Sub Group on Advanced Biofuels

Quick Scan Literature Review on Biofuels Feedstock Resource Availability

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Take away Messages

The key take away messages from the estimations made in this memo are:

1. There are many studies focusing on assessing the availability of advances biofuel feedstock resources for a national, EU and/or global perspective. Many of these provide information on today's resource potential and also are forward looking to 2020, 2030 or 2050

2. Each study sets out different focus areas, assumptions, calculation methods and uses different data sets. This makes it difficult to easily compare information on availability of sustainable biomass resources and their corresponding (advanced) biofuels production potential and the displacement potential for fossil fuels in road transport.

3. Two different approaches can be seen from the reviewed reports: (i) an approach based on the assessment of wastes and residues in a given, current existing, setting, and (ii) an approach which challenges the potential improvements of current practices, e.g. in the agricultural operations. The resulting estimates for biomass resource availability differ accordingly

4. Notwithstanding these differences, even the cautiously estimated share of advanced biofuel production (i.e. separate from and in addition to crop-based biofuels) on current existing, and future forecasted availability indicate a possible contribution of at least 7% in 2020 and a similar or slightly higher share in 2030 in the EU context.

5. Based on these estimates, it is concluded that for the SGAB target of 6% share of advanced biofuels in total transport in 2030 under the base scenario sufficient feedstocks resources will be available.

6. The approaches that focus on improving agricultural and/or silvicultural operations provide insights that substantially more resources could be made available for all purposes including bioenergy. This reflects a kind of 'hidden potential': the opportunities can only be grasped when efforts towards such improved agricultural, forestry and waste collection management techniques are undertaken.

7. Based on such improved practises that can be implemented relatively easily it is concluded that for the SGAB target of at least 9% of advanced biofuels in total transport in 2030 under the progressive scenario sufficient feedstock resources will be available.

Background and purpose of this memo

The SGAB group, Sub-group on Advanced biofuels to the Sustainable Transport Forum, STF, had as one of its main defined deliverables to provide a recommendation on targets for advanced biofuels in 2030. During the discussions it became clear that insights on the potential availability of biofuels resources would be supportive to understand these 2030-targets. This information summarizes insights from recent reports and studies on the potential availability of resources for biofuels in Europe. This memo does not intend to provide a scientific-level review, nor does it intend to provide a complete overview of all resource availability studies. Based on information provided by the SGAB members and observers and of members of the core-team, information has been drawn from a suggested set of reports and studies:

- Biofrontiers – Responsible innovation for tomorrow's liquid fuels; Harrison, P., Malins, C, and Searle, S., 2016
- Advanced Biofuel Feedstocks – An Assessment of Sustainability, E4Tech, 2014
- A reassessment of global bioenergy potential in 2050, Searle, S, Malins, C, 2015

- Boosting Biofuels – Sustainable Path to Greater Energy Security, IRENA, 2016
- The Energy Report – 100% renewable energy by 2050, Ecofys, for WWF, 2011
- Biomass Futures – Deliverable 3.3: Atlas of EU biomass potentials, Alterra and IIASA, for EC DG ENER 2012
- Maximising the yield of biomass from residues of agricultural crops and biomass from forestry – ECOFYS, University of Hohenheim, Unique Forestry and Land Use GmbH and Scientific Energy Centre "Biomass" study under Framework Contract SRD/MOVE/ENER/SRD.1/2012-409
- Sectorial data provided by the European Waste to Advanced Biofuels Association (EWABA)
- Sectorial data provided by the European Recovered Fuel Organisation (ERFO)

It is important to indicate that these reports have been commissioned for different reasons and in most cases not specifically address biomass resource availability for the biofuels sector in EU or provide information on the time horizon of 2030. In the following tables information from the various reports is assembled and where possible addressed towards the biofuels sector and to the time horizons of 2020 and 2030. Table 1 reflects information for the EU Context and Table 2 reflects global information on biomass resource availability

Table 1 Resource estimate and potential biofuel production (EU context)

Report	Resource estimate[1]		Resulting biofuels potential		Displacement in road transport fuels
	(tonnes, as provided in reports)	(expressed in PJ primary energy)	In tonnes advanced biofuels	in PJ advanced biofuels	
Biofrontiers, 2016	140 million tonnes of wastes and residue feedstocks		27 million in 2020		7% in 2020
Advanced Biofuel Feedstocks – An Assessment of Sustainability, 2014	2,961 wet Mt/yr			5,500 in 2020 (eq. to 128 Mtoe)	
Biomass Futures, Atlas of EU biomass potentials, 2012. Resource potentials are for total bioenergy utilisations.	314 Mtoe (2012) 375-429 (2020) *) 353-411 (2030) *)	13,100 15,700-18,000 14,800-17,200			

*) In Biomass Futures project for 2020 and 2030 two scenarios have been explored: a reference scenario (higher potentials) and a sustainability scenario (lower potentials), resulting in different levels of resource mobilization. For information please refer to the Biomass Futures reports.

[1] Information is as provided in the reports

Table 2 Resource estimate and potential biofuel production (Global context)

Report	Resource estimate		Resulting biofuels potential		Displacement in road transport fuels
	(tonnes, as provided in reports)	(expressed in PJ primary energy)	In tonnes advanced biofuels	in PJ advanced biofuels	
Advanced Biofuel Feedstocks – An Assessment of Sustainability, 2014	26,149 wet Mt/yr			51,494 in 2020 (eq. to 1,230 Mtoe)	
A reassessment of global bioenergy potential in 2050: • Sustainable energy crop production • Wastes and forestry/crop residues		40-110 thousand*) 10-20 thousand		10-20 thousand in 2050	
Boosting Biofuels, 2016, potential in 2050: • Biofuels from agricultural residues 2050 • Biofuel potential of higher crop yields • Sustainable biofuel from pasture land • Biofuels on land from reduced waste • Expanding biofuels by cultivating forests • Advanced biofuels from algae		46-95 thousand 83 thousand 142 thousand 117 thousand 83-141 thousand too early stage of development to estimate its realistic potential		18-38 thousand in 2050 33 thousand in 2050 57 thousand in 2050 46 thousand in 2050 21-56 thousand in 2050	
*) This would be the maximum plausible limit in 2050 for all energy functions (transport, electricity, heating and cooling)					

Information on Resource availability from various studies

A) Information on availability from the Biofrontiers-study

In a multi-stakeholder process initiated by European Climate Foundation for the Biofrontiers report the participating stakeholders[2] aimed to evaluate the boundaries under which advanced biofuels can contribute to mitigating carbon emissions in transport. The group "explored supply chains for low-carbon fuels, ranging from wastes and residues from households, forestry and agriculture to energy crops grown on land with low economic and environmental value. For a description of how sustainability is defined when the report discussed sustainably available resources we refer to the Biofrontiers report. In this memo we have limited ourselves to only providing the figures as presented in the report.

The report summarizes the projected sustainable available as follows for 2020 and 2030:

- In 2020, around 220 million tonnes of waste and residue feedstock are projected to be sustainably available in Europe. This could potentially deliver up 41 million tonnes of advanced biofuels, displacing up to 11% of road transport fuels. Taking into account that a large part of this resource base is committed for use in the heat and power sector, about two third of this potential could be actually available for advanced biofuels: 140 million tonnes of waste and residue feedstocks, 27 million tonnes of advanced biofuels, displacing approx. 7% of road transport fuels.

[2] BioChemtex, UPM, Clariant, Ewaba, European Climate Foundation, Du Pont, Low CVP, LanzaTech, IEEP, Transport and Environment, PetroTec Biodiesel, Novozymes.

- In addition to this potential based on wastes and residues the report indicates that "it is much harder to make an authoritative estimate of the resource that could be produced from expanding biomass cropping." The report concludes that there is "justification to proceed with a more detailed assessment particularly in relation to the nature, suitability, availability and scale of 'marginal; farmland and near farmland that might be available in order to make more informed decisions around both EU policy development as well as more practical decisions around industry deployment potential".

In one of the reviewed reports (Searle and Malins, 2013, Availability of cellulosic residues and wastes in EU) for the Biofrontiers report, it is estimated that biofuels from these resources could potentially displace 13% of road fuel consumption in 2020 and 16% in 2030, adding that competing use in other markets was not taking into account.

Background on the figure of 27 million tonnes

In Table 1, page 4, the number of 27 million tonnes of biofuels has been mentioned, following the Biofrontiers report. The report does not provide the underlying information, except that it is based on agricultural and forestry residues and wastes in EU, taking into account other energy uses and also uses in other sectors, to determine sustainable availability for advanced biofuels.

The Biofrontiers report used the information from the paper "Waste and residue availability for advanced biofuels production in EU Member States, by Stephanie Searle, and Chris Malins, published in Biomass and Bioenergy (2016) to determine this figure.

. *agricultural residue availability was estimated for 12 crops, and indicated in tonnes (dry basis)*

. *for forestry residue the same*

. *the estimate of biogenic waste availability is based on 8 different categories of waste (paper and cardboard wastes; wood wastes; animal and mixed food waste; vegetal wastes; animal faeces, urine, and manure; household and similar wastes; sorting residues; and common sludges), assuming 63% of the household waste as biogenic and 50% of sorting residues biomass based. All quantities have been converted to oven dyr basis based on moisture content data in 2006 IPCC Guidelines for national Greenhouse gas inventories, chapter 2*

These three categories bring the number of 140 million tonnes (dry basis) resource potential for advanced biofuels. To determine the biofuel potential, agricultural and forestry residues are assumed to be processed into ethanol or drop in diesel. Biogenic waste is converted into drop in diesel. Further assumptions: ethanol yield of 0,25 tonne per tonne feedstock and for drop in diesel 0,2 tonne per tonne feedstock for agricultural and forestry feedstock, conversion factor of 0,16 for biogenic waste. From this the 140 million tonnes (dry basis) results in the mentioned 27 million tonnes of advanced biofuels, being a mixture of ethanol and drop in diesel.

B) Information on resource availability from the Advanced Biofuel Feedstocks – An Assessment of Sustainability report

In 2014 E4Tech UK provided a report on Advanced Biofuels Feedstocks for a project carried out by the ARUP URS consortium for the UK Department of transport. In this report information regarding basic characteristics, supply potentials, technology compatibility, economics and sustainability has been collected on the feedstocks that are included in the Annex IX lists. For availability feedstock supply data for 2020 were collected (in million tonnes/yr and PJ/yr or biofuel equivalent) for the UK, EU and globally. The report has been published before the adoption of the Directive amending the RED and FQD (2015/1513/EU).

The report provides an overview of the current and 2020 feedstock supply in wet metric tonnes per year for wastes and residues (where appropriate: the corresponding bio-fraction) and also indicates the current feedstock supply for renewable electricity and waste carbon gases. The latter two could be used for the production of e-fuels and low-carbon fossil-based fuels. From these the current and

2020 biofuel production potential are provided. An important disclaimer in the report emphasis that these 'biofuel production potentials do not consider the availability of sufficient novel conversion plant capacity to use these feedstocks'.

This information summarized below relates to the EU figures provided in the report and has accumulated the data for the various biomass related waste and feedstocks:

Feedstock	Current feedstock supply (wet Mt/yr)	2020 feedstock supply (wet Mt/yr)	Current biofuel production potential (PJ/yr)	2020 biofuels production potential (PJ/yr)
Biomass feedstocks in Annex IX	3,124	2,961	5,345	5,500
Renewable electricity (in Mtoe)	51	82	1,536	2,455
Waste carbon gases	10	10	36	59

The 2020 biofuel production potential for EU for the Annex IX feedstocks translates to 131 Mtoe/yr[3], i.e. approximately 50% of the road transport needs in the EU. In a March-2015 memo, Shell indicates similar potentials, based on their analysis of 'credible and reasonable external estimates […]that 30 to 60 million ha of land could be spared with a potential to provide 25% to 50% of EU total transport demand".[4]

This information summarized below relates to the global figures provided in the report and has accumulated the data for the various biomass related waste and feedstocks:

Feedstock	Current feedstock supply (wet Mt/yr)	2020 feedstock supply (wet Mt/yr)	Current biofuel production potential (PJ/yr)	2020 biofuels production potential (PJ/yr)
Biomass feedstocks in Annex IX	22,349	26,149	42,010	51,494
Renewable electricity (in Mtoe)	403	575	12142	17,316
Waste carbon gases	101	138	375	511

The 2020 global biofuel production potential for the Annex IX feedstocks translates to 1,230 Mtoe/yr, also approx. half of global transport energy consumption, according to IEA information (2,550 Mtoe in 2015[5]).

C) Information from the report "A reassessment of global bioenergy potential in 2050"

In 'An reassessment of global bioenergy potential in 2050 the authors estimate global resource availability and limits for final energy use. "Even allowing for the conversion of virtually all 'unused' grasslands and savannah, we find that the maximum plausible limit to sustainable energy crops production in 2050 would be 40-110 EJ/yr. Combined with forestry, crop residues, and wastes, the maximum limi to long-term total biomass availability is 60-120 EJ/yr in primary energy. After accounting for current trends in bioenergy allocation and conversion losses, we estimate maximum potentials of 10-20 EJ/yr of biofuel, 20-40 EJ/yr of electricity and 10-30 EJ/yr of heating in 2050. These findings suggest that many technical projections and aspirational goals for future bioenergy use could be difficult or impossible to achieve sustainably."

[3] based on 41.868 PJ/Mtoe

[4] 2015, Shell, Energy crops in the EU and advanced biofuels.

[5] Derived from information in 2016, IEA, Key World Energy Statistics

In their paper Searle and Malins present a large variety of studies that have investigated biomass potentials. In Figure 1, an overview is presented with the corresponding estimates.

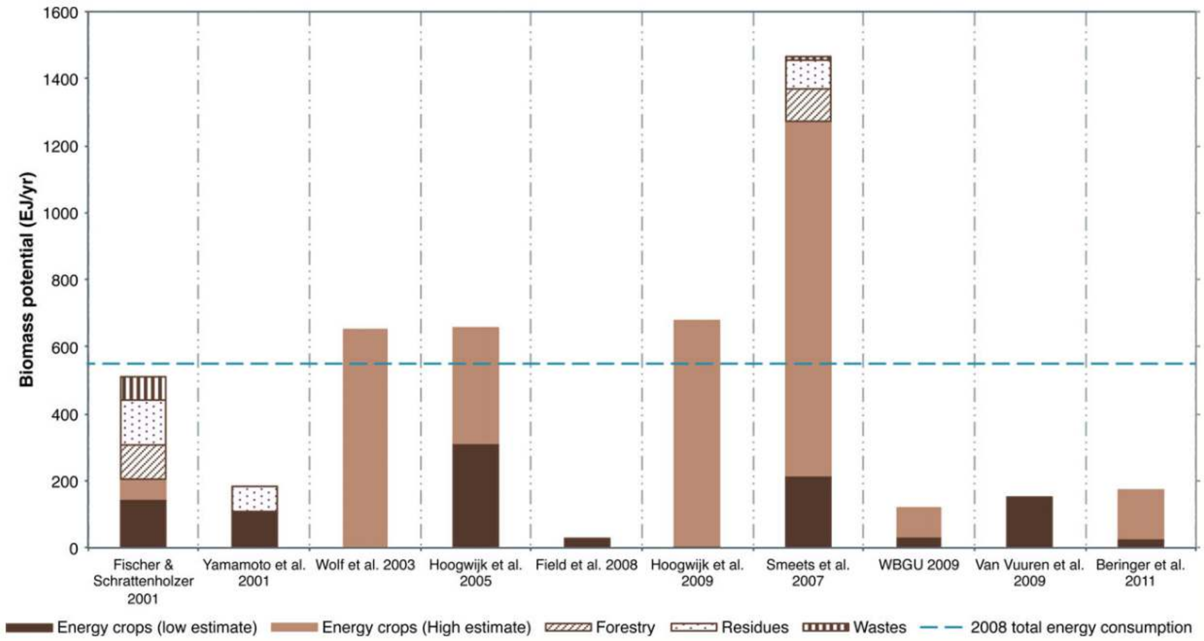


Fig. 1 Total biomass potential broken down by feedstock in original studies compared to world energy consumption.

D) Information from the 2016-IRENA report

In the recent IRENA-report Boosting Biofuels, Sustainable Paths to Greater Energy Security it is explored how to untap the substantial potential to expand both food and fuel supply in a sustainable fashion. The report investigated the following sustainable biofuel pathways:

- Boosting yields of food crops and associated residues on existing farmland;
- Freeing up existing farmland for biofuels crops through further yield improvements
- Reducing losses and waste in the food chain to free up additional farmland for biofuel crops
- Improving livestock management to free up pasture land for biofuels crops
- Afforestation using fast-growing tree species
- Cultivation of algae from organic waste streams or carbon dioxide.

The IRENA report assesses the agricultural residue potential by 2050 at 79-128 EJ. Correcting for assumed alternative use as animal feed, of these resources 46-95 EJ could be available for biofuels use. In this methodology alternative use in other energy markets (heating and cooling, electricity) is not taken into account.

The report provides insights in the amounts of biomass residues and additional biomass production that could be made available by identifying how much agricultural land could be freed up if actions were taken to counter inefficiency within the agricultural production itself, or to prevent losses in the food supply chain. As an example the report states that, following the conclusion from FAO that currently about one third of food produced from human consumption is lost or wasted globally. Based on available data, the total percentage and tonnage lost or wasted could be calculated for each food group, whether produced in developed and developing countries. On basis of this the report concluded that up to 442 million hectares of land could be freed up in 2050 by eliminating losses and waste from crops directly consumed as food, and another 340 million hectare could be made available by eliminating losses and waste of meat and dairy products. This 782 million ha of freed up agricultural should be seen in comparison to the total agricultural land worldwide, which is roughly 5,000 million ha.

With respect to bioenergy potential from algae the report concludes that algal bioenergy is still at too early a stage of development to estimate its realistic potential.

The report summarized the bioenergy potential in 2050 as follows, indicating that 102-219 EJ of advanced biofuels could be produced.

Table 4: Bioenergy Potential in 2050: Aspirational Targets and Theoretical Potential (EJ)

Category	Primary Biomass Energy Content	End-use Bioenergy with 1G Biofuel or Combined Heat and Power (80% Efficiency)	End-use Bioenergy with 2G Biofuel Conversion (40% Efficiency)	REmap Assumptions for Primary Biomass Energy in 2030 (Reference)
Agricultural Residues	46 - 95	36 - 76	18 - 38	19 - 48
Higher Crop Yields	47 - 88	37 - 70	19 - 35	0 - 0
Pasture Land	71 - 142	57 - 114	28 - 57	33 - 39
Reduced Food Waste	40 - 83	32 - 66	16 - 33	18 - 18
Cultivating Forests	83 - 141	42 - 112	21 - 56	41 - 58
Total	**287 - 549**	**204 - 438**	**102 - 219**	**112 - 162**

EJ= Exajoules

For the range of potential shown in each column, the left-hand (smaller) value represents an aspirational target, while the right-hand (larger) value represents theoretical potential.

E) Information from The Energy Report

In 'The Energy Report' WWF's vision of a 100% renewable energy supply by 2050 has been challenged. To investigate whether such a scenario would be possible, a basic assumption was that the investigation should be based on current's best available renewable energy technology. The study concluded that such a vision was possible to realise, at reasonable costs. To achieve such vision though, it would be key to bring down final energy consumption from 520 EJ in a business as usual scenario to 270 EJ by 2050 by means of aggressive end use energy savings and efficiency. Furthermore, the share of electrical energy in final energy consumption needed to increase significantly. See diagram below.

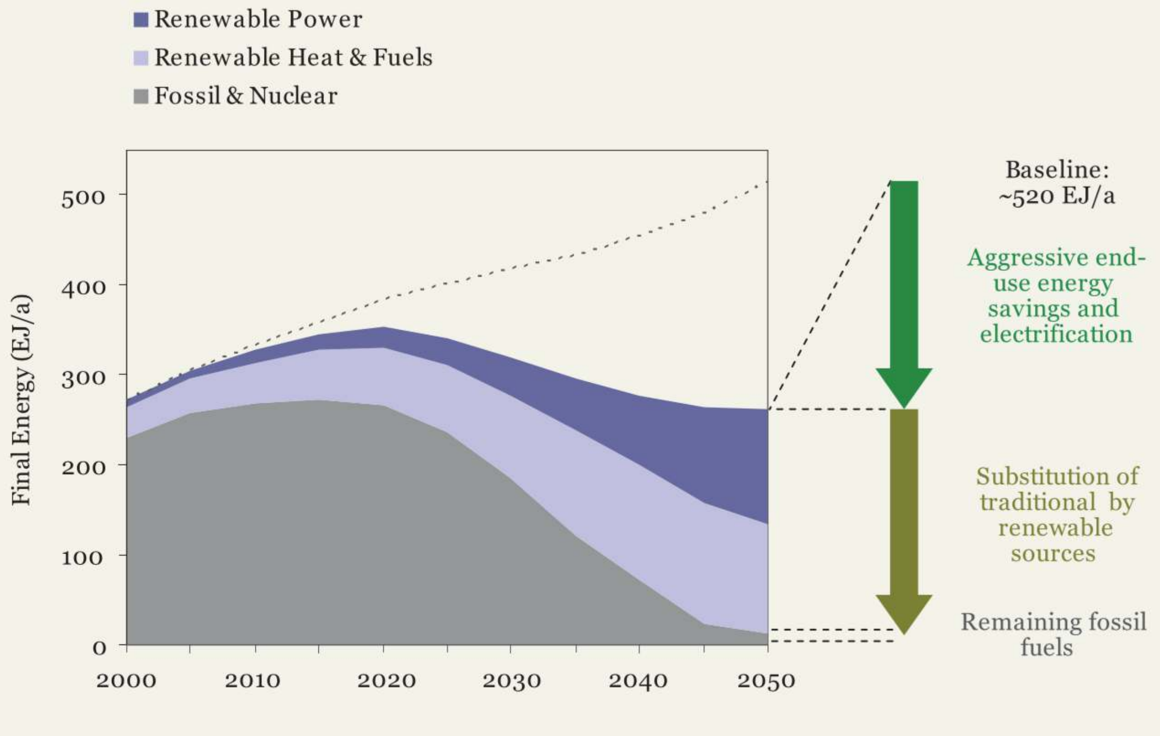


Figure 1
Evolution of energy supply in the Energy Scenario, showing the key developments.
Source: The Ecofys Energy Scenario, December 2010.

In the process of 'electrification', priority is given to solar energy, wind power and geothermal energy. Biomass would be only used for electricity generation when these other sources reached their limits. The core attention for biomass was for (in particular high temperature) heat generation and to replace liquid fuels in segments where electrification of mobility would be difficult.

The report in length discussed the supply potentials for sustainable bioenergy. While minimising the role of biomass for energy to first deploy non-biomass renewable sources like wind and energy, the reports assesses whether the supply of the required biomass would still stay within sustainable potential limits. Within the section of biomass a preference order for utilisation is followed: firstly, residues and wastes are utilised, followed by complementary fellings from forestry operations, energy cropping and ultimately, given that the state of development at the time of the report (2011) is not at commercial scale available, algae. In this scenario no food crops will used for biomass energy.

From below diagram it can be seen that the especially for energy crops and algae only a limited amount of the supply potential, i.e. land that could be made available for the production of energy crops if appropriate actions were taken. In the underlying analysis 250 million ha would be required worldwide to grow energy crops, whereas the report concluded that a total sustainable land potential of 673 million ha could be envisaged by 2050, while fulfilling the needs for food and other biobased functions from the remaining agricultural land (see next diagram).

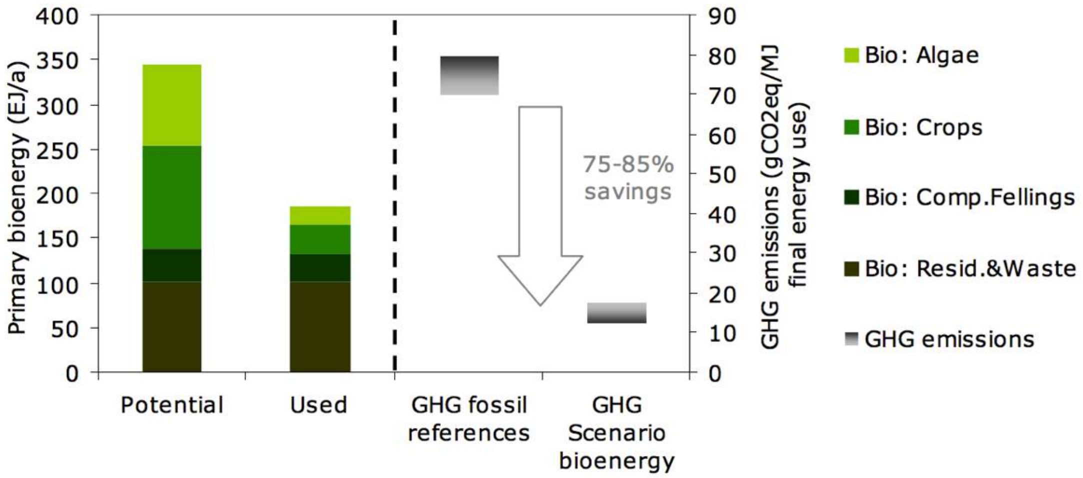
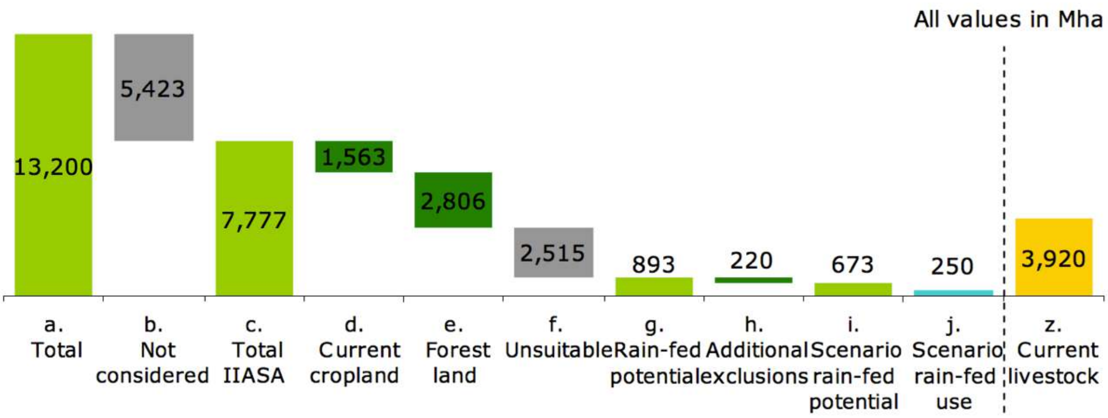


Figure 5 - 1 Overview of the Energy Scenario's sustainable bioenergy use versus sustainable potential and sustainable bioenergy greenhouse gas (GHG) emissions versus fossil references for 2050.



a. Total global land mass (excluding Antarctica)
b. Excluded: protected land, barren land, urban areas, water bodies
c. Total land considered in the IIASA study
d. Excluded: current agricultural cropland
e. Excluded: unprotected forested land
f. Excluded: not suitable for rain-fed agriculture
g. Potential for rain-fed agriculture
h. Excluded: additional land for biodiversity protection, human development, food demand
i. Energy Scenario potential for energy crops
j. Energy Scenario: land use for energy crops
z. Current land used to support livestock (for reference only; overlaps with other categories)

Figure 5 - 5 Results of the Energy Scenario assessment of land potential for rain-fed cultivation of energy crops.

Most of the biomass resources would end up being used in the transport sector (about nearly 50 EJ, see graph below), and the remaining for high temperature in industry, nearly 20 EJ and less than 5 EJ for low temperature heating in buildings.

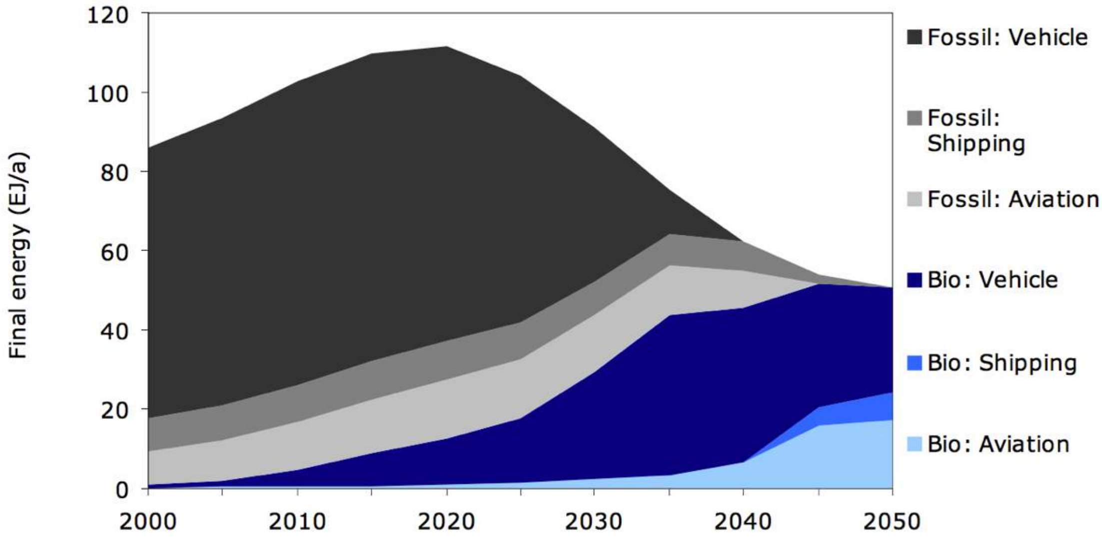


Figure 4 - 13 Split of supply options in the global Transport sector (excluding electricity).

F) Information on resource availability from the Biomass futures project

In its Leaflet document[6] the objective of the Biomass Futures is described as, among others, determining the role biomass can play in meeting the stated EU policy targets, gaining insights in the trade-offs among the energy and the non-energy market sectors for biomass. With respect to Availability & Supply the project aims to provide a comprehensive strategic analysis of biomass supply options and their availability in response to different demands and different sustainability criteria in a timeframe from 2010- 2030.

In the Biomass Futures project (reports are from 2012) the technical potential for biomass resources in Europe have been investigated for both 2020 and 2030 and for a reference and a sustainability scenario, based on different mobilisation strategies[7]. The report focuses on resources from agriculture, forestry operations and on wastes. In the agricultural and forestry operations it includes both specific grown for energy purpose resources and residues.

The numbers in the table below indicate total biomass resource availability. They are not directed towards a preferred energy sector (electricity, heating/cooling or transport. Numbers are given in Mtoe, so for PJ multiply by 41.8.

For 2030 sustainability scenario a potential of 353 Mtoe (primary energy) of residue resources is expected to be available. The project does not indicate how much of these resources would become available for the transport sector. Making the assumption that 25% of these resources could be directed to the transport sector, and assuming a conversion rate of 40% to produce an advanced biofuel would result in a potential of 35 Mtoe (final energy) of advanced biofuels. When focusing only on the wastes and residues potential the 2030 potential under a sustainability scenario would be 224 Mtoe (primary energy, resulting in 22 Mtoe (final energy) of advanced biofuels (equalling 940 PJ).

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6 See www.biomassfutures.eu. The Biomass Futures project was carried out for EC DG Energy.

7 For the sustainability scenario the following criteria were applied:
For all bioenergy consumed in the EU the following mitigation requirements are set: Biofuel/bioliquids: 80% GHG mitigation as compared to fossil fuel (comparator EU average diesel and petrol emission 2030), Bioelectricity and heat: 80% GHG mitigation as compared to fossil energy (comparator country specific depending on 2030 fossil mix). This includes compensation for iLUC related GHG emissions. Furthermore, for all bioenergy consumed in EU limitations on the use of biomass from biodiverse land or land with high carbon stock.

The largest resource potential (106 Mtoe) is to be found in the "agricultural residues" category as is indicated in the table below, whereas forestry residues also are expected to contribute 74 Mtoe by 2030.

Table 3 Potentials (Mtoe) per aggregate class compared over time and scenario (source Biomass Futures, 2012)

Resource potential (in Mtoe)	**2012**	**2020 Reference**	**2020 Sustainability**	**2030 Reference**	**2030 Sustainability**
Wastes	42	36	36	33	33
Agricultural residues	89	106	106	106	106
Rotational crops	9	17	0	20	0
Perennial crops	0	58	52	49	37
Landscape care wood	9	15	11	12	11
Roundwood production	57	56	56	56	56
Additional harvestable roundwood	41	38	35	39	36
Primary forestry residues	20	41	19	42	19
Secondary forestry residues	14	15	15	17	17
Tertiary forestry residues	32	45	45	38	38
Total	**314**	**429**	**375**	**411**	**353**

Total (waste and residues only, based on grey coloured cells))*	*206*	*258*	*232*	*248*	*224*
*) This waste-based total is added for the purpose of this report. This row was not in the table presented in the biomass Futures project					

G) Information on resources availability from the DG ENER Study Maximising the yield of biomass from residues of agricultural crops and biomass from forestry

The study addressed the potential for yield increase of agricultural crop residues and biomass from forestry in the European Union, Ukraine, Russia and Belarus. A stepwise approach was used to identify the realistic potential in the study area, starting with an estimate of the theoretical potential based on crop- and forest-type specific best practices for yield increase, which is then narrowed down to a technical-sustainable potential. The study concluded that there is a huge potential for yield increase of agricultural crop residues and biomass from forestry in the geographical areas addressed as well as in the European Union.

The realistic potential is derived from the technical-sustainable potential. Developed best practice strategies for residue yield increase were assessed with regard to their feasibility of application in the EU, Ukraine, Russia and Belarus. The realistic potential is further limited due to identified barriers which prevent or reduce the impact of best practice strategies of residue yield increase. A barrier is only caused by regional aspects, e.g. policies, social acceptance, regional economic resources.

The estimated realistic potential for agricultural crop residues and biomass from forestry in the European Union, Ukraine, Russia and Belarus is displayed in table 4 below.

Table 4: Realistic potential from agricultural crop residues and biomass from forestry

Region	Agricultural crop residues, excluding grass - Realistic potential (Mt/ year)	Biomass from forestry – Realistic yield increase (Mt/year)
EU	74.89	43.5
Ukraine	17.67	
Belarus	1.75	
Russia	27.00	2.57
Total	**121.30**	**46.07**

Increasing the yield of agricultural residues

The comprehensive analysis in the agricultural sector focusses on yield increase for straw from cereal (wheat, barley, rye, and oat) and oil crops (rape seed, sunflower), maize stover and cobs, sugar beet leave and wood from wine production. The table below displays the estimated realistic potential for agricultural crop residues. Based on Eurostat data for cultivated area for 2013, about 121 million tonnes of biomass could have been produced by agricultural crop residues.

Additionally, the study estimates the potential biomass from grassland. Grass is not a residue, but offers an enormous potential for additional biomass, as grassland need to be mowed for maintenance. The realistic potential for grasslands is 31.47 million tonnes per year, so that the overall estimated realistic potential for agricultural crop residues and grassland is 152.77 million tonnes per year.

Within the EU, residues from wheat, maize and barley contribute most to the realistic potential. Depending on the actual yield, the yield increase effect due to best practice strategies adds up to 16% for straw residues and even up to 21% for sugar beet leaves. The detailed analysis in this study divides EU Member States into regions with low, medium and high yields. In high yielding regions like France the impact is low as French farmers already apply proper crop management. Whereas in Romania, which is a low-yielding country, the impact is higher.

The realistic potential of agricultural crop residues for the EU is provided in the table below.

Table 5: Realistic potential (RP) of agricultural crop residues in the EU

Crop	Yield increase in RP through best practice strategies	High yielding (i.a. France) Mt/year	Medium yielding (i.a. Poland) Mt/year	Low yielding (i.a. Romania) Mt/year	Total Realistic potential (Mt/year)
Wheat	4-11%	5.095	6.891	19.298	31.285
Barley	7-13%	2.379	4.755	4.856	11.990
Maize	9-16%	3.096	5.020	7.339	15.455
Rye	7-13%	0.130	0.880	0.924	1.935
Oats	7-13%	0.388	0.568	0.504	1.460
Sunflower	9-16%	0.118	0.802	0.832	1.752
Rape	9-16%	0.614	2.113	5.933	8.661
Sugar beet	14-21%	0.047	0.321	0.333	0.701
Wine	13-17%	0.031	0.655	0.558	1.244
Total		11.9	22.0	40.6	74.5

For each agriculture crop the authors have developed best practice strategies to increase actual yield for a specific crop and best practice strategies specific to residue recovery rate and harvest technology. Best practice strategies to increase actual yield for a specific crop cover ideal management practices for: Crop variety, Fertilisation, Crop protection, Cultivation practices, Crop rotation and other management practices like for instance irrigation.

Increasing the yield of biomass from forests

The information base for the forestry section of this study was unfortunately quite insufficient. A harmonised dataset of European Forest Types (EFT) had to be created for the assessment. There is a high potential for yield improvements in forestry, especially in south-eastern Europe, Belarus, Ukraine and Russia. This can be seen not only in the yield increase which is achieved through the application of best practices, but is also evident when it comes to improving the rate of utilisation (e.g., through improved forest accessibility) of forest biomass which is currently readily available.

Table 6 below provides the overview of estimations for the realistic potential for biomass from forestry in the EU, Belarus and Ukraine for the most relevant forest types. The highest realistic yield increase of 21% was calculated for boreal forests.

Table 6: Realistic potential for biomass from forestry in EU, Belarus and Ukraine (in tonnes dry matter)*

European Forest Type	***Realistic Yield increase***			***Realistic utilisation rate***	***Realistic additional harvest potential***	
(EFT)	in %	1,000 t/year	t/ha/year	in %	1,000 t/year	t/ha/year
Boreal Forests	**21%**	12,852	0.41	**0%**	0	0.00
Hemiboreal Forests	**15%**	13,236	0.39	**2%**	1,637	0.05
Alpine Forests	**12%**	1,859	0.34	**4%**	507	0.09
Mesophytic Deciduous Forests	**19%**	4,853	0.39	**10%**	2,791	0.23
Beech Forests	**13%**	1,925	0.51	**3%**	326	0.09
Mountainous Beech Forests	**20%**	4,114	0.55	**13%**	2,284	0.31
Thermophilous deciduous Forests	**15%**	1,081	0.15	**2%**	130	0.02
Coniferous forests of the Mediterranean	**17%**	1,992	0.20	**1%**	117	0.01
Introduced tree species Forests	**11%**	1,594	0.26	**0%**	0	0.00
Total	**15%**	43,507	0.30	**2%**	7,792	0.05

* Please note the figures are provided in t/ha here to allow a comparison with the realistic potential of biomass from agricultural residues, whereas the calculation in chapter 3 forestry are in m^3/ha.

A realistic outcome, when applying all yield measures and under consideration of regional barriers, would increase the yield by 15% or 0.3 t/ha/year, whereas the improved utilization rate only results in an improvement of 2% or 0.05 t/ha/year. About 80% of the absolute yield effect can be obtained in the four forest types Boreal Forests, Hemiboreal Forests, Mesophytic Deciduous Forests and Mountainous Beech Forests. These forest types are dominant due to the area and yield within the nine forest types under consideration.

In Russia, when applying all yield measures and under consideration of regional barriers, the yield would increase by 10%, whereas the improved utilization rate results in an improvement of 26%. The Boreal Forests are the dominant forest type which contains about 80% of the area and 60% of the yield.

For the assessment on forests best practice strategies are formulated for the nine most relevant forest types by bundling single yield measures in appropriate combinations. In contrast to the agricultural part the focus of the assessment on forests was clearly on maximising the total wood biomass production and is not limited to particular tree parts. Best practice strategies for forests included measures on different levels:

1. Species level (Breeding, Introduction of non-native species)
2. Site level (Optimised species-site matching, Water management, Soil improvement)
3. Forest stand level (Tree species composition and mixture, Optimised management regime, Coppice improvement, Improving degraded forests
4. Forest Management level (Preventing biotic and abiotic damages, Fire management, Improving forest accessibility)
5. Forest operations level (Optimised harvesting technique, Use of previously unexploited tree compartments)

The concept of sustainable forest management (SFM), as agreed by the Ministerial Conference on the Protection of Forests in Europe (MCPFE), were always taken into consideration as guiding principles while developing the yield measures and defining best practice strategies. Due to the varying climate, topography, site conditions and forest structure not all of the yield measures can be applied within each forest type. It is important to bear in mind that the majority of management measures conducted in forestry have a long-term perspective of more than 20 years. Changes require more time than in agriculture before they take significant effect.

A number of barriers limit the application of best practice strategies to all recommended regions. As a result, the yield increase and the additional harvesting potential cannot be achieved completely within the timeline of 20-30 years. Whereas in the technical-sustainable potential the additional harvest potential of biomass from forests is 28,431,000m^3/a, it decreases to 13,244,000m^3/a in the realistic potential.

H) Information on resource availability for Used Cooking Oils (UCO)

The European Climate Foundation carried out a study by Greenea and the European Waste to Advanced Biofuels Association (EWABA) that provided the following quantitative relevant facts on the availability of EU UCO feedstock (in tons):

Collection Type	Availability	Actual collection	Uncollected volumes
Household	854,000	47,736	806,264
Professional	806,000	675,600	130,400
Totals	**1,660,000**	**723,336**	**936,664**

In general terms, Greenea & EWABA highlighted that these figures are conservative as they represent less than a third of the EU cooking oil consumption per capita, indicating that the actual existing EU volumes are far greater. Increasing collection beyond this point would however require a marketing and infrastructure framework which seems unattainable at the moment. A number of EWABA members, notably the German Association of Waste-Based Biofuel Producers (MVaK) which represents the totality of waste-based biofuels producers in Germany and Austria, have indicated that the actual collection figures for Germany and Austria are well above the levels represented in Greenea estimations.

EWABA maintains that the existing collectable resources (from households, restaurants and the food industry) are indeed far greater than these. An earlier Ecofys analysis (2013) indicated that the total UCO potential in the EU-27 is 3.55 million tonnes, which is equivalent to 8 liters of UCO per capita. This estimate, includes the gastronomy sector, food processors and households.

In this context we note that the actual EU collectable resources are in the 2.70-3.00 million range.

Achieving these levels would indeed require boosting collection practices across the EU. It is important for the European Union to develop key provisions in this direction to pave the way for future binding provisions on UCO segregation and collection.

I) Information on resource availability for Solid Recovered Fuels (SRF)

When waste derived fuels are produced according to the requirements of the CEN/TC 343 standards (namely EN15359), they are referred to as “Solid Recovered Fuel” (SRF). Today, only a small part of waste derived fuels are produced in accordance with EN15359. Nevertheless, the two terms SRF and RDF are often confused and misused. The fact that a large number of waste management companies are generating RDF, but that the term SRF is incorrectly applied, makes it hard to obtain an accurate overview of the current markets. SRF is produced from a wide range of non-hazardous wastes. Important sources include Municipal Solid Waste (MSW), Commercial & Industrial Waste (C&IW) and Construction & Demolition Waste (C&DW).

In several Member States, MSW is incinerated and thus not available for SRF production. Furthermore, the waste management infrastructure of many Member States still needs to be developed. Based on European Environmental Agency 2013 data in 2010 more than 100 Mt of MSW were landfilled in Europe (EU-28 + 5 non-EU countries). Based on these figures, an assumed 50 Mt could become available for the production of SRF/RDF.

In 2012, according to data from the European Environment Agency, 270 Mt of manufacturing waste were generated in the EU compared to 213 Mt of household waste. Manufacturing waste covers both process-specific waste and mixed waste from offices, shops etc. Estimates would suggest that 50% of all manufacturing waste is a (dry) mixed waste.

A conservative estimate would suggest that 63 Mt of SRF/RDF could be produced each year as shown in the table below.

Waste	Arising EU (Mt/year)	Assumption	Potential volume SRF (Mt/year)
MSW	213	• 50 Mt additionally available for SRF • Output MBT 35% SRF	17.5 (in addition to current production)
C&IW	270	• 50% available for SRF • Output 15% SRF	20
C&DW	630	• 20% available for sorting • Output 15% SRF	19

Currently available data indicate that approximately 13.5 Mt SRF/RDF are used in the EU. 12 Mt are used in cement plants and dedicated waste-to-energy plants. Estimates suggest a further 1.5 Mt are used in other applications. In total, more than 5,000 million m3 of Russian gas is replaced with

SRF/RDF. A first attempt assuming very moderate substitution rates shows that the market for SRF could amount to at least some 53 Mt.

A conservative estimate also shows that, today, some 63 Mt of SRF could be produced from mixed wastes such as MSW, C&IW and C&DW.

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