than fossil fuels
- emissions that might be caused by indirect land use change must be reported on by the Commission. This will be done by estimating emissions that would take place globally when land is used for growing crops for biofuels to be used in the EU instead of growing food and feed crops (estimated ILUC emission values)
- Only 7% of every EU country's 10% renewable energy target in the transport sector can be met by first generation biofuels (produced from sugars, oil crops, etc.); at the same time, 2nd and 3rd generation biofuels will count more. These biofuels are produced from materials (municipal waste, algae, etc.) that do not compete with food and feed crops
- after 2020, governments would financially support only 2nd and 3rd generation biofuels

5.5 Invasive alien species

Invasive alien species (IAS) pose a serious threat to biodiversity in Europe, robust action is needed to:

- prevent the introduction of these species
- prevent the establishment of these species
- tackle those already present in the EU

The Biodiversity strategy proposes a comprehensive EU wide instrument to address this issue which impacts on species planted for energy crops, forest resilience and health and import activity associated with these sectors.

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[79] Brussels, 17.10.2012 SWD(2012) 344 final COMMISSION STAFF WORKING DOCUMENT EXECUTIVE SUMMARY OF THE IMPACT ASSESSMENT ON INDIRECT LAND-USE CHANGE RELATED TO BIOFUELS AND BIOLIQUIDS

New Regulation[80] on invasive alien species was published in the Official Journal on 4 November 2014. It entered into force on 1 January 2015. The new regulation seeks to address the problem of IAS in a comprehensive manner so as to protect native biodiversity and ecosystem services, as well as to minimize and mitigate the human health or economic impacts that these species can have.

An uncertainty in any forecasting study such as this is the likelihood of an invasive species being introduced into Europe that could have a devastating effect on the distribution and health of tree species or plant species utilised for energy crops.

5.6 Circular economy

Towards a circular economy: A zero waste programme for Europe[81] presents the case that valuable materials are leaking from our economies. Turning Europe into a more circular economy[82] means:

- boosting recycling and preventing the loss of valuable materials;
- creating jobs and economic growth;
- showing how new business models, eco-design and industrial symbiosis can move us towards zero-waste;
- reducing greenhouse emissions and environmental impacts.

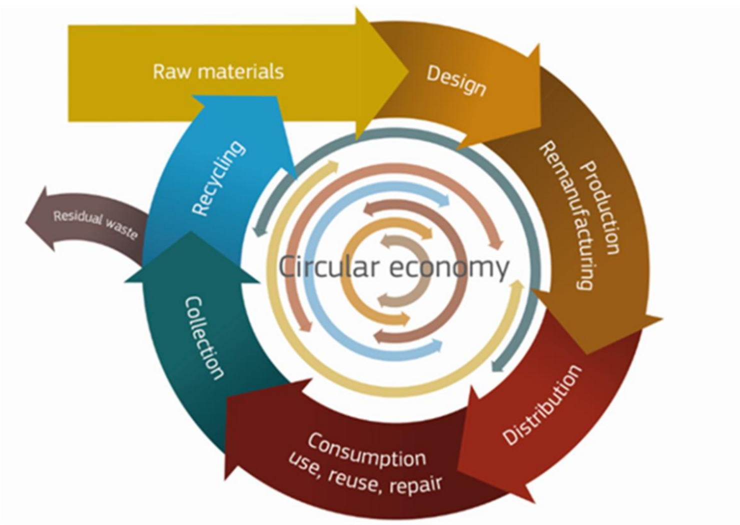

Figure 19. Circular economy approaches 'design out' waste and typically involve innovation throughout the value chain, rather than relying solely on solutions at the end of life of a product.

[80] http://ec.europa.eu/environment/nature/invasivealien/index_en.htm
[81] COM(2014) 398 final/2 Towards a circular economy: A zero waste programme for Europe
[82] http://ec.europa.eu/environment/circular-economy/

Figure 19 illustrates in a simplified way the main phases of a circular economy model. The phases are interlinked, as materials can be used in a cascading way. The aim is to minimise the resources escaping from the circle so that the system functions in an optimal way.

In order to support design and innovation for a more circular economy, the Commission encourages **the cascading principle in the sustainable use of biomass**, taking into account all biomass using sectors so that biomass can be utilised in a most resource efficient way.

The European Union has set out its political commitment[83] to reduce waste generation, to recycle waste into a major, reliable source of raw materials for the Union, **to recover energy only from non-recyclable materials** and to virtually eliminate landfilling.

Europe has made substantial progress in turning waste into a resource and promoting sustainable ways of waste management such as recycling. However, performance varies considerably between Member States. **Six member states have already effectively eliminated the landfilling of municipal waste**, reducing it from 90% to less than 5% in the past 20 years and reaching recycling rates of 85% in certain regions. In others over 90% of waste is still landfilled and less than 5% is recycled. This suggests the opportunity to utilise ligno-cellulosic waste as a biomass feedstock for energy will vary across member states.

The key elements included in this study of the legislative proposal are the aims to:

- Increase recycling/re-use of municipal waste to 70% in 2030;
- Increase packaging waste recycling/re-use to 80% in 2030 with material-specific targets set to gradually increase between 2020 and 2030 (to reach 90% for paper by 2025 and 80% for wood by the end of 2030);
- Phase out landfilling by 2025 for recyclable (including plastics, paper, metals, glass and bio-waste) waste in non-hazardous waste landfills – corresponding to a maximum landfilling rate of 25%;
- Reduce food waste generation by 30% by 2025;
- Mechanisms and policy to simplify reporting and enable processing

Member States' performance will be monitored against the target of 70% recycling by 2020, with measures including increased landfill charges for construction and demolition waste, or additional sorting obligations on major demolition sites to improve the quality of recyclates. The EU is already forecast to increase its resource productivity by 15% between 2014 and 2030 under a business as usual scenario. Using smart policies to promote the transition to a more circular economy, as called for by the European Resource Efficiency Platform, it would be possible to double this rate[84].

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[83] European Commission's 7th Environmental Action Plan (EAP)

[84] SWD (2014) 211. COMMISSION STAFF WORKING DOCUMENT Analysis of an EU target for Resource Productivity accompanying the document Towards a circular economy: A zero waste programme for Europe

5.7 Climate change

The impacts of climate change present a significant challenge to forecasts for future energy demand and for available volumes of biomass feedstocks. At the European level a comprehensive package of policy measures to reduce greenhouse gas emissions has been initiated through the European Climate Change Programme (ECCP).

EU leaders agreed on 23 October 2014 the domestic 2030 greenhouse gas reduction target of at least 40% compared to 1990 together with the other main building blocks of the 2030 policy framework for climate and energy, as proposed by the European Commission in January 2014. This 2030 policy framework aims to make the European Union's economy and energy system more competitive, secure and sustainable and also sets a target of at least 27% for renewable energy and energy savings by 2030.

Aspects of the International Panel on Climate Change (IPCC) Scenarios for Europe:

- Temperature - Annual temperatures over Europe warm at a rate of between 0.1 and 0.4°C per decade.
- Temperature - In winter, the continental interior of Eastern Europe and western Russia warms more rapidly (0.15-0.6°C per decade) than elsewhere.
- Temperature - Winters currently classified as cold (occurring 1 year in 10 during 1961-1990) become much rarer by the 2020s and disappear almost entirely by the 2080s. In contrast, hot summers become much more frequent.
- Precipitation - The general pattern of future change in annual precipitation over Europe is for widespread increases in northern Europe (between +1 and +2% per decade), smaller decreases across southern Europe (maximum 1% per decade), and small or ambiguous changes in central Europe (France, Germany, Hungary, Belarus).
- Precipitation - There is a marked contrast between winter and summer patterns of precipitation change. Most of Europe gets wetter in the winter season (between +1 and +4% per decade). In summer, there is a strong gradient of change between northern Europe (wetting of as much as +2% per decade) and southern Europe (drying of as much as 5% per decade).
- Weather extremes – It is likely that frequencies and intensities of summer heat waves will increase, intense precipitation events will increase in frequency, especially in winter, and that summer drought risk will increase in central and southern Europe; and possible that gale frequencies will increase. The impacts are increased stress of growing biomass and an increase in chance of windblown events creating unpredicted peaks and troughs in woody biomass availability.

- Sea level - Global-mean sea level rises by the 2050s by 13-68 cm which presents significant increase in sea water flooding potential (assuming no increase is sea defences) of low lying coastal regions and a threat to agricultural use of these land areas.

Assuming IPCC scenarios[85] that more northerly parts of Europe become warmer and wetter and other parts of Europe will become drier can create impacts for biomass energy that are not comprehensively understood[86]:

- Increase in growth rates of forest and crop biomass due to water availability and temperature stimulus
- Decrease in growth rates of forest and crop biomass due to water stress
- Risk of long term security of biomass due to increased wind blow and storm events and increased risk of forest and bush fires
- Increased spread of pests and disease on crops and forestry causing crop failure, yield reduction or more drastic forestry management processes being implemented such as clear felling of *Phytopthora* diseased larch causing spikes in biomass availability.
- Restocking of northerly forests with more southern provenance seed stock
- New tree species being considered for wider resilience to climate change and future risk of pests and diseases – a mixed portfolio of trees for Europe

These risks and challenges to assumed volumes of biomass feedstocks available need to be measured and quantified more fully.

This study assumes that the 0.5°C temperature rise by 2030 will have an overall zero net effect on biomass availability due to the gain in volume cancelling the loss in volume due to pests.

5.8 Greenhouse gas emissions from bioenergy

It's been widely recognized in science[87] that bioenergy use cannot be assumed to create zero greenhouse gas emissions, an assumption of most EU climate and energy policies. As explained by the Scientific Committee of the European Environmental Agency (2011)[88]:

[85] http://www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=495
[86] Lindner et al (2014) Climate change and European forests: What do we know, what are the uncertainties, and what are the implications for forest management? Journal of Environmental Management 146 (2014) 69-83 http://www.sciencedirect.com/science/article/pii/S030147971400379X
[87] See for example Joint Research Centre (2013), Matthews et al. (2014), Manomet Center for Conservation Sciences(2010)
[88] EEA Scientific Committee (2011), Opinion of the EEA Scientific Committee on Greenhouse Gas Accounting in Relation to Bioenergy

"Producing energy from biomass is meant to reduce GHG emissions. But burning biomass increases the amount of carbon in the air (just like burning coal, oil and gas) if harvesting the biomass decreases the amount of carbon stored in plants and soils, or reduces ongoing carbon sequestration."

As recognized by the European Commission in its legislative proposal to address indirect land use emissions of biofuels and in studies commissioned by the Commission, considerable risk of high greenhouse gas emissions are particularly related to use of land based crops and use of stemwood from dedicated harvests for energy.

Greenhouse gas emissions from bioenergy use have been taken into consideration in the three foundation studies. IEEP study 2014 on potential land availability for energy production considers only land which is not under recent arable use in order to minimize possible emissions from indirect land use change and excludes land with high biodiversity value and high carbon stock land in order to avoid emissions from direct land use change.

The IINAS study 2014 on wood availability also calculated the emissions from the carbon stock changes in forests in a bioenergy production system, in comparison to a situation in absence of a bioenergy system. Of the five bioenergy systems modelled, only biomass from residues and from so called advanced harvests have intensities that over time are below the intensities of fossil fuels.

In this study, constraints for the sustainable potential of biomass for energy have been posed to minimize the risk of high biogenic emission from bioenergy. As explained, arable land already in use has been excluded from the sustainable potential as well as roundwood (which is also used up by various competing uses).

6 Sustainable potential

Sustainability criteria act as a further constraint on the technical and technical for energy potentials leading in the end to a sustainable potential available for energy of low environmental risk. There is an absolute need for the inclusion of sustainability in bioenergy potential to ensure an approach consistent with low environmental risk. Bioenergy is the subject of vigorous debate and due to increased awareness of land use change, citizen demands and the industry and political responsibilities there is a collective move towards more sustainable practices. These are inconsistent and rarely comparable. The concept of sustainable implementation of biomass used for energy contains multiple environmental, economic and social aspects and integrating these aspects may be complex.

Some biomass feedstocks show substantial theoretical potential while their implementation potential is rather limited due to the limitations of land quality, costs of extraction and transport and demand for competing use. In existing resource studies and assessments, it is sometimes difficult to distinguish between theoretical and technical potential and between economic and implementation potential.

Transformation of theoretical to technical and implementation potentials manifestly deals with the economic, practical and bio-physical constraints. Sustainable implementation requires wider Low Biodiversity Risk scenarios being implemented and reduced availability of lingo-cellulosic waste and food waste as impacts of circular economy implementation and tighter policy interventions.

6.1 Sustainable potential

For the final outcome the sustainable implementation potential, additional environmental, economic and social criteria have been integrated for forest and agricultural biomass, for land availability and for waste, which include:

- Increase of 5% in strictly protected forests
- 5% increase in retained trees on harvest sites
- Constraints on residue removal from unproductive poor soils and a maximum of 70% residue removal allowed on other soils.
- No stump extraction[89]
- 33% of all agricultural residue left on land to maintain soil condition[90]
- Land for energy crops should not displace food production within the current agricultural area, or do so only minimum negative impacts and risk to the environment (including ILUC)

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[89] All environmental constraints for woody biomass are as in IINAS study 2014

[90] ICCT study 2014

- Any crop production must satisfy as a minimum the conditions set out under Article 17 (3) –(6) of Renewable Energy Directive[91]
- Reduce food waste generation by 30% by 2025;

At present 37 Mha of EU forest is protected for conservation purposes by the Natura 2000 network. Protected areas of various levels cover about 11% of total EU27 forest. Retention of some live and deadwood trees is encouraged and a 5-10% minimum of the wood volume retained has been suggested. In deriving the technical potential limits to the total removal from EU forests are made. The IINAS study looked at some of these with stricter environmental controls focussing on lower total mobilisation from the forest, application of fertiliser to limit detrimental effects of removing logging residue was not allowed, stump extraction was not permitted and constraints imposed on residue extraction. Using the LOW 2020 and LOW 2030 scenario data it is clear that forest residues shrink to very low volumes with no stump extraction and thinning residues left in the forest. The sustainable potentials available for biomass energy are presented in Table 12 and Figure 20. The 2010 data for Forest stemwood and Energy crop maximum potential are not directly comparable to the 2020 and 2030 forecast data as they have different constraints applied to them The 2010 sustainable potential from energy crops includes 5.5Mha of existing land under energy crops for biofuel. This was phased out for 2020 and 2030 data. The 2020 and 2030 Forest stemwood data has the IINAS 2014 study lower mobilisation scenario applied to them.

Mtoe	2010	2020	2030
Forest stemwood	39.7[92]	15.6	7.6
Forest residue	21.9	10.3	10.4
Non-forest woody residue	34.5	48.2	42.6
Agricultural waste	46.1	49.4	52.4
Manure	27.1	21.7	18.9
Sewage	2.7	2.9	3.0
UCO	1.1	1.1	1.2
Ligno-cellulosic waste	16.7	12.6	8.1
Landfill gas	2.9	2.9	0.5
Energy crop maximum potential[93]	29.3[94]	7.2	7.4

Table 12. The sustainable potential for biomass feedstocks. The 2010 data for Forest stemwood and Energy crop maximum potential are not directly comparable to the 2020 and 2030 forecast data as they have less constraints applied to them

[91] These include protection of land with high biodiversity value, high carbon stock land; land that was formerly peatland; and must respect rules governing the receipt of support through the Common Agricultural Policy

[92] The environmental constraints of the IINAS 2014 LOW lower mobilisation scenario are not applied to the 2010 data

[93] IEEP study 2014 figure of 1.35Mha LOW lower mobilisation scenario applied

[94] Includes 5.5Mha in use in 2010 for biofuel production. This land potential is phased out for 2020 and 2030.

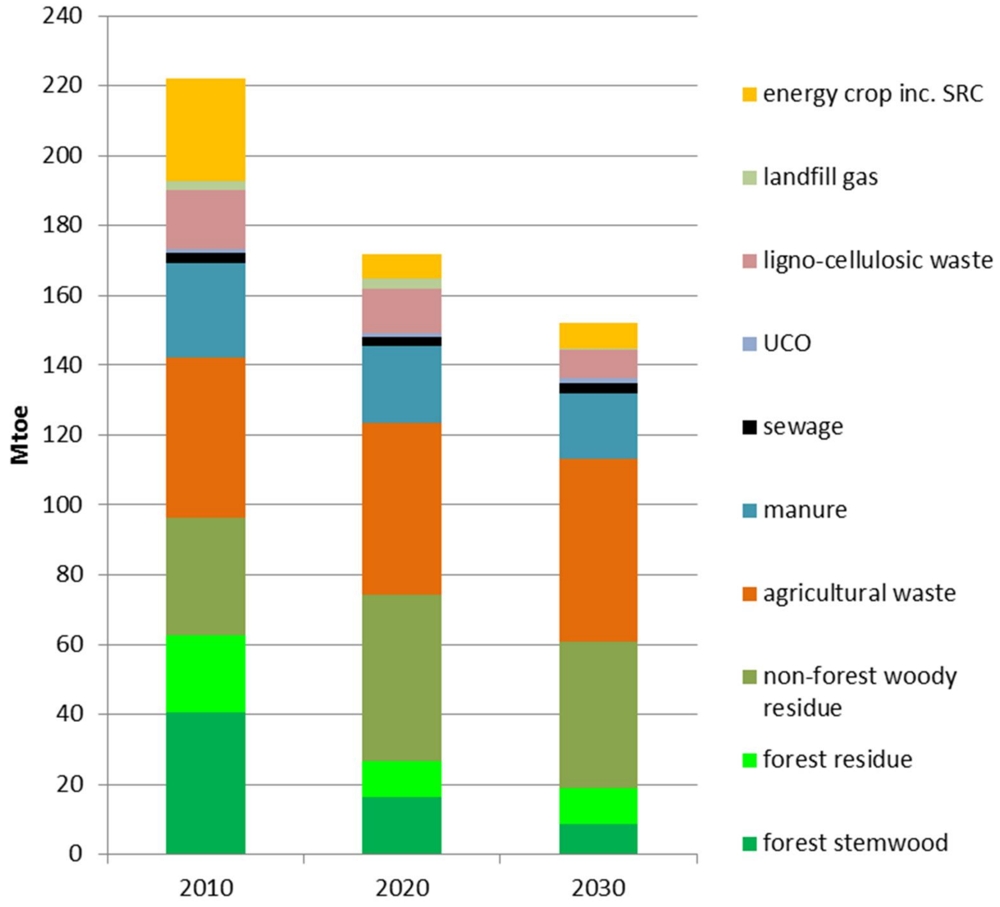
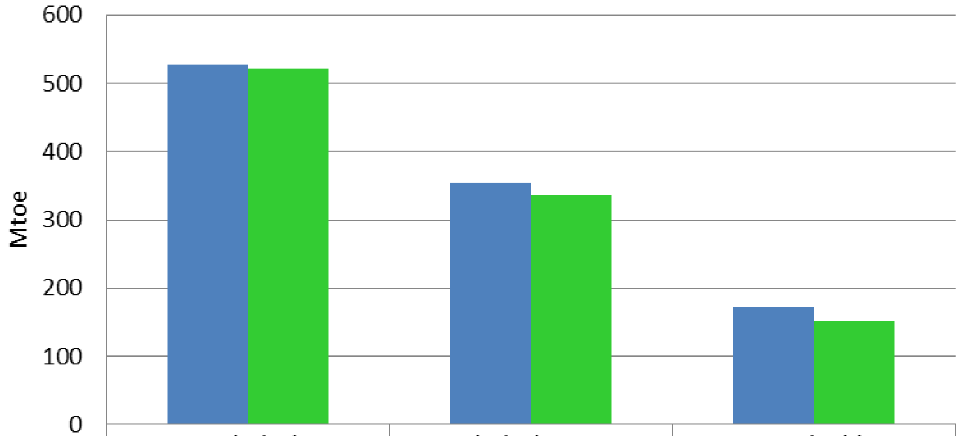


Figure 20. The sustainable potential available for energy on implementation of stricter forest environmental controls (IINAS 2014), 33% agricultural residue left on land, less land used for energy crop. Totals 222.0 Mtoe (2010), 171.9 Mtoe (2020) and 152.2 Mtoe (2030).

It is important to keep stemwood and residue separated as it shows there is 'forest resource' sustainably available for biomass (in part as residue) against an increasing need to import timber stemwood for construction uses. UNECE 2011 statistics show that 85-87% stemwood demand is satisfied by internal EU27 production. A summary of the competing uses and the sustainability constraints imposed on the biomass feedstocks is presented in Table 13.

A summary is presented in Figure 21 and for each feedstock to enable comparison across all potentials (T = technical TE= technical for energy S = sustainable) in Table 14 and Figure 22. Under the conditions of the sustainable scenario of biomass feedstocks forest stemwood in 2030 indicates demand is close to European supply. This is a result of increasing demand for stemwood for construction timber, packaging and pulp and paper across Europe.



	technical	technical energy	sustainable
2020	527.3	354.1	171.9
2030	521.8	335.5	152.2

Figure 21. The sustainable potential is 32.6% of the 2020 technical potential; 29.2% of the 2030 technical potential.

	Competing demands	Sustainability constraints
Forest stemwood	Construction timber, non-construction timber, pulp and paper, packaging	Below the annual growth increment
Forest residue		Conservation and maintenance of soil condition
Non-forest woody residue	Wood-based panel manufacture	
Agricultural waste	For animal husbandry, polymers and composting. Assumed to be 33%	33% left on the land to maintain soil condition
Manure	50% used in land care	
Sewage	36% used in land care	
Used cooking oil		
Ligno-cellulosic waste	Composting, recycling (paper and board), animal bedding, wood-based panel products	Reduce food waste generation by 30% by 2025
Landfill gas	Reduction in potential as landfill is phased out by 2030 and gas potential declines	
Energy crop	Focus on land use and competing demands for food, materials and conservation.	Those in the IEEP study 2014 (i) Do not displace food and feed production (ii) Minimise negative impacts of land use change on the environment (iii) Apply as a minimum article 17(3)-(6) of the RED protection of areas of high biodiversity

Table 13. Summary of competing uses and sustainability constraints imposed on potential calculations for each biomass feedstock.

Feedstock (Mtoe)	2010	2020	2030
forest stemwood T	130.5	132.8	134.2
forest stemwood TE	39.7	35.9	28.2
forest stemwood S	39.7	15.6	7.6
forest residue T	21.9	51.2	52.4
forest residue TE	21.9	51.2	52.4
forest residue S	21.9	10.3	10.4
non-forest woody residue T	45.1	59.2	53.0
non-forest woody residue TE	34.5	48.2	42.6
non-forest woody residue S	34.5	48.2	42.6
agricultural waste T	138.4	148.2	157.2
agricultural waste TE	92.3	98.8	104.8
agricultural waste S	46.1	49.4	52.4
manure T	30.8	27.7	24.9
manure TE	27.1	21.7	18.9
manure S	27.1	21.7	18.9
sewage T	4.5	4.7	4.9
sewage TE	2.7	2.9	3.0
sewage S	2.7	2.9	3.0
UCO T	2.1	2.1	2.2
UCO TE	1.1	1.1	1.2
UCO S	1.1	1.1	1.2
Ligno-cellulosic waste T	36.5	27.4	17.8
Ligno-cellulosic waste TE	32.3	20.2	9.1
Ligno-cellulosic waste S	16.7	12.6	8.1
landfill gas T	2.9	2.9	0.5
landfill gas TE	2.9	2.9	0.5
landfill gas S	2.9	2.9	0.5
energy crop inc. SRC T	67.5	71.1	74.7
energy crop inc. SRC TE	67.5	71.1	74.7
energy crop inc. SRC S	29.3	7.2	7.4

Table 14. Summary feedstock Mtoe for technical (T), technical energy (TE) and sustainable (S) biomass feedstock potentials.

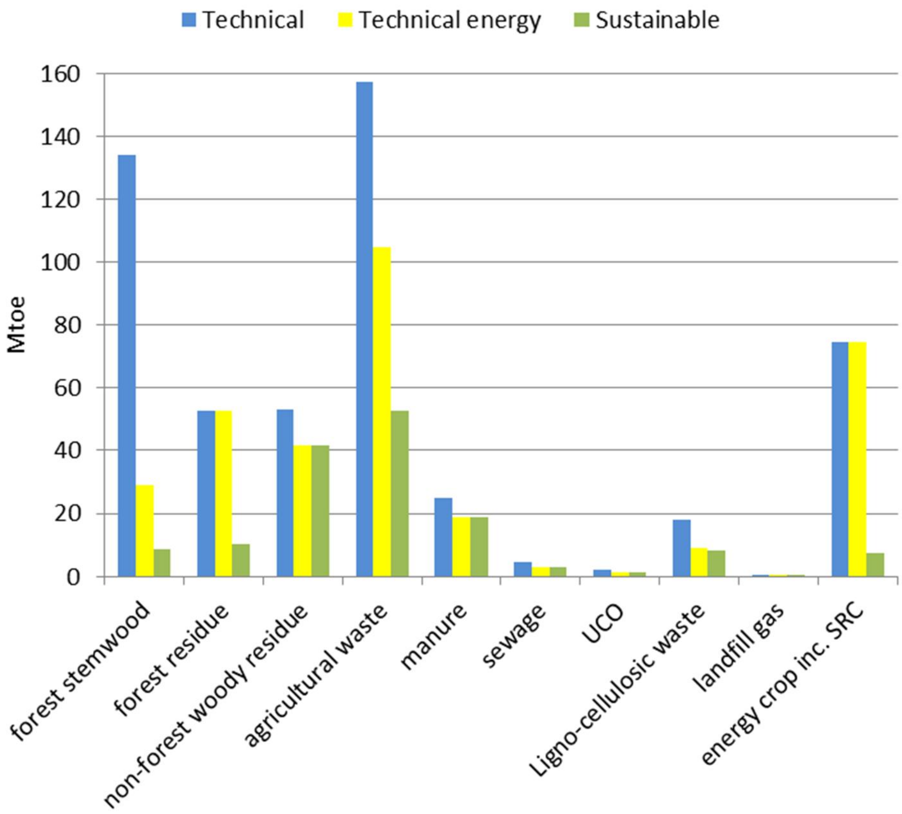


Figure 22. Summary of technical, technical for energy and sustainable potentials for biomass feedstocks in 2030.

7 Renewable Energy Sources

The landscape associated with gross final energy consumption is a slight reduction moving towards 2030, consumption falling due to efficiencies in energy use. There is also an increase in the share of the renewable energy in Europe as part of the gross final energy consumption (Figure 23). The main drivers of reduction in consumption are the developments in final energy demand. These reflect the implemented energy efficiency policies that include, among others, the Energy Efficiency Directive (EED), Energy Performance of Buildings Directive (EPBD), the Eco-design Directive and a host of implementing Regulations for specific products, CO_2 emissions standards for light duty vehicles.

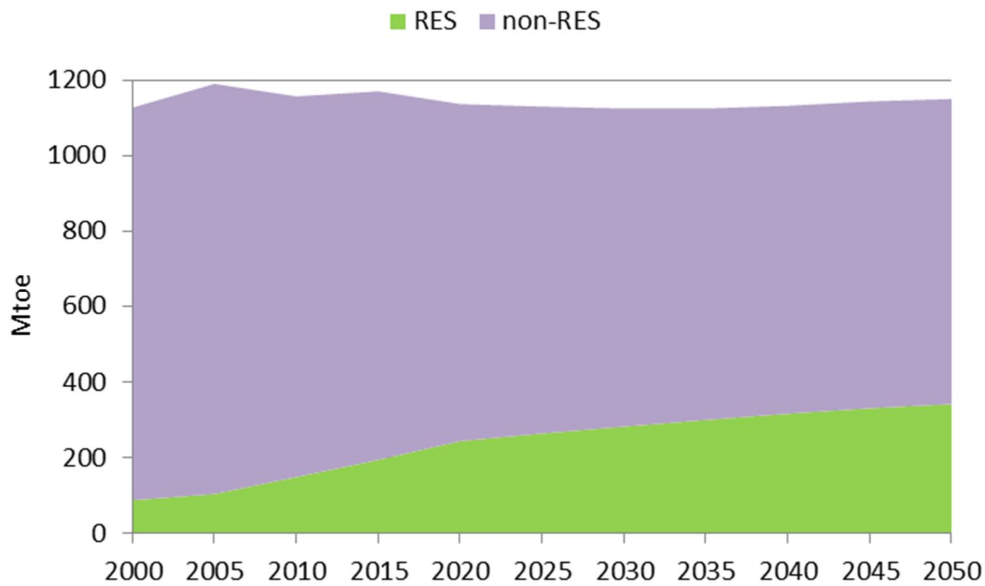


Figure 23. Historical and forecast trends of decreasing Gross Final Energy Consumption and increasing contribution by renewable energy sources in Europe[95].

The other dominant feature across all projections is that solid biomass is expected to contribute upward of 50% of total RES production (and therefore an equivalent proportion in gross final energy consumption) in Europe (Figure 24). Europe is committed to reducing its GHG emissions by 80-95 % by 2050 and in the shorter term by 2020 to reduce GHG by 20%, increase the share of renewables to 20%, and save 20% energy.

[95] EU ENERGY, TRANSPORT AND GHG EMISSIONS TRENDS TO 2050 REFERENCE SCENARIO 2013 page 39 https://ec.europa.eu/energy/sites/ener/files/documents/trends_to_2050_update_2013.pdf

Whilst progress is being made the overwhelming majority of the population of Europe live in countries that have <20% renewable energy (Figure 25).

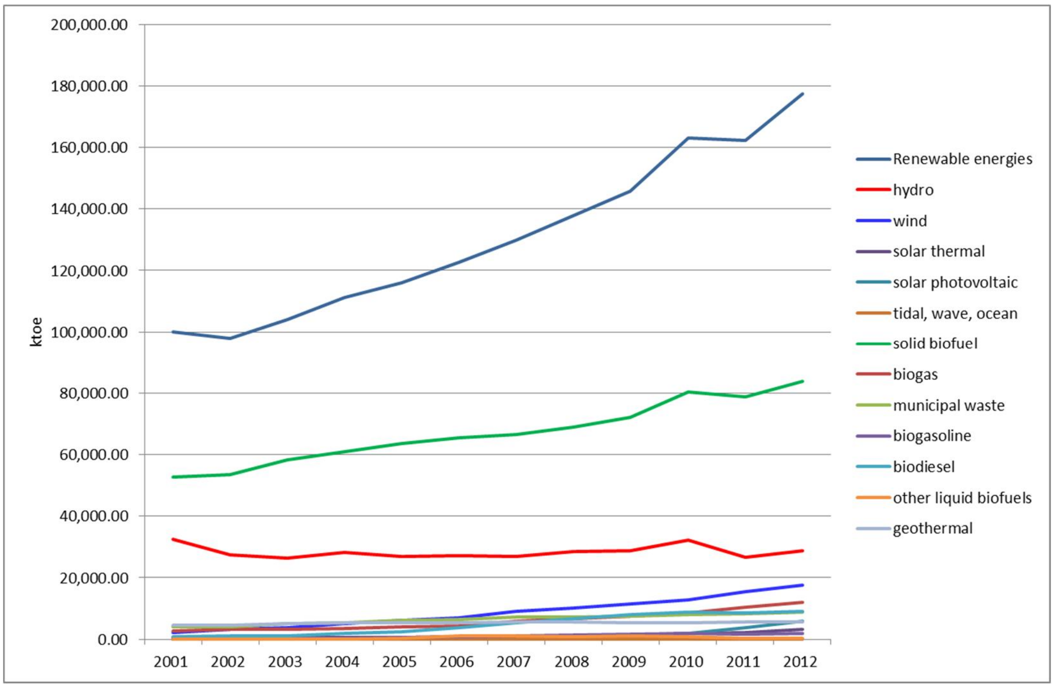


Figure 24. Approximately 50% of primary production of renewable energy has been from solid biofuels.
Total RES energy and individual RES sources from EUROSTAT 2012 data.

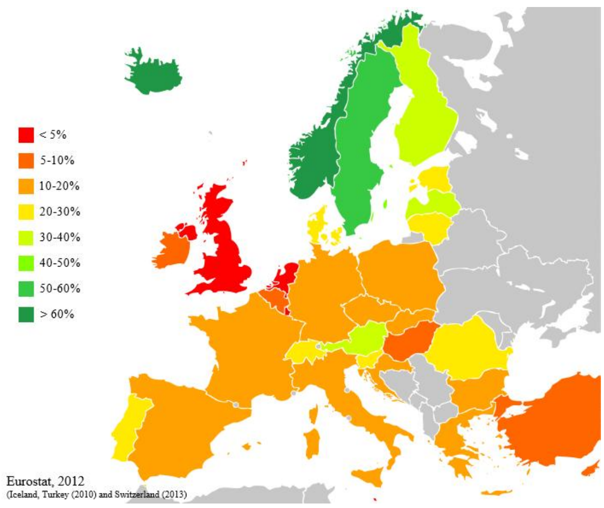


Figure 25. The share of renewable energies in gross final energy consumption by country EUROSTAT 2012

7.1 Renewable Energy - total RES and biomass and waste contribution

Directive 2009/28/EC concerns the promotion of the use of energy from renewable sources in order to limit greenhouse gas emissions and to promote cleaner transport. The Renewables Directive 2009 provides the common framework and each member state has a target calculated according to the share of renewable sources in its gross final consumption of 2020. Moreover the share of energy from renewable sources in the transport sector must amount to at least 10% of final consumption by sector in 2020. Each member state established a National Renewable Energy Action Plan (NREAP) which set out the shares of energy from renewable sources.

From the Energy Roadmap 2050 two scenarios were selected to compare with this study findings:

- **The Roadmap 2050 Reference scenario (Roadmap 2050 REF)**[96] is the 'business as usual' scenario includes current trends and long-term projections on economic development (gross domestic product (GDP) growth 1.7 % pa). It uses the PRIMES model[97] for energy and CO2 emission projections. The scenario includes all binding targets set out in EU legislation regarding development of renewable energies and reductions of greenhouse gas (GHG) emissions, as well as the latest legislation promoting energy efficiency. The scenario includes policies adopted by March 2010, including the 2020 targets for renewable energy sources (RES) share and greenhouse gas (GHG) reductions as well as the emissions trading scheme (ETS) directive. It includes the EU's 2050 objective of reducing GHG emissions by 80-95%. The RES share in gross final energy consumption (i.e. the definition for the existing 20% target) rises to at least 55% in 2050. Legally binding national targets for RES share in gross final energy consumption are achieved in 2020; 10% target for RES in transport is achieved for EU27.

- **The Roadmap 2050 high renewable energy sources scenario (Roadmap 2050 HIGH RES)** is a decarbonisation scenario that builds on the reference scenario with strong support measures for RES leading to a very high share of RES in gross final energy consumption (75% in 2050) and a share of RES in electricity consumption reaching 97%. The RES share in gross final energy consumption reaches 75%, up 65 percentage points from current levels. The RES share in transport increases to 73%. The RES share in power generation reaches 86%.

The **European Commission's reference scenario 2030 (EC 2030 REF)** in the impact assessment of the 2030 climate and energy policy framework communication explores the consequences of current trends, including full implementation of policies adopted by late spring 2012. The scenario has been developed through modelling with PRIMES, GAINS and other related models and benefited from the comments of Member State experts.

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[96] European Commission Reference Scenario to 2050 (2011), European Commission, Brussels, Belgium.

[97] PRIMES model is a modelling system that simulates a market equilibrium solution for energy supply and demand in the EU28 and its Member States.

A summary of the scenarios is presented in Table 15.

Scenario name	GHG or CO2-emissions reduction, economy-wide	Share of renewables in gross final energy consumption	Reduction in primary energy by improved energy efficiency	Carbon policy
Roadmap 2050 REF	Total GHG reduction of 20% in 2020 relative to 1990	20% by 2020 27% by 2030	Europe Union has set itself a target for 2020 of saving 20% of its primary energy consumption compared to projections	Implemented Policies until March 2010 & achievement of legally binding targets Revised ETS Directive applied until 2050
Roadmap 2050 HIGH RES	Total GHG reduction of between 79 to 82% in 2050 relative to 1990.	22-25% by 2020 40-45% by 2030 55-75% by 2050 2050 75% in gross final energy consumption and 97% in electricity consumption	38% reduction in energy use by 2050	Implemented Policies until March 2010 & achievement of legally binding targets Revised ETS Directive applied until 2050
EC 2030 REF	Total GHG reduction of 24% in 2020, 32 % in 2030 and 44 % in 2050 relative to 1990.	21% by 2020 24% by 2030 29% by 2050.	Overall to energy savings of 17% in 2020 compared to the relevant baseline 21% energy savings in 2030.	GHG Effort Sharing Decision (Decision No 406/2009/EC) including achievement of the legally binding 2020 targets for non-ETS emissions at aggregated EU level, assuming use of transfer provisions between Member States

Table 15. Summary of scenarios used for comparison of this study's potentials

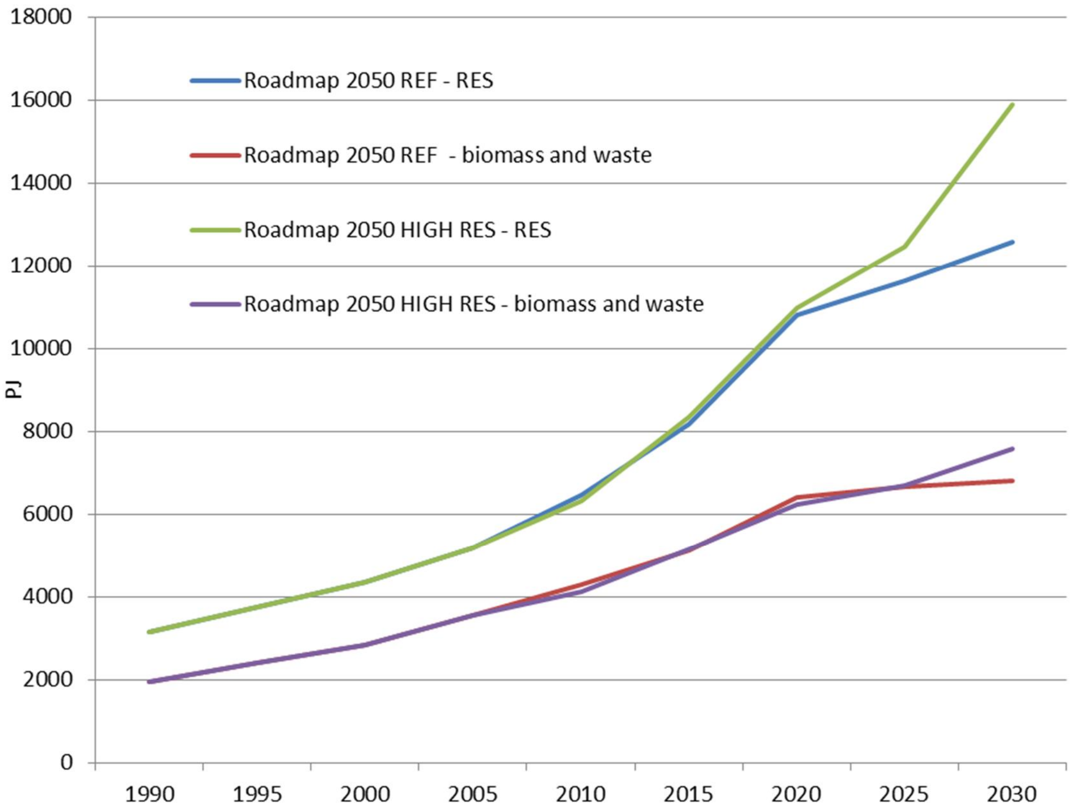

Figure 26. Roadmap 2050 REF and Roadmap 2050 HIGH RES scenarios showing total RES production and the biomass and waste proportion PJ for EU28[98]*.*

According to the recent "State of Play" report of the European Commission[99] solid and gaseous biomass used for electricity, heating and cooling production is the biggest source of renewable energy in the EU and is key to achieving the 2020 renewable energy targets and the EU long-term decarbonisation goals by 2050. The report notes that according to the NREAPs EU final bioenergy demand is 140 Mtoe in total in 2020. Figure 26 shows at 2020 and 2030 the proportion of renewable energy produced with biomass and waste is forecast to be 57% and 54% respectively.

Increasing concerns have been expressed by a number of stakeholders about the potential sustainability risks associated with such large-scale use of biomass for energy, including those stemming from imports from third countries. While biomass imports are estimated to triple between 2010 and 2020, the EU demand for solid and gaseous biomass for bioenergy production is likely to continue to be met largely through

[98] Energy Roadmap 2050 https://ec.europa.eu/energy/sites/ener/files/documents/2012_energy_roadmap_2050_en.pdf https://ec.europa.eu/energy/sites/ener/files/documents/sec_2011_1565_part2.pdf

[99] State of play on the sustainability of solid and gaseous biomass used for electricity, heating and cooling in the EU. European Commission Brussels, 28.7.2014 SWD(2014) 259 final http://ec.europa.eu/energy/sites/ener/files/2014_biomass_state_of_play_.pdf

domestic raw material up to 2020. Biomass demand is projected to further increase up to 2030, including imports, which poses the question at the heart of this study as to whether there is sufficient supply of sustainable, and cost-effective, biomass for all uses in the EU.

Summary data cross-referencing the outcomes from this study with RES projections are made in Table 16 and Figure 27. Whilst in 2020 the sustainable potential of biomass forecast to be available and the demand share of RES that is biomass and waste derived in the scenarios are broadly matched in 2030 the forecast share of RES in all scenarios that is biomass and waste derived is greater than the sustainable potential of biomass forecast to be available.

NOTE: The EC 2030 REF has a biomass demand for energy of 178 Mtoe[100]. The scenario is for a 32.4% GHG reduction in 2030 compared to 1990, 24.4% RES final energy consumption and a 21.0% energy savings in 2030.

The GHG40/EE/RES30 is politically relevant from the 2030 impact assessment as it is close to agreement albeit with slightly more ambitious RES at 30%, GHG reduction of 40% compared to 1990 and energy efficiency with no pre-set target at 30.1%.

2010	Mtoe	2020	2030
	POTENTIALS		
445.6	This study Technical	490.9	483.6
287.5	This study Technical for energy	317.6	297.2
222.0	This study Sustainable	171.9	152.2
	DEMANDS		
102.4	Roadmap 2050 REF (biomass + waste)	152.7	162.8
98.5	Roadmap 2050 HIGH RES (biomass + waste)	149.0	180.9
	NREAP totals	140.0	
	EC 2030 REF		178.0
	GHG40/EE/RES30		192.0

Table 16. Summary of energy (Mtoe) potentials and demand scenarios for 2020 and 2030. Some data for 2010 (lefthand column) is actual data for biomass use so is not directly comparable to the forecasts under scenarios.

The biomass feedstock potentials from this study are converted to total primary energy demand met by biomass (%) and the share of the RES target met by the biomass feedstock outcomes (%) (Table 17).

100 EC (2014) SWD (2014) 15 final A policy framework for climate and energy in the period from 2020 up to 2030 Table 8 page 62 http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014SC0015&from=EN

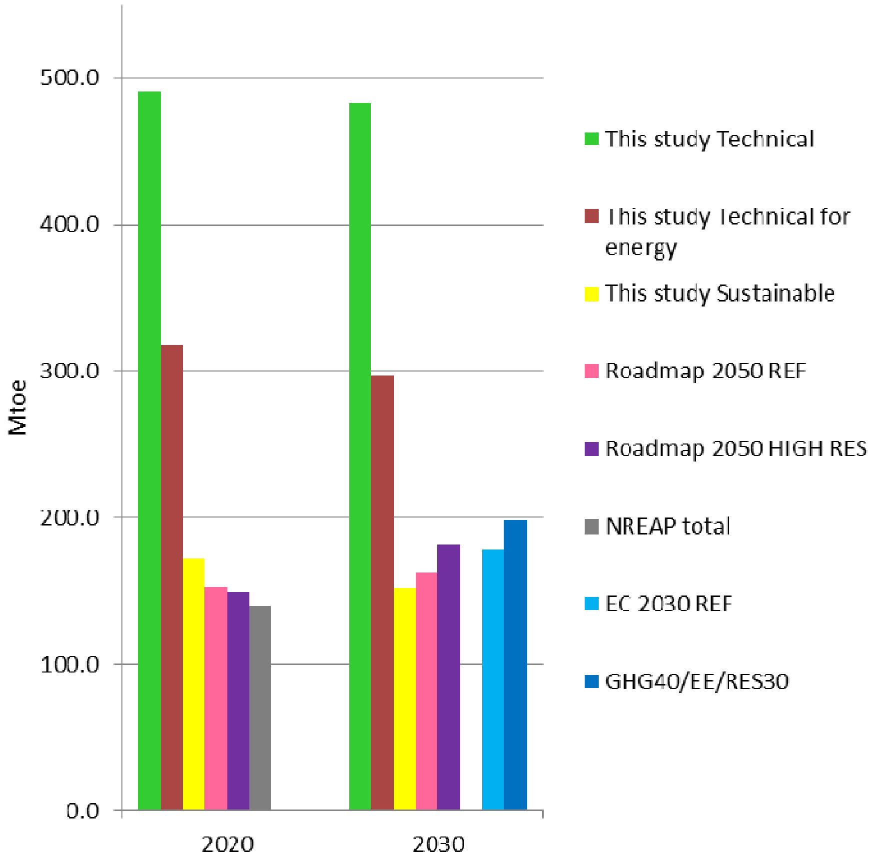

Figure 27. Energy potentials and forecast demands for biomass feedstocks (Mtoe) for 2020 and 2030.

% total primary energy consumption met by biomass	2020	2030		
% total RES target share of primary energy met by biomass			2020	2030
POTENTIALS				
This study Technical	26.0	25.5	130.2	94.3
This study Technical for energy	16.8	15.6	84.2	58.0
This study Sustainable	9.1	8.0	**45.6**	**29.7**
DEMANDS				
Roadmap 2050 REF (biomass and waste)	8.1	8.6	40.5	31.8
Roadmap 2050 HIGH RES (biomass and waste)	7.9	9.5	39.5	35.3
EC 2030 REF		9.4		34.7
GHG40/EE/RES30		10.1		37.4

Table 17. A comparison of primary energy demand met by biomass for different study scenarios compared to RES targets for 2020 and 2030.

In 2012 65.5% of all RES was biomass and waste derived (Figure 28) and whilst this figure is expected to be lower by 2015 it is significantly higher than the sustainable potential available for energy proportions in Table 17. The primary production of renewable energy within the EU-28 in 2012 was 177.3 Mtoe a 22.3% share of total primary energy production from all sources.

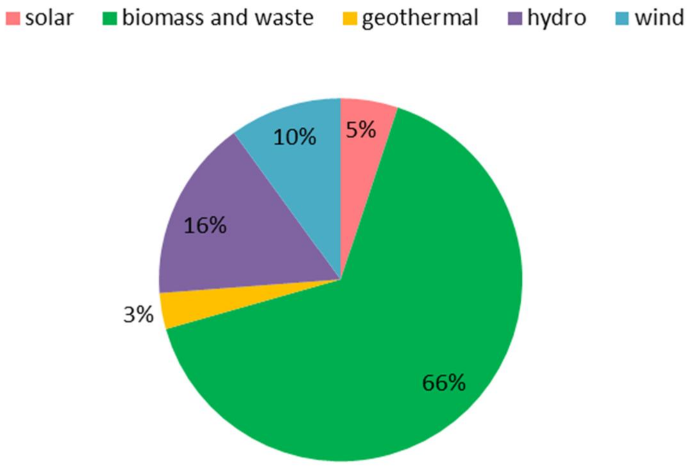

Figure 28. A snapshot of total RES primary energy production in 2012 in the EU28 by renewable energy source EUROSTAT data

In the next section we consider some scenarios for RES based on the calculated values of biomass available from this study.

7.2 Biomass energy pegged to sustainable potentials and existing renewable energy targets

Taking forward the technical potentials and sustainable potentials from this study it is possible to back calculate the energy required from non-biomass RES to meet the renewable energy targets for 2020 and 2030 (Table 18). The EU 2030 REF 21% energy savings are assumed.

Mtoe biomass	2020	2030
This study Technical for energy	317.6	297.2
This study Sustainable	171.9	152.2
Mtoe non-biomass RES required to meet target	**2020**	**2030**
This study Technical for energy	59.4	215,8
This study Sustainable	205.1	360.8

Table 18. Non-biomass renewable energy required to meet RES targets 20% 2020 and 27% 2030

For 2020 solid biomass reported as a summation of NREAPs is projected to deliver 95 Mtoe, biofuel for transport 30 Mtoe, and biogas 10 Mtoe which is around 35 Mtoe less than this study calculates as available from the EU28 under a sustainable scenario.

The target in 2020 of 20% of total energy demand (1885 Mtoe) being met by renewable energy equates to 377 Mtoe. This study shows sustainable biomass can account for 45.6% of total RES in 2020 i.e. 172.0 Mtoe of total energy demand. Using the sustainable biomass potential for 2030 of 152.3 Mtoe then 70.3% of renewable energy would need to come from a non-biomass source or sources which is the inverse of the 2013 data position (Figure 29).

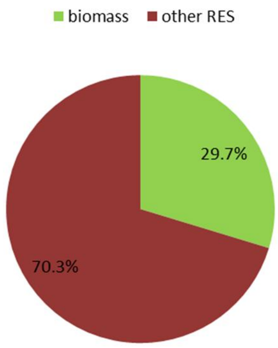

Figure 29. 2030 sustainable biomass feedstock scenario total RES primary energy

When NREAP projections for 2020 for other RES have been summed and using the sustainable potential for biomass from this study then the gap in RES is 36% shown by the yellow section in Figure 30 which is 135.8 Mtoe of primary energy consumption. The EU 2030 REF 17% energy savings for 2020 are assumed.

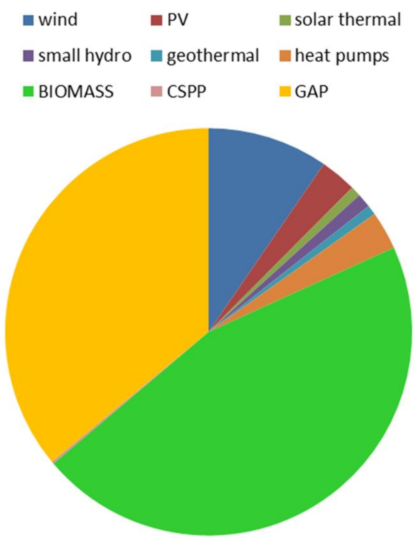

Figure 30. 2020 GAP in RES at forecast energy demand when using the sustainable potential of biomass and NREAP projections for other RES

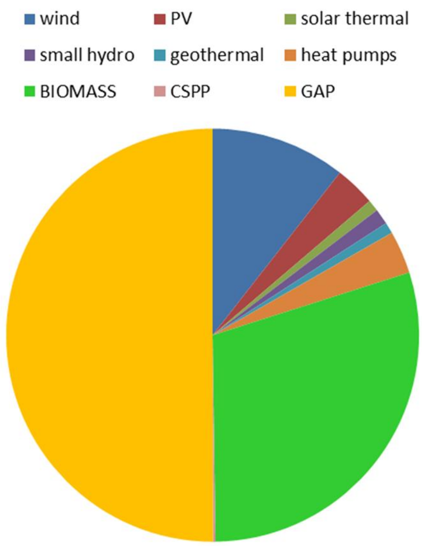

Figure 31. 2030 GAP in RES at forecast energy demand when using the sustainable potential of biomass and NREAP projections for other RES

The target in 2030 of 27% of total energy demand (1899 Mtoe) being met by renewable energy equates to 513 Mtoe. In 2030 there is 152.3 Mtoe available from sustainable biomass. The NREAP targets for 2020 have been summed for other RES and assume EurObserv'ER data trends from 2015 to 2020 continue for all RES to 2030 then the gap in RES is 50% shown by the yellow section in Figure 31 which is 256.5 Mtoe of total primary energy consumption. The EU 2030 REF 21% energy savings are assumed.

7.3 Biomass energy pegged to sustainable potentials and 45% RES target for 2030

With a more ambitious scenario of 45% of European primary energy demand being met by RES in 2030; equivalent to 855 Mtoe (Table 19).

% total primary energy consumption met by biomass	2030	
% total RES target share of primary energy met by biomass		2030
POTENTIALS		
This study Technical	25.5	56.6
This study Technical for energy	15.6	34.8
This study Sustainable	8.0	**17.8**
DEMANDS		
Roadmap 2050 REF (biomass and waste)	8.6	19.1
Roadmap 2050 HIGH RES (biomass and waste)	9.5	21.2

Table 19. A comparison of total primary energy demand met by biomass for different study scenarios compared to RES targets for 2020 and 2030.

Taking forward the technical potentials and sustainable potentials from this study it is possible to back calculate the energy required from non-biomass RES to meet the RES 2020 and 2030 European targets (Table 20).

Mtoe biomass	2030
This study Technical for energy	297.2
This study Sustainable	152.2
Mtoe non-biomass RES required to meet target	**2030**
This study Technical for energy	557.8
This study Sustainable	702.8

Table 20. Non-biomass RES required to meet 45% RES target

Using the sustainable biomass potential for 2030 then 82.2% of RES primary energy has to come from other non-biomass sources Figure 32.

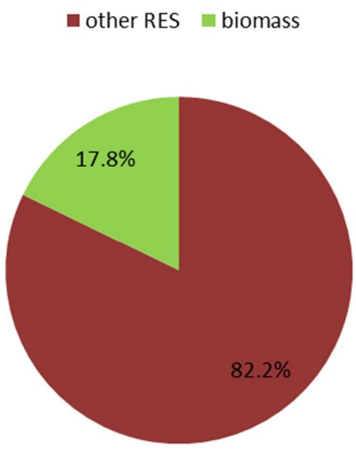

Figure 32. 2030 sustainable biomass feedstock scenario total RES primary energy

In 2030 total primary energy demand of 1899 Mtoe of which 45% (855Mtoe) is the RES target. In 2030 there is 152.2 Mtoe available from sustainable biomass. The NREAP targets for 2020 for other RES are summed and assume EurObserv'ER data trends from 2015 to 2020 continue for all RES to 2030 then the gap in RES is 68.7% shown by the yellow section in Figure 33 or 587.4 Mtoe of primary energy demand.

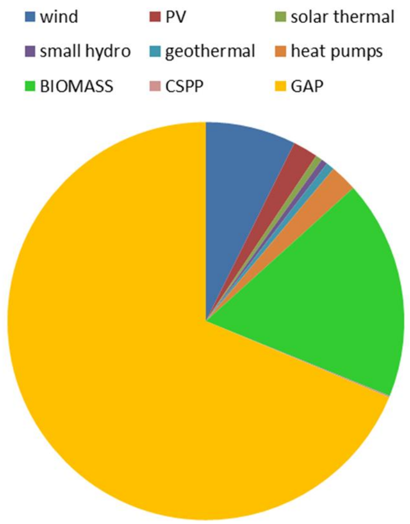

Figure 33. 2030 GAP in RES at forecast energy demand

Whilst improvements in energy efficiency and subsequent reduction in total demand may occur it is assumed that the required substantial energy efficiency measures are impossible to deploy in a 5 and 15 year time frame. The gaps identified above require a major upshift in deployment of other RES technologies if sustainable biomass conditions are to be observed AND renewable energy targets are to be met. For example:

2020 (20% RES) 135.8 Mtoe gap would require nearly 4 times increase in projected 2020 wind energy capacity or over 9 times increase in the projected 2020 solar energy capacity (PV, thermal, CSPP).

2030 (27% RES) 256.5 Mtoe gap would require nearly 5 times increase in projected 2030 wind energy capacity or nearly 12 times increase in the projected 2030 solar energy capacity.

2030 (45% RES) 587.4 Mtoe gap would nearly 11 times increase in projected 2030 wind energy capacity or over 25 times increase in the projected 2030 solar energy capacity.

These figures show the upshift in renewable deployment that is required for Europe to meet its targets, illustrated by placing reliance on one form of RES whilst maintaining the use of only the sustainable biomass potential. However, a more likely scenario is that wind and solar and a mixed portfolio will continue to develop and expand in addition to new technologies such as tidal lagoons coming on stream. NOTE EurObserv'ER data records that for most EU countries that set solar thermal targets in their NREAPs each year are drifting further and further away from them. Presented as total Mtoe (Figure 34) the forecast to meet RES contribution targets highlights the gap if only sustainable potentials of biomass are available.

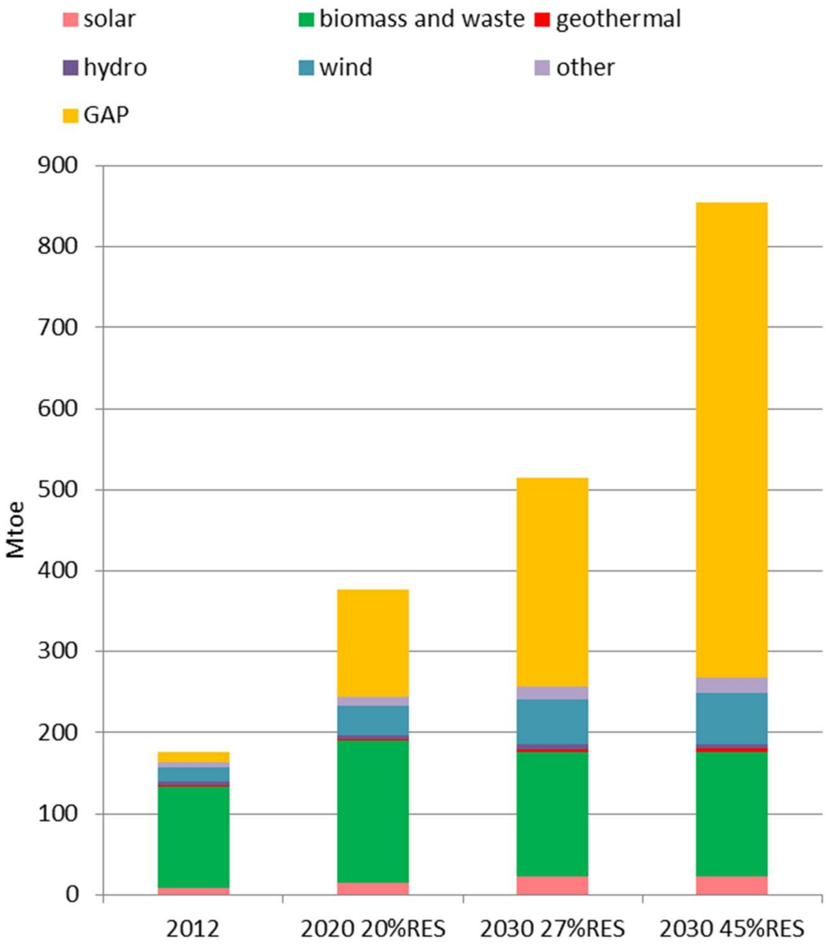

Figure 34. Scenarios presented as total Mtoe from RES sources. NOTE in 2020 it is likely that 20% overall European RES target will be met with heavier reliance on biomass than illustrated.

8 Conversion of biomass potential to energy

This study does not elaborate on different biomass energy pathways or scenarios but now considers the energy recovered from the sustainable biomass potentials identified earlier on conversion to heat, electricity, CHP and biofuel for transport.

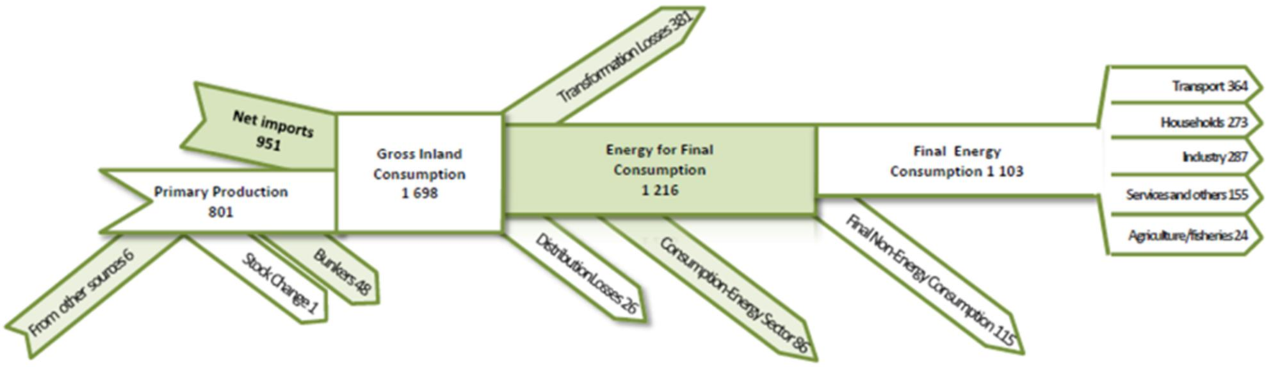

Figure 35. European Union energy flow in 2011 (Mtoe)

Figure 35 shows the gross inland consumption of energy in Europe in 2011 as 1698 Mtoe. This total consumption must take into account the losses that occur during transformation (381 Mtoe) distribution (26 Mtoe) and consumption by the energy sector (86 Mtoe). These result in an energy for final consumption (as delivered in principle) of 1216 Mtoe of which a further 115 Mtoe does not end up as final energy consumed (1103 Mtoe). The breakdown of final energy consumed is transport (364 Mtoe), households (273 Mtoe), industry (287 Mtoe), services and others (155 Mtoe) and agriculture and fisheries (24 Mtoe).

From a gross inland consumption to the final energy consumed there is a 35% loss in the system. This presents a significant opportunity to be more efficient as the equivalent identified in this study as being sustainable potential from biomass feedstocks in 2020 of 172.0 Mtoe and in 2030 of 152.3 Mtoe is broadly equivalent half to the transformation losses of all energy consumption in 2011.

8.1 Energy Efficiency

The Energy Roadmap 2050 has demonstrated that energy efficiency (EE) is a major component of any decarbonisation strategy. It is present to a very significant degree in any such scenario, but its magnitude can change - not least in correspondence to the decarbonisation ambition. With given GHG ambition (target), the magnitude of EE varies according to the recourse that is made on switching directly or indirectly (via the use of low carbon electricity in end use sectors) to fuels with no or few CO2 emissions (e.g. RES, nuclear, fossil fuels with carbon capture and storage (CCS)). The type of energy efficiency measures involved is also important.

Energy Efficiency policies and measures already adopted include:

- Energy performance of buildings Directive (EPBD)
- Energy Efficiency Directive (EED)
- Eco-design Directive and all implementing Regulations
- Energy Labelling Directive and its delegated Regulations
- CO_2 standards in transport
- Excise and emission taxes, fiscal incentives (e.g. tax rebates)

In addition measures like the EU ETS, road pricing and congestion charges, local policies to encourage walking, cycling and public transport use as well as measures to promote the development and use of innovative technologies help improving energy efficiency. The energy savings (efficiency) for the scenarios used are detailed in Table 15. For example EU 2030 REF has an overall to energy saving of 17% in 2020 compared to the relevant baseline and a 21% energy saving in 2030.

8.2 Processing losses

The impacts on biomass demand and supply of representative policy options as estimated with the PRIMES model included estimation of processing losses of biomass feedstocks. For 2030 modelled data around 40% of the total biomass feedstock potential was lost in processing the biomass feedstock[101] to produce bioenergy.

A compilation of energy conversion pathway efficiencies are presented (Table 21) as secondary energy output per unit of primary energy needed to convert biomass feedstock to energy. These indicate the differences in efficiency of conversion for biomass feedstocks. The conversions are dominated by wood and bioenergy crops such as rapeseed which do not feature significantly in the sustainable potentials of this study. Many of the feedstock conversion pathway efficiencies to electricity and transport are not available. Considering Table 21 the most efficient use of the biomass feedstock would be as heat and the least efficient in a power plant to produce electricity. In Table 22 for illustrative purposes the study considered what transformation might occur on conversion of the sustainable biomass feedstock to heat based on specific feedstock conversion efficiencies taken from Table 21.

Converting the sustainable potential to energy highlights the difference in energy that can be gained when different conversion pathways are used. In the case of heat in Table 22 an estimated 60.7 Mtoe of the

[101] EC SWD(2014) 15 final A policy framework for climate and energy in the period from 2020 up to 2030 Table 8 http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014SC0015&from=EN

sustainable biomass feedstock potential energy is lost in transformation to heat energy, representing an overall 40% processing loss or 60% efficiency of conversion.

	Heat efficiency	Power efficiency	IINAS study 2014 conversion efficiencies	
	Lauri et al 2012[102]		2020	2030
Heat plant (coal)	0.90			
logs			0.65	0.70
Heat plant (wood) pellets	0.85		0.83	0.85
District heat			0.83	0.85
Power plant (coal)		0.40		
Power plant (wood)		0.35	0.39	0.41
CHP plant (coal)	0.60	0.20		
CHP plant (wood)	0.65	0.15		
Biodiesel forest residue			0.50	0.55
Biodiesel rapeseed			0.85	0.85
Ethanol forest residue			0.50	0.60
Ethanol sugarbeet			0.70	0.70

Table 21. Energy conversion pathway efficiencies expressed as secondary energy output per unit of primary energy needed to convert biomass feedstock

Mtoe	Sustainable biomass feedstock	Conversion efficiency	HEAT
Forest stemwood	7.6	0.7	5.3
Forest residue	10.4	0.6	6.2
Non-forest woody residue	42.6	0.7	29.8
Agricultural waste	52.4	0.6	31.4
Manure	18.9	0.4	7.6
Sewage	3.0	0.4	1.2
UCO	1.2	0.8	1.0
Ligno-cellulosic waste	8.1	0.5	4.1
Landfill gas	0.5	0.8	0.4
Energy crop max potential[103]	7.4	0.6	4.4
TOTAL	**152.2**		**91.5**

Table 22. Sustainable biomass energy conversion efficiency for 2030 feedstock availability.

[102] Lauri P., Kallio A.M.I. and Schneider U.A. (2012) Price of CO2 emission sand use of wood in Europe *Forest Policy and Economics* 15 (2012) 123-131

[103] IEEP 2014 study

9 Summary & Recommendations

In Europe, there is increasing demand for biomass for energy, alongside existing (construction, pulp and paper) and more novel uses of biomass (chemicals) to produce a broad range of materials. More than half of EU's renewable energy target for 2020 is expected to be made out of bioenergy. Even though the policy framework for renewable energy until 2030 still is largely unclear, bioenergy is assumed to play an equally important role. This has led to several studies, including ones commissioned by the European Commission as well as by NGOs, already indicating increasing competition over biomass and conflicts with sustainable domestic supplies of biomass and the expected demand in 2020 and 2030.

This study aimed at improving our knowledge and understanding on the potential of sustainable biomass for energy. The main objective of the study is to facilitate progressive and robust policy to ensure the sustainable use of biomass for energy in Europe. Europe has committed itself to reduce its GHG emissions by 80-95 % by 2050 and in the shorter term, by 2020, to reduce GHG by 20%, increase the share of renewables to 20%, and save 20% energy.

Renewable energy in general is vital for our sustainable future in Europe. The fundamental big picture must ensure the greenhouse gas impacts of renewable energy are accounted for and low impact choices are made in policy initiatives. In addition, there are four key issues that are prominent when considering availability of feedstocks and the extent of using biomass as renewable energy.

1. There is an expectation both now and in all generic forecasts for renewable energy sources of business as usual and that biomass feedstocks will be the source of approximately 50% of the total renewable energy for Europe;
2. Biomass feedstocks are finite;
3. Non-energy sectors are 'competing' for biomass feedstocks;
4. Biomass as a natural and renewable resource is in most cases a intrinsic component of European ecosystems.

European Directives and Strategies indicate reductions in certain biomass feedstock availability. They also provide boundaries and limitations on the extent that energy crops could fulfil energy needs and limitations on forest and agricultural land crop extraction and management that reduce biodiversity. These strategies are priority and must remain robust.

A series of boundaries and limitations have been applied when considering potential in this study of the availability of biomass feedstocks and thus their potential for energy in order to determine the sustainability potential for biomass feedstocks in Europe.

The boundaries are:

Europe should limit the ecological footprint of its consumption, and not deliberately increase it through policies. It should focus on becoming more aligned towards consuming no more than Europe can produce (albeit that this may comprise of European sourced biomass and imported material).

Conservation as a competing demand for land and for the quality of the managed land (agricultural and forestry) must also be considered. For the final outcome the sustainable potential, additional environmental, economic and social criteria have been integrated which include:

- Increase of 5% in strictly protected forests
- 5% increase in retained trees on harvest sites
- Constraints on residue removal from unproductive poor soils and a maximum of 70% residue removal allowed on other soils.
- No stump extraction[104]
- 33% of all agricultural residue left on land to maintain soil condition[105]
- Land for energy crops should not displace food production within the current agricultural area, or do so only minimum negative impacts and risk to the environment (including ILUC)
- Any crop production must satisfy as a minimum the conditions set out under Article 17 (3) –(6) of Renewable Energy Directive[106]
- Reduce food waste generation by 30% by 2025;

Information has been taken forward from the three foundation studies (IINAS 2014; IEEP 2014; ICCT 2014) on availability of wood, land for energy crops and lingo-cellulosic waste. The study has used energy demand estimations from the various European Commission scenarios including the Roadmap 2050. New information has been gathered on forecasts of competing demands placed on those biomass feedstocks from non-energy demands such as pulp and paper or construction timber and removal of these from the total technical potential gives the technical potential available for energy.

[104] All environmental constraints for woody biomass are as in IINAS study 2014

[105] ICCT study 2014

[106] These include protection of land with high biodiversity value, high carbon stock land; land that was formerly peatland; and must respect rules governing the receipt of support through the Common Agricultural Policy

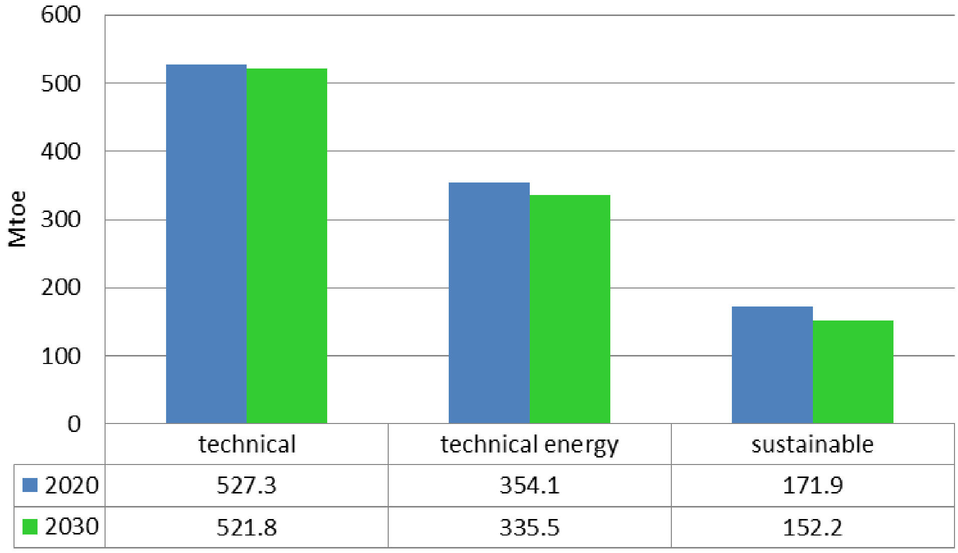

Figure 36. The sustainable potential is approximately 32.6% of the 2020 technical potential; 29.2% of the 2030 technical potential.

The sustainable potential of biomass feedstocks for energy in 2030 is calculated to be 152.2 Mtoe which is 29.2% of the total technical potential calculated (Figure 36). In all cases with the European Commission scenarios the forecast share of renewable energy that is met by biomass and waste derived under 'business as usual' scenarios is greater than the sustainable volume of biomass feedstocks calculated to be available for energy in this study.

The sustainable potential derived could yield a theoretical 8% final energy consumption met by biomass in 2030, or 4.8% of consumption if converted to heat, with the total share of renewable energy that is met by biomass as 30%. In 2012 65.5% of all RES was biomass and waste and whilst this figure is expected to be lower by 2015 it is significantly higher from the sustainable potential proportions highlighted here as 30% for 2030 (Figure 37). Even with continuing growth trends for other renewable energy sources, there is a gap between the RES targets and the sustainable amount of biomass available for energy plus the other available energy from renewables, assuming trends develop as expected in the NREAPs of EU member states. In addition the material use demands are assumed to develop according to forest sector model projections, which are in part disputed as they do not take account of structural changes in the sector and in consumption; an example being the shift from print media to electronic media. This gap is 36% of all renewable energy for 2020 and 50% for 2030. If the 27% RES 2030 target is to be met than this will require a huge upshift in deployment of wind, solar and other renewable energy sources across Europe.

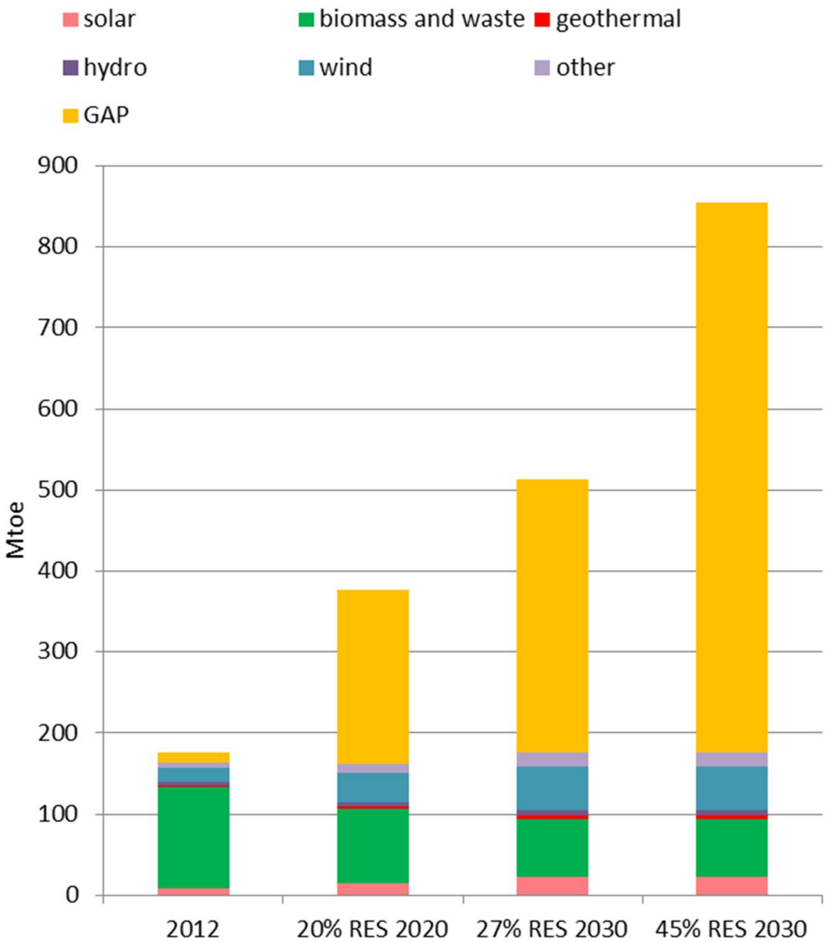

Figure 37. Scenarios presented as total Mtoe from RES sources. NOTE in 2020 it is likely that 20% overall European RES target will be met with heavier reliance on biomass than illustrated.

Biomass feedstocks have a role to play in current and future RES for Europe as it decarbonises energy. The study assumed import of biomass for energy, expanding Europe's global land footprint above current levels (1.3ha per capita), is not desired and that annual harvest increments in Europe's forests do not increase significantly. This study concludes the contribution made by sustainable biomass to European renewable energy will be relatively modest.

To challenge the conflicts with sustainable domestic supplies of biomass and the expected demand for energy in 2020 and 2030 this study recommends to:

1. Establish strict sustainability criteria for biomass feedstocks
2. Prioritise the use of resources by facilitating the use of biomass feedstocks that have not competing demands such as wastes and residues
3. Ensure biomass feedstocks go to the most energy efficient means of conversion

4. Avoid use of biomass that can be a driver for loss of biodiversity, linked to intensity of land use, direct and ILUC to ensure
5. Maintain a requirement for 33% of agricultural residue being left on the land to maintain soil condition.
6. Encourage management of forests and woodlands to be positive for carbon stocks such as systems that promote regeneration to enhance forest growth.
7. Strengthen Energy Efficiency policies and measures and deep pan-European implementation should be accelerated.
8. Unlock the deployment of solar and wind RES to begin to "live within our means" for energy.

Cutting energy consumption, limiting policy incentives, and balancing the demand and supply of biomass will allow a smooth transition to a low-carbon economy. Future energy systems need to rely on efficient and smart use of energy mostly generated from solar, wind and other renewables that don't emit carbon. Wood and biomass waste and residues can play a limited role, but require strict environmental safeguards.

Appendix A: Hierarchy of use for biomass feedstocks

Each feedstock was assigned a value on a scale of 1 to 5 (1 being good and 5 being difficult) for five criteria:

- Ease of use: defined as the ease with which a biomass feedstock lends itself to use as a biomass energy source, including closeness to point of need, amount of processing, versatility element of the feedstock
- Existing use for energy: is it widely already used for energy (1) to not used at all for energy (5)
- Alternative uses: is the biomass source unwanted by other sectors (1) or is it extensively used by other adding value sectors (5)
- Total volume: the feedstock is available in abundance (1) or available only in small or fragmented quantities (5)
- Sustainability: a subjective view on the sustainability of the feedstock, it is a co-product of another process (1) it is a primary source that is 'damaging' to access (5)
- Uncertainty/risk of future availability

These five values were then summed and the total scores were ranked with the lowest total being at the top of the hierarchy of feedstocks – i.e. the one that should be considered first for use as biomass in energy. Many of the higher ranked feedstocks in this initial first sift were waste products that had limited alternative use demands, coloured purple in Figure 2, which could be a metric for consideration of priority for potential for use for biomass energy.

RANK	Feedstock name	Ease of use and versatility	Existing use for energy	Alternative uses	Total volume	Sustainability	Sum
1	Used Cooking Oil	1	1	1	1	1	5
1	Food Waste	1	1	1	1	1	5
2	Household rubbish (Municipal Solid Waste)	1	1	1	1	2	6
3	Livestock Waste	2	2	2	1	1	8
3	Livestock processing waste industry	2	5	2	1	1	8
3	Fish processing waste industry	2	5	2	1	1	8
4	Arboricultural arisings	2	2	1	2	2	9
5	Bark	1	1	3	3	2	10
5	Demolition waste	2	2	1	4	1	10
6	Sewage	3	4	1	1	2	11
7	Chips and sawdust	1	1	5	3	2	12
7	Black liquor	2	3	1	3	3	12
7	Sawdust and Chips	1	1	5	3	2	12
7	Off-cuts	1	1	5	3	2	12
7	Refurbishment waste	2	3	1	5	1	12
8	Short rotation forestry (SRF)	1	1	1	5	5	13
8	Forest thinnings	3	2	2	3	3	13
8	Agricultural crop residue from harvest (Crop residues)	1	1	4	4	3	13
9	Lop and top (Forestry residues)	3	3	2	3	3	14
10	Harvested forest softwood	1	5	5	1	3	15
10	Construction new build site (this definition includes fence erection,	2	2	5	5	1	15

	laying a deck in an existing garden, new bridge in garden)						
10	Manufacturing waste	2	4	3	3	3	15
11	Perennial agricultural crops (Herbaceous grasses)	2	1	5	5	3	16
12	Harvested forest hardwood	1	5	5	3	3	17
12	Harvested coppice	1	3	5	5	3	17
12	Landscape management	3	5	3	3	3	17
12	Short rotation coppice (SRC)	2	1	5	5	4	17
12	Agricultural residue from processing	1	5	5	5	1	17
12	Recovered paper	1	5	5	1	5	17
12	Recovered cardboard	1	5	5	1	5	17
12	Paper pulp	1	5	5	1	5	17
12	Paper and Cardboard	1	5	5	1	5	17
12	Garden waste	1	5	5	3	3	17
13	Stumps and roots (Forestry residues)	5	3	3	3	4	18
14	Food (and fodder) crops for energy primary and secondary	2	2	5	5	5	19
15	Charcoal	1	5	5	5	5	21
15	Falling boards	1	5	5	5	5	21
16	Algae	5	4	5	5	4	23

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Appendix C Calculations

Workings #1

Using conversion factors in Table 2 of this report (Mm^3 to Mtoe conversion 0.21) the data from Table 3 of the IINAS 2014 study were converted to yield the technical potential.

2010	2020	2030	
621.3	632.4	638.9	Mm3
130.5	132.8	134.2	Mtoe

Workings #2

Conversion of agricultural residue

15,800MJ/t of agric. residues at 12-15% mc[107,108] = 0.377toe/t = 0.377Mtoe/Mt e.g. 367Mt = 138.4 Mtoe

NOTE: 3704 Kcal/kg cereal straw = 3,704,000 Kcal/t = 0.37toe/t = 0.37Mtoe/Mt[109]

Workings #3

Energy crops including SRC calculated for 2020 as the existing 5.5 Mha in energy crop production and the 1.35 Mha sustainable fraction from the IEEP study 2014, totalling 6.85 Mha in 2020. Yield taken as 11.5 dry t/ha gives 78.8 Modt converted (Table 2) to 34.7 Mtoe. A 5% growth is assumed to estimate the 2010 and 2030 positions.

Workings #4

Ligno-cellulosic waste

Food and garden waste 60% moisture content

Wood waste 20% moisture content

Paper waste 6% moisture content

107 http://www.biomassenergycentre.org.uk/portal/page?_pageid=75,17972&_dad=portal&_schema=PORTAL

108 Digest of UK energy statistics has 13.4 GJ/t for straw as net average calorific value DUKES (2013) and 15.8 GJ/t for straw gross calorific value. The energy content can be expressed as an upper (or gross) value and a lower (or net) value. The difference between the two values is due to the release of energy from the condensation of water in the products of combustion. Gross calorific values are used as the efficiency of conversion of heat energy in a fuel to, for example, electricity in a power station accounts for the moisture content. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/338750/DUKES_2014_printed.pdf

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Potential and Sustainable conversion of Mt to Mtoe

e.g. 74.6Mt = 74.6*0.4 = 29.84Modt *0.44[110] = 13.1 Mtoe

e.g. 62.2Mt = 62.2*0.8 = 49.76Modt *0.44 = 21.9 Mtoe

potential	2010	2030		2010	2030	
food and garden waste	74.6	52.2	Mt	13.1	9.2	Mtoe
wood waste	62.2	43.5	Mt	21.9	15.3	Mtoe
paper waste	23.2	16.3	Mt	9.6	6.7	Mtoe
				44.6	**31.2**	**Mtoe**

sustainable	2010	2030		2010	2030	
food and garden waste	37.6	26.3	Mt	6.6	4.6	Mtoe
wood waste	8	5.6	Mt	2.8	2.0	Mtoe
paper waste	17.6	12.3	Mt	7.3	5.1	Mtoe
				16.7	**11.7**	**Mtoe**

Workings #5

	2010	2020	2030
RWE total Mm^3	664.0	710.0	759.4
Mtoe total	139.4	149.1	159.5
Co-products total Mtoe	20.4	21.6	20.4
Stemwood only Mtoe	119	127.5	139.1

Workings #6

107,000 odt for population of 66million converted to population of 508million

107,000 x (508/66) = 823,000 ≈ 1Modt

213,000 x (508/66) = 1,639,000 ≈ 2 Modt

110 Modt to Mtoe conversion for biomass Table 2

Workings #7

213,000 odt for population of 66million people converted to population of 300,000 people

213,000 x (0.3/66) = 10,650 ≈10,000