Sustainable and optimal use of biomass for energy in the EU beyond 2020

Final report

PricewaterhouseCoopers EU Services EESV's consortium

To

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The content of this report does not reflect the official opinion of the European Union. Responsibility for the information and views expressed in the report lies entirely with the authors.

Abbreviations

A	Annum (year)
BAU	Business As Usual
CAPEX	Capital Expenses
CAP	Common Agricultural Policy
CH4	Methane
CHP	Combined Heat and Power
CO2	Carbon dioxide
EC	EC
EU	European Union (EU28)
EUCO27	Baseline policy scenario for the 2030 goals of the EU (40% GHG reduction compared with 1990 levels, at least 27% for both RES and Energy Savings)
FQD	Fuel Quality Directive
FSC	Forest Stewardship Council
GDP	Gross Domestic Product
GHG	Greenhouse gas
GJ	Giga joule (1 x 109 joule)
iLUC	Indirect land use change
IPCC	Intergovernmental Panel on Climate Change
Ktoe	kilotonne (1 x 106 kg) of oil equivalent
Mha	Million hectare
MJ	Mega joule (1 x 106 joule)
M m^3	Million cubic metre (sometimes also hm^3 is used)
Mtoe	Million tonne of oil equivalent (41.868 PJ)
N2O	Nitrous oxide
NG	Natural Gas
NGO	Non-governmental organization
NUTS	Nomenclature of Territorial Units for Statistics
OPEX	Operational Expenses
pa	Per annum
PEFC	Programme for the Endorsement of Forest Certification
PJ	Peta joule (1 x 1015 joule)
PV	Photovoltaics
RED	Renewable Energy Directive
RES	Renewable energy supply
RES-E	Renewable electricity
RES-H	Renewable heat
RES-T	Renewable transport
SFI	Sustainable Forestry Initiative
SFM	Sustainable Forest Management
SME	Small and medium-sized enterprises
swe	Solid Wood Equivalent
T	Metric tonne (1000 kg)
toe	Tonne of oil equivalent (41.868 GJ)
UK	United Kingdom
US	United States
€bln	billions of euros
€mln	millions of euros

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Executive Summary

I.1. Background to this report

The European Union (EU) has set ambitious climate and energy targets for 2030, including an EU-wide target for renewable energy of at least 27% of final energy consumption. Energy from biomass and the renewable share of waste (hearafter abbreviated to biomass) contributes almost two-thirds (123 Mtoe, 63.1%) of the 28 Member States (MS's) primary combined renewable energy production today and is expected to further increase through 2030. A heavily debated issue in the public domain is to define the maximum supply potential of EU28 sustainable biomass, and what might be the evolution of demand by 2030, both for energy and industrial needs. In the preparation of the EU renewable energy package which was presented at the end of 2016, the European Commission (EC) carried out research and analysis on how to ensure sustainable supply, combined with optimal use of biomass for energy in the period after 2020.

The Directorate General for Energy (DG ENER) of the EC retained this Consortium led by PwC, which includes VITO, TU Wien, Utrecht University, INFRO and Rütter Soceco to support the Commission's analysis. This study includes:

- An assessment of the biomass supply potentials, in relation to the anticipated demand trends in bioenergy and material use post-2020; this task was based on a desk review of available literature, complemented by an expert workshop.
- An analysis of potential gaps in the existing EU and national policy and regulatory framework addressing the sustainability of biomass systems for bioenergy; this task was based on a desk review and an analysis of the replies to the public consultation held by the EC at the beginning of 2016 on the EU bioenergy sustainability policy.
- An identification of possible policy options and a consequent assessment of thier socio-economic and environmental impacts - with reference to a policy baseline. This task was carried out using the Green-X model and the MULTIREG model. The modelling approach assumes the achievement of the EU 2030 climate and energy framework (40% GHG savings, at least 27% RES share and at least 27% energy efficiency).

Limitations to the study and modelling include:

- *Energy efficiency assuptions*. It should be noted that the modelling approach does not include the updated 30% energy efficiency target proposed by the EC in November 2016.
- *Modelling is constrained to the EU energy system.* Actual competition effects between energy and other markets are not covered in the modelling. In the assessment of biomass supply scenarios, amounts of biomass required in other biomass markets such as food and feed and materials (including novel industrial use for biochemical production) were considered not available for EU energy use, so in fact these other markets are prioritised over energy use. Availability of extra-EU biomass imports is also exogenous to the model.
- *Impacts of sustainability regulations on the bioenergy supply are handled exogenously to our modelling system.* The assumptions used in this study to determine the impact of sustainability requirements on biomass supply potentials may not fully reflect the regional context or the design of sustainability requirements (where details can make a big difference). This is particularly relevant for the so-called 'risk-based approach' related to forestry biomass, therefore the assessment of the impacts for this policy option are subject to a relatively high uncertainty level.

- *Impacts of sustainability regulations affecting only large-scale bioenergy plants.* According to the assumption made for assessing the policy options, as default only large-scale plants are affected by certain sustainability requirements, whereas small end-users are not affected. Green-X classifies all plants above 5 MW (thermal capacity) as large-scale. On the other hand, the current policy debate refers to a 20 MW threshold. As a consequence, the Green-X modelling may overestimate the impacts of applying the sustainability criteria since it considers a larger portion of the market to be affected by the regulation. Currently plants between 5 and 20 MW represent around 16% of cumulative installed capacities of all bioenergy plants consuming wood chips at EU level.

I.2. Policy context and problem definition

I.2.1. Role of bioenergy

In a world of cheap fossil energy, the growth of bioenergy and renewable energy is mainly policy driven, through targets and incentives. Biomass represents today more than 60% of current renewable energy production in the EU28 – the majority from solid biomass. Based on the Green-X model calculations in this project, for the baseline policy scenario (EUCO27), it is expected that by 2030 the share of biomass will be around 50% of overall renewable energy production. In absolute terms, it is projected that final energy demand from biomass will stabilize to approximately 147 Mtoe by 2030, compared to 124 Mtoe in 2020.

The project considered biomass supply potentials from forest, agriculture and waste sources as well as the possibility to import biomass from outside the EU. Particularly for biomass from forests and for imported biomass, a set of future sustainable utilisation scenarios was considered, including: a "*restricted*" scenario, which presents high utilisation restrictions and reduced availability; a "*reference*" scenario, given today's circumstances; and a "*resource*" scenario, with high mobilisation efforts and maximum possible sustainable utilisation, e.g. through increased forest management.

The current estimated potential of biomass supply is consistently above today's primary production of biomass for energy in the EU28. Also in the longer term, potentials - both restricted, reference and resource potential scenarios - are clearly higher than the amounts that will be required for bioenergy demand. The domestic supply potential in the EU28 in 2030 ranges between 338 Mtoe in the restricted supply scenario to 391 Mtoe in the resource supply scenario. In practice, potential for agricultural biomass was estimated at 211 Mtoe, of which only 22-30% (45 to 64 Mtoe) is used in the baseline scenario for 2030. In terms of forestry biomass, the consumption in 2030 is estimated at 76-110 Mtoe, which is very close to the potential (79 Mtoe in the restricted potential to 146 Mtoe in the resource potential), so forestry biomass potential is expected to be largely used, particularly in case high utilisation restrictions are applied for forestry biomass. In terms of waste biomass, it is expected that 78% of the potential (23 Mtoe compared to 29 Mtoe) will be used for bioenergy in 2030. It should however be noted that despite being available, part of this supply potential may be difficult to mobilise or more expensive compared to imports. The future share of extra-EU imports is estimated to increase from 4.4% (5.6 Mtoe) in 2014 to 8% (16 Mtoe) by 2030 with range between 5% (9 Mtoe) in the restricted supply scenario to 15% (32 Mtoe) in the resource supply scenario.

I.2.2. Policy context

The EU Renewable Energy Directive (RED, 2009/28/EC) include binding sustainability criteria for biofuels for transport and bioliquids used in other sectors. For solid and gaseous biomass used in the heating and cooling sector and for electricity generation, the Commission decided in 2010 not to introduce EU-wide binding criteria but to provide non-binding recommendations to Member States, given that some had already introduced or planned to introduce national biomass sustainability requirements. The Commission reconfirmed this approach in a report published in 2014 (SWD(2014)259).

In its Communication on the 2030 policy framework for climate and energy (COM(2014)15), the European Commission proposed a new policy framework on climate and energy for 2030 including binding EU targets for GHG reduction, the share of renewable energy in energy demand, and energy efficiency improvements by 2030. This proposal was broadly endorsed by the European Council in October 2014. In 2015, in its Energy Union Framework Strategy, the Commission announced that it would propose a new Renewable Energy Package for the post-2020 period, including a new policy for sustainable biomass and biofuels. The Commission also stated in its 2015 Communication on the Circular Economy that it will 'ensure coherence and synergies with the circular economy when examining the sustainability of bioenergy under the Energy Union'.

The EU Directive on Indirect Land Use Change (EU)2015/1513), amending the Renewable Energy Directive, introduced a cap of 7% of the share of biofuels from crops grown on agricultural land to be accounted against the 10% RES in transport target, and an indicative target of 0.5% for advanced biofuels by 2020. In July 2016 the European Commission presented a legislative proposal (COM/2016/479) to integrate greenhouse gas emissions and removals from land use, land use-change and forestry (LULUCF) into the 2030 climate and energy framework, which is also in line with the Paris Agreement.

I.2.3. Nature and extent of the problem

At the beginning of 2016, the Commission organised a public consultation in view of the development of a sustainable bioenergy policy for the period after 2020. Within this project, the consultation's responses have been analysed. Among others, a key result was that more than 60% of almost 1,000 respondents see a clear need for additional legislative action on bioenergy sustainability, focusing on solid biomass and biogas. The following issues have been raised:

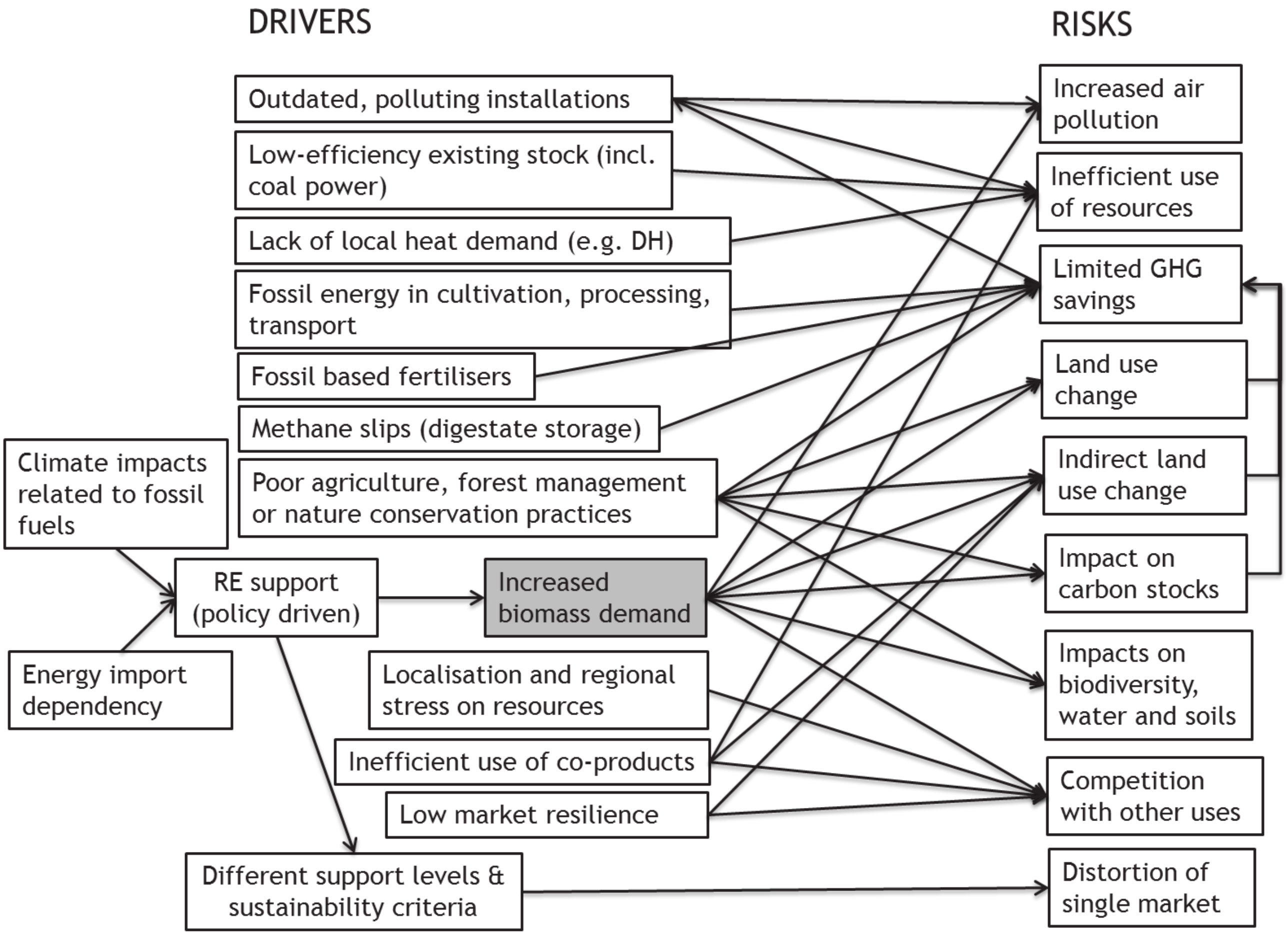
- Poor *greenhouse gas performance* of certain bioenergy pathways, due to:
    - Supply chain greenhouse gas emissions, including emissions related to direct land use change, biomass cultivation, transport and processing;
    - Biogenic emissions related to changes in carbon stock, particularly in forest and soils;
    - Indirect emissions related to displacement effects.
- Impacts of biomass production on *biodiversity, soil and water*;
- Impacts of biomass combustion on *air quality*;
- Low *conversion efficiency* of biomass to electricity;
- *Competition* with non-energy end-use markets;
- *Distortion of biomass trade* due to diverging national sustainability schemes.

In order to identify the need for additional EU action, it is important to analyse if these risks are already addressed by the existing EU or Member States' policy framework and indicate if there are policy gaps. The Project Consortium considered energy, climate, environment and agricultural policy at EU level, as well as the approaches of the UK, The Netherlands, Belgium and Denmark in terms of sustainability of solid biomass for energy.

Increased demand for biomass, incentivised by renewable energy support is a central driver for most of these risks. Green-X calculations for the baseline policy scenario have shown that the biomass supply to cover the 2030 demand for biomass resources for energy utilisation is largely European-based, around 8% of all biomass demand will be imported from outside the EU (i.e. 16 Mtoe) compared to 5.6 Mtoe in 2014 (i.e. 4.4%). Many of the identified risks, in particular related to the feedstock production, concern imported biomass from non-EU countries.

Based on all mentioned sustainability risks and linking them to potential drivers, the following problem tree was produced by the consortium, indicating the main risks and drivers for bioenergy.

Figure 0-1 Problem tree for sustainability risks related to solid biomass and biogas for heat and power



The following table provides an overview of potential policy gaps in relation to the risks listed above.

Potential risks	Policy gaps
Supply chain related greenhouse gas emissions	One of the major issues in the analysis is that, under the existing Renewable Energy Directive, binding sustainability criteria apply only to transport biofuels and bioliquids, but not for other applications like solid or gaseous biomass for electricity or heat production. This can create uncertainties and risks as some of these pathways may provide only limited GHG savings compared to fossil pathways.
Greenhouse gas emissions related to changes in biogenic carbon stocks	Risks of carbon stock loss in forests or agricultural soils are expected to be mitigated for most European Member States, as a result of well-established sustainable forest management, expressed in national forest laws and sustainable forest management certification, and clear regulatory framework affecting agricultural practices (CAP). Such regulatory frameworks might not be in place in third countries outside the European Union. This can be considered as a policy gap, particularly for imports of solid biomass. Importing biomass from countries that have not committed to LULUCF accounting may need dedicated assessment on the local impact on carbon stocks.
Greenhouse gas emissions related to indirect land use change (iLUC)	iLUC impacts are currently only accounted for transport biofuels through the amendments to the Renewable Energy Directive (in Directive (EU)2015/1513). When similar fuels like bioliquids or biogas from maize are used for electricity or heating, no limitations are applied. The iLUC impact of other (lignocellulose) energy crops is expected to be lower, as such crops can have higher energy yield per hectare. Moreover, these crops have the potential to be grown on degraded or currently unused lands. So far, knowledge on iLUC impacts of such crops is limited.
Impacts on biodiversity, soil and water	While risks in the EU are largely covered by environmental regulations, for non-EU biomass resources, these risks may not be covered with similar adequate regulations and enforcement. The Renewable Energy Directive includes provisions for biofuels and bioliquids to exclude biomass from highly biodiverse land. In relation to solid biomass for energy, only few Member States include such provisions in a national sustainability scheme, which can be considered a policy gap for the other Member States.
Impact on air quality	Emissions of medium and large scale biomass combustion are regulated through European directives; for small scale installations, Ecodesign requirements will become mandatory from 2020. The combustion in open fires, older (uncontrolled) stoves and firing places may still be an issue in relation to air quality. For the latter, Member States can take action in the frame of the National Emissions Ceiling Directive.
Efficiency of biomass conversion	Biomass co-firing or converted biomass power plants show typically low conversion efficiency compared to heating or CHP production. This is because these plants are not always aimed at valorising residual heat. Within the EU Emission Trading System (ETS) biomass is viewed as carbon neutral or zero emission. As such, this system might not promote the energy efficient conversion of biomass to electricity and/or heat, so additional provisions may be needed (e.g. in the frame of the Energy Efficiency Directive). A GHG threshold may provide an extra incentive - next to economics - to reach higher efficiency levels as the end use conversion efficiency also impacts the GHG performance of several biomass value chains.
Competition with non-energy end-use markets	Some Member States list types of biomass that under certain conditions are (not) entitled to receive support for energy production, e.g. when there are recycling options. Nevertheless, this approach is not consistently applied between Member States, which can distort the single market. Mind that bioenergy and biobased products are also complementary, as in many cases energy is a co-product of wood based products through the use of residues.
Distortion of the single market	Some Member States have developed their own approach regarding sustainability requirements for solid biomass, particularly with imports from outside the EU in mind, as EU biomass is largely governed by EU and Member States regulations. Even though they were inspired by the recommendations of the EC in COM(2010)11, the lack of EU-wide harmonized sustainability criteria for solid biomass - in contrast to biofuels and bioliquids - has led to different Member States approaches, which impacts trade options within the EU. This can be considered a policy gap.

On the basis of the gap analysis, the following key issues were identified:

- Some bioenergy pathways may have limited life cycle GHG emission reductions compared to the fossil fuel reference, in relation to biomass cultivation, transport and processing, or potentially also in relation to changes in forest carbon stocks.
- Harvesting solid biomass for bioenergy may impact biodiversity - through land use (e.g. management of forests or agricultural land), and land use change (e.g. deforestation).
- Biomass for power applications can have low energy conversion efficiency.
- Some types of biomass for heat and power may compete with other consumers of forest biomass (e.g. pulp & paper or wood panel industries).
- Different national sustainability schemes may lead to distortions of biomass trade and impact the the single market, leading to higher administrative costs for economic operators.

I.3. Policy objectives and options for EU action

I.3.1. Policy objectives

The EU’s energy policy is characterised by the following main objectives: (i) ensuring a secure and reliable energy supply; (ii) establishing a competitive environment for energy providers so that energy is available at affordable and competitive prices, and (iii) achieving a sustainable energy consumption, based on lower greenhouse gas emission and wider environmental impacts.

The EU has agreed the following 2030 climate and energy targets:

- a binding EU target of at least a 40% reduction in greenhouse gas emissions by 2030, compared to 1990;
- a EU binding target of at least 27% of renewable energy in final energy consumption;
- a EU binding target of increasing energy efficiency increase by at least 27% - to be reviewed by 2020, potentially raising the target to 30% for 2030;
- the completion of the internal energy market by reaching an electricity interconnection target of 15% between EU countries by 2030, and pushing forward important infrastructure projects.

With regard to biomass, the Commission indicated that “*an improved biomass policy will be necessary to maximise the resource efficient use of biomass in order to deliver robust and verifiable greenhouse gas savings and to allow for fair competition between the various uses of biomass resources (…). This should also encompass the sustainable use of land, the sustainable management of forests in line with the EU's forest strategy and address indirect land use effects as with biofuels. Improved energy efficiency makes an essential contribution to all of the major objectives of EU climate and energy policies*”.

These general strategic objectives can be expressed as five specific operational goals related to bioenergy sustainability: (i) ensure that bioenergy use in the EU contributes to climate change mitigation; (ii) avoid direct and indirect land use change; (iii) minimize biodiversity impacts; (iv) ensure efficient biomass convertion into energy, and (v) avoid any barriers to trade of biomass, distorting the EU internal market.

I.3.2. Options for EU action

At the request of the EC, the Consortium assessed the following policy options, aimed at addressing one or more of the key issues:

- **Option 1 – baseline**: refers to the current situation, e.g. sustainability criteria for biofuels and bioliquids, no additional EU action on biomass for heat and power. There are five alternative options to the baseline, as described below.
- **Option 2 – EU biomass sustainability criteria for heat and power**: EU sustainability criteria for biofuels are continued (as in Option 1) and they are extended to solid biomass and biogas for heat and power production. More specifically, the land criteria and cross-compliance rules for agricultural biomass are identical to the criteria for biofuels and bioliquids. For GHG savings, a specific threshold for heat and power applications is set at 70%. These requirements apply to large scale plants, i.e. above a certain scale (base case: 4-5 MW thermal biomass input).
- **Option 3a – SFM certification requirement**: this option is similar to Option 2 in terms of the land criteria for agricultural biomass and of the GHG saving criteria. For forestry biomass, the land criteria are replaced by a new criterion on Sustainable Forest Management (SFM). This means that all forest biomass used for energy generation should demonstrate compliance through SFM certification.
- **Option 3b – risk-based approach for forest biomass**: Building on Option 2, a risk-based approach is applied to minimize the risk of unstainable woodfuel harvesting. Evidence of compliance with such requirement would be gathered first at national or sub-national level in the country of forest biomass production. Where this evidence is not available, operators would be required to provide evidence at the forest holding level.
- **Option 4 – energy efficiency requirement**: This option builds on Option 2, in terms of GHG savings and land criteria; in addition, it introduces a minimum efficiency standard (base case of 65%) for the conversion of biomass in new large-scale electricity and heat installations.
- **Option 5 – stemwood cap**: Also building on Option 2, in terms of GHG savings and land use criteria; this option introduces a cap on the use of stemwood for bioenergy at the MS level. This option would not cover firewood currently used for residential heating, since such use is not covered by national support schemes and therefore cannot be easily verified.

I.4. Analysis of the impacts of the five policy options

Below are listed the criteria used to assess the impact of, and to compare and contrast, the various policy options on sustainability measures post-2020:

- biomass supply and demand
- extra-EU imports
- direct GHG savings
- land use change and biodiversity
- overall investment and operational costs
- support expenditures & households energy costs
- gross value added
- employment (including SMEs)
- administrative costs

The following is a brief summary, providing comparison between the policy options.

I.4.1. Impacts on biomass supply and demand

Supply and demand impacts are calculated through the Green-X model.

Policy option 2 (*EU biomass criteria for heat and power*) would have only limited impacts on bioenergy demand (-0.4%, ~0.5 Mtoe) compared to the baseline (policy option 1). This shows that solid and gaseous biomass used for heat and electricity generation can generally meet the threshold of 70% direct savings in GHG emissions. As for biomass supply, the model indicates a negligible decline in forest biomass demand, a very small increase in agricultural biomass and a small decline in waste biomass demand. This last is attributable to the impact of the GHG requirement on biogas plants using maize as co-feed in the anaerobic digestion (AD) process.

Policy option 3a (*SFM certification requirement*) would result in significant change for the supply and demand of biomass use in energy, based on the modelling assumption applied[1]. The model further predicts a change for forestry biomass supply (-26%, ~26 Mtoe from MS supply; -66%, ~7 Mtoe from Extra-EU imports), which is only partly offset by an increase in domestic agricultural biomass (+19%, ~10 Mtoe). As a result, bioenergy demand in 2030 would decline by 16% compared to the baseline (~23 Mtoe). Most affected is the heat sector (-24%), with the direct use of biomass for heating & cooling in households, tertiary[2] and other industrial uses expected to decline by more than 30% (~23 Mtoe). Less pronounced impacts are found for derived heat, from CHP and district heating units, and for biomass use in the electricity sector (small decline of ~1 Mtoe). To compensate for the decline of bioenergy use in heating & cooling and power generation, the energy production of other renewable sources is expected to increase. In particular, advanced biofuels using previously untapped domestic supply experience a significant increase (+20%, ~1.2 Mtoe). In addition, we expect a small shift in RES use from the heat to the electricity sector.

Less pronounced impacts can be seen for **policy option 3b** (*risk-based approach for forestry biomass*). On the basis of the simplified assumption that all Extra-EU imports of forestry biomass will be affected, this option could result in strong decline of biomass imports by 66% (~7 Mtoe). This impact would be partly offset by an increased use of domestic biomass supply from both agriculture and forestry. Total final energy demand for biomass declines by 3.3% (~5 Mtoe) compared to the baseline. The reduced contribution of biomass towards overall 2030 RES target fulfilment, specifically the decline of biomass in the heat and in the electricity sector, is off set by a small increased use of biofuels in transport and by an increased use of other RES for power generation and for heating & cooling.

Policy option 4 (*energy efficiency requirement*) implies a redirection of biomass use in the electricity sector towards efficient CHP production, affecting investment decisions in the years post-2020 since new electricity-only installations would not qualify anymore for public support or be accounted against the RES targets. As a result, a small increase in heat and CHP production from biomass is expected (~0.3 Mtoe), but the decline of bio-electricity (-5%, ~1.2 Mtoe) is more pronounced. This is offset largely by an uptake in other renewables in both the electricity and heating & cooling sectors. Total bioenergy demand is 0.7% (~1 Mtoe) lower than in the baseline.

[1] The impact of SFM requirement on EU biomass supply depends to a large extent on the applied SFM criteria. The Restricted biomass supply scenario for both domestic EU biomass supply and extra-EU imports was selected for policy option 3a (*SFM certification requirement*) implying very strict harvesting guidelines and forest management practices (focus on environmental concerns, forests are set aside to protect biodiversity with strong limitations on harvest possibilities). In policy option 3b (*risk-based approach for forest biomass*), the Restricted supply scenario only applies to extra-EU imports of solid biomass. A detailed description of the extra-EU supply scenario assumptions is provided in Table 1-1.

[2] Tertiary biomass resources are post-consumer residue streams including animal fats and greases, used vegetable oils, packaging wastes, and construction and demolition debris

Policy option 5 (*stemwood cap*) restricts the use of stemwood for energy biomass production. The model finds a 4% decline in domestic biomass use (~4.2 Mtoe) and an 8% decline in Extra-EU imports of solid biomass (~0.8 Mtoe). This is partially offset by an increased MS agricultural biomass demand (~1.9 Mtoe). Under this policy option total bioenergy demand is reduced by 2.7% (~4 Mtoe) compared to the baseline. The most significant demand changes (-5%, ~3.5 Mtoe) are found in the direct use for heating & cooling (in households, tertiary and industry). The decrease in biomass use is partly offset by a strongly increased use of other RES, particularly RES electricity (RES-E).

Impact on Extra-EU solid biomass imports

Impacts on biomass imports are assessed through the Green-X and ArcGis Network modelling system.[3] In the baseline scenario, Extra-EU imports of solid biomass are estimated to increase to more than 10 Mtoe by 2030, from 3.9 Mtoe in 2014. The US, Canada and Russia are expected to remain large suppliers to the EU, respectively accounting for 37%, 10% and 10% of total imports. There will likely also be imports of palm kernel shells from South-East Asia (~5% of imports), straw pellets from Ukraine (~8% of imports). Also, relatively large amounts of wood pellets are imported from energy crops cultivated in Sub-Saharan Africa (~21% of solid biomass imports). Note however that, as a result of the negative investment climate and political instability, this development is highly uncertain.

The implied chain of custody costs of policy option 2 (i.e. land and GHG saving criteria) are relatively small compared to the total cost of imported pellets. Also, the efficiency criterion of policy option 4 does not significantly affect these international supply chains (< 2%) because by 2030, imported solid biomass is mainly used in efficient heat applications (82%). On the short term to 2020, extra-EU imported wood pellets will mainly be used for dedicated power generation, for example in co-firing and converted coal units to pellets (AEBIOM 2016). Many of these projects might however end before 2030 whilst heat markets are less dependent on support schemes and show continuous expansion. It is therefore possible that imported wood pellets will shift to residential and commercial heating applications in the future.Under the assumption used in this report[4], policy option 3a (SFM certification) and policy option 3b (risk-based approach for forestry biomass) assume the same reduction in extra-EU solid biomass supply[2]. Both policy options would therefore reduce biomass imports by up to two thirds. Policy option 5 (stemwood cap) would reduce pellet imports from non-EU countries by at least 8% as a result of the increased cost of pulpgrade stemwood used as feedstock for wood pellet production.

I.4.2. Environmental impacts

Impact on direct GHG savings

Direct GHG impacts are assessed by the Green-X model following the EU common GHG accounting methodology. Policy option 3a (*SFM certification*) delivers the highest GHG emission savings of all options considered. This option could provide an additional avoidance increasing to 69 Mt CO_2 per year by 2030, representing an increase in emission savings of renewable energy of ~4.5% compared to the baseline. Over the period 2021-2030, cumulative emission savings amount to 173 Mt CO_2 which is only 2.5 times the GHG avoidance achieved in 2030. This indicates that the increase in GHG savings does not follow a linear trajectory. Instead, increases in GHG savings are expected to be more pronounced in the final years close to 2030 when stronger modal and sectoral shifts in bioenergy and in RES use are applicable. These significant improvements in GHG performance are caused by the shift of RES demand

[3] Impacts concerning the availability of imports (and domestic EU potentials) are handled exogenously to our modelling system, reflected in scenario assumptions (see for example Table 1-1). The supply scenario assumptions are general and do not accurately reflect the impact of the assessed policy options.
[4] It should be noted that the strongly reduced supply of solid biomass is the result of very conservative assumptions regarding impacts on biomass imports as described in Table 1-1. The actual impacts will highly depend on how the risk-based approach will be actually implemented.

from heating & cooling to the electricity sector. Fossil-based electricity on average has a higher carbon intensity per unit of final energy than fossil-based heat supply, due to the difference in thermal conversion efficiency of electricity (generally 25-45%) and heat applications (generally 75-90%). Therefore, replacing fossil-based electricity yields higher fossil fuel savings and a higher net GHG impact per unit of electricity generated compared to replacing fossil-based heat[5].

In contrast, the GHG performance of policy options 2 (*EU biomass criteria for heat and power*) and 4 (*energy efficiency requirement*) are both very similar to policy option 1 (baseline). Policy options 3b (*risk-based approach*) and 5 (*stemwood cap*) result in significant GHG savings of 24 Mt CO_2 and 17 Mt CO_2 by 2030 respectively, a reduction of GHG emissions of 1.5% and 1.1% when compared to the baseline.[6] This is linked to the reduced use of bioenergy and a shift away from renewable heat to renewable electricity and the linked higher GHG savings of replacing fossil electricity compared to fossil-based heat as outlined above.

Impact on land use change and biodiversity

Impacts associated with land use, including impacts on biodiversity, were assessed only qualitatively, based on the projected demand for dedicated energy crops.

Policy option 3a (*SFM certification*) shows the largest difference in agricultural land use in the EU compared to baseline due to its strict requirements for forestry biomass. The reduced supply of forestry biomass partly leads to a shift to the cultivation of perennial lignocellulosic crops (e.g. willow, grassy crops, i.e. neither food nor feed), increasing the total area to 2.2 Mha of perennial crops by 2030 compared to 1Mha in the baseline scenario. Under policy option 3a, total arable land used for the cultivation of energy crops, including oil, sugar and starch crops (i.e. those in the food and feed categories), is 22% larger (~1.4 Mha) compared to baseline.

Policy option 3b (*risk-based approach*) reduces availabilities of Extra-EU forestry biomass driving increases in MS agricultural land use of 6%, when compared to baseline. An additional 0.2 Mha is used for biofuels (oil, starches, sugar) when compared to baseline, another 0.2 Mha is under cultivation of perennial crops.

The increased supply cost of stemwood in policy Option 5 (*stemwood cap*) leads to almost the same increase in agricultural land use in the EU when compared to policy option 3b (*risk-based approach*). Policy option 2 (*EU biomass criteria for heat and power*) and policy option 4 (*energy efficiency requirement*) show no significant impact on agricultural land use when compared to the baseline.

I.4.3. Economic impacts

Impact on overall investment and operational costs

Overall investment and operational costs are assessed through the Green-X model. Policy option 3a (SFM certification) shows the largest deviation from option 1 (baseline) in terms of investments in all types of renewables. Average Capital Expenditures (CAPEX) increase by 24% for renewable energy in total (€12.7bln per annum) within the period 2021-2030 – i.e. up from €53.0bln to €65.7bln pa. CAPEX for biomass installations is reduced by 24% (i.e. from €22.2bln to €16.8bln pa). The reduction in CAPEX for biomass is equal to the decrease in biomass usage.

[5] For example, the fossil fuel comparators (FFC) defined in the SWD(2014) 259 are for heat: 80 gCO_2/MJ_{heat} and for electricity: 186 $gCO_2/MJ_{electricity}$.

[6] The corresponding cumulative savings compared to baseline over the whole period 2021-2030 are 153 Mt CO2 under policy option 3b (*risk-based approach*) and 108 Mt CO2 for policy option 5 (*stemwood cap*).

Policy option 2 (EU biomass criteria for heat and power) investments are barely distinguishable from the baseline, and the other policy options (with exception of option 3a, see above) show relatively small changes, ranging from an average increase in CAPEX for all renewables of 2% for policy option 4 (energy efficiency requirement) and 5.5% under policy option 3b (risk-based approach). The declines in CAPEX for biomass installations under policy options 3b and 5 are also due to the decrease in biomass use, driven by their stricter sustainability criteria.

Higher investments in other more capital-intensive renewable energy technologies, such as solar and wind, would lead to lower Operational Expenditures (OPEX). However, relative changes in OPEX results are smaller in magnitude than those for CAPEX. For policy option 3a (SFM certification) a 3.1% decline in OPEX (-€2.8bln pa) is seen on average for total renewable energy in the period 2021-2030, whereas biomass total OPEX shows a decrease of about 6.5%.

A combined consideration of CAPEX and OPEX shows that the increase in CAPEX clearly outweighs the decline in OPEX for total renewable energy. For instance, for policy option 3a (*SFM certification*) an increase in CAPEX+OPEX of about €10.0bln pa throughout the period from 2021-2030 can be identified. Policy option 3b (*risk-based approach*) leads to an increase in CAPEX+OPEX of €3 bln pa; a similar number is found for policy option 5 (*stemwood cap).* The impact for policy option 2 (*EU biomass criteria for heat and power*) is around €0.3bln pa; for policy option 4 (*energy efficiency requirement*) it is €0.6bln pa.

Impact on support expenditures & households energy costs

Support expenditures are also assessed through the Green-X model. Within this report we have assumed that support expenditures will be entirely passed on to households, leading to a decrease in real purchasing power of households.[7]

Support expenditures vary significantly for *new installations post-2020.* This is because significant changes in available RES capacities post-2020 (once most "low hanging fruit" opportunities are completed) combined with the phase-out of existing bioenergy plants, will require more expensive RES technologies to be deployed. These technologies will require higher financial incentives precipitating an increase in related expenditures.

Both policy option 2 (*EU biomass criteria for heat and power)* and policy option 4 *(energy efficiency requirement)* could lead to modest increases in support expenditures of around 3% (€0.4bln pa) on average in the period 2021-2030*.* There is a potential doubling of support costs for policy option 3a (*SFM certification*), i.e. by 118% (€14.1bln pa). For option 3b (*risk-based approach*), support expenditures for new installations increase by as much as €3.9bln pa. For option 5 (stemwood cap), the increase is €2.8bln pa.

Total renewable energy support expenditure, which includes those renewable energy technologies installed by 2020 plus new installations, shows an increase in annual support expenditures under all policy options compared to baseline (option 1). This increase is negligible under policy options 2 (*EU biomass criteria for heat and power*) and 4 (*energy efficiency requirement*) – i.e. support expenditures increase by 0.1% (option 2) and 0.3% (option 4) on average, respectively. However under policy option 3a (*SFM certification*) annual support expenditures are significantly increased by 23% (€14.3bln pa). Policy options 3b (*risk-based approach*) and 5 (*stemwood cap*) produce moderate increases of ~6% (€3.6bln pa) and ~4% (€2.2bln pa), respectively.

Impact on gross value added

Our analysis shows small but positive impacts on gross value added in the EU for all policy options, ranging from €0.3bln pa for policy option 2 (*EU biomass criteria for heat and power*)

[7] It is common practice across EU MSs that support expenditures for renewable energies are to a large extent passed on to households. Generally, the remainder of related cost is paid by the service sector and by industry, and these costs would then, in last consequence, be transferred on to households in an indirect manner.

to ~€5bln pa for policy option 3a (*SFM certification*). The differing results come from the specific relationship each policy option has on additional expenditures for RES use - a positive economic impact, and additional policy support expenditures or a negative economic impact. The increasing use of capital-intensive RES technologies such as wind and PV rather than the more labour intensive biomass technologies has the general effect of increasing value added for all policy options studied here.

The projected impacts are modest compared to the overall EU GDP, but there are differences between the policy options in terms of structural shifts between RES technologies and between industries. These shifts are most pronounced for policy option 3a (*SFM certification*), mid-range for options 3b (*risk-based approach*) and 5 (*stemwood cap*) and smallest for options 2 and 4. These differences are attributable to the specific patterns of RES deployment versus policy support expenditures in the five contrasting policy options. For example the comparatively large increase in value added under policy option 3a (*SFM certification*) is partly due to the substitution of bioenergy plants to more capital intensive technologies like wind power. Higher capital intensity leads c.p. to larger direct value added impacts. Furthermore, indirect effects occur in the supply chains of RES technologies on one hand (deployment effect) and of goods and services purchased by households on the other hand (income and budget effect). They are a result of complex shifts between industries and countries active in the respective supply chains.

Impact on administrative costs

The Standard Cost Model methodology was used to assess the administrative costs incurred by economic operators and public administrations for each policy option. There are some uncertainties in the estimates, they should be considered as "order of magnitude" estimates. The exact burden will depend on system design, e.g. if market participants can use default values, build on existing governance systems, demonstrate compliance through certification systems, need to perform specific auditing or can apply self-declarations.

In the baseline option, administrative costs are related to sustainability requirements for biofuels. For public administrations one-off costs are inexistent as no further transposition of laws are needed and recurring costs were estimated to be nominal.

In policy option 2 *(EU biomass criteria for heat and power)* administrative costs are added compared with the baseline scenario, as biomass-based heat and power generators will need to demonstrate compliance with the sustainability criteria. Private operators need certification to comply with land requirements in this case. On the other hand, public administration one-off costs are present because they need to adapt the extension of land criteria to national legislation and recurring costs are higher because it is necessary to verify more biomass and end users.

For policy option 3a *(SFM certification requirement)* administrative costs for economic operators and public administrators would be the highest of all considered options because of the new forest certification requirement for forest operators. For public administrations, one-off and recurring costs are higher than baseline and policy option 2 (EU biomass criteria for heat and power) due to the higher effort to adapt national laws to the extension of land criteria jointly with SFM certification.

In policy option 3b *(risk-based approach for forestry biomass)* total administrative costs are higher than baseline and lower than other options because forests within the EU are considered low-risk areas, with moderate efforts to show compliance.

In policy option 4 *(energy efficiency requirement)*, administrative costs for private participants and public administrators are higher than the baseline and policy option 2 (EU biomass criteria for heat and power), but less than option 3a (SFM certification). From private participants' side, this is because new plants above 4 MW installed post-2020 need to demonstrate compliance with the energy efficiency requirement. From the public administration side national laws need to be adapted to the energy efficiency criteria and there is more effort needed by public administrations in monitoring and verification activities.

In policy option 5 *(stemwood cap)*, administrative costs for private participants and public administrators are higher than baseline and somewhat higher than in option 2 (EU biomass criteria for heat and power). More effort is needed to demonstrate the roundwood cap requirement for private participants.

I.4.4. Social impacts: on employment & SMEs

The Multireg model was used to assess social impacts of the indientified policy options. The employment results are a combination of outcomes for value added and impacts on labour productivity. Labour productivity increases for all policy options due to the shift from biomass to more capital-intensive RES technologies, such as wind and solar technology.

The modeling indicates negligible positive impacts on employment in the EU28 for all policy options compared to baseline, ranging between an extra 3 to 7 thousand job-years for policy options 2 (*EU biomass criteria for heat and power*), 3a (*SFM certification*), 3b (*risk-based approach for forest biomass*) and 4 (*energy efficiency requirement*) and 20 thousand job-years for policy option 5 (*stemwood cap*). With relative increases in EU employment between 0.001% and 0.009% and considering the underlying data and modelling uncertainty, the impacts can be considered as being in the same order of magnitude. Employment by SMEs ranges between 2 and 5 thousand job-years for policy options 2, 3a, 3b and 4 and 13 thousand job-years for policy option 5.

I.4.5. Summary of the impacts of the identified policy options

The following table presents a summaryof all impacts analysed for all policy options:

Table 0-1 Summary of the impacts of the policy options (compared to the baseline)

Impacts on: (compared to option 1 - baseline)	Policy option 2 EU biomass criteria for heat and power	Policy option 3a SFM certification	Policy option 3b Risk-based approach for forest biomass	Policy option 4 Energy efficiency requirement	Policy option 5 Stemwood cap
Biomass supply and demand	0.5% decline in biomass demand	16% decline in biomass demand Strong shift from RES heat to (non-biomass) RES electricity and biofuels Strong decline of forest biomass supply (under modelling assumptions), only partly offset by an increased use of agricultural biomass	3.0% decline of biomass demand Small shift from RES heat to (non-biomass) RES electricity Strong reduction of Extra-EU import of forest biomass (under modelling assumptions)	1.5% decline of overall biomass demand	2.3% decline of overall biomass demand, in particular for heat production from biomass (-4%) Mainly counter-balanced by a growth of (non-biomass) electricity
Direct GHG savings	+0.1% GHG savings	+4.4% GHG savings	+1.5% GHG savings	no impact	+1.1% GHG savings
Land use change	No additional agricultural land use	Reduced supply of forest biomass results in shift to energy crops (+1.4 Mha)	Reduced supply of forest biomass results in shift to energy crops (+0.4 Mha)	No additional agricultural land use	Reduced supply of forest biomass results in shift to energy crops (+0.3 Mha).
Overall investments and operational costs	+€0.4bln pa increase in CAPEX for RES Combined effect of CAPEX+OPEX of +€0.3bln pa	+€12.7bln pa increase in CAPEX for RES Combined effect of CAPEX+OPEX of +€10.0bln pa	+€2.9bln pa increase in CAPEX for RES, minor impact on OPEX Combined effect of CAPEX+OPEX of +€3.0bln pa	+€1.1bln pa increase in CAPEX for RES Combined effect of CAPEX+OPEX of +€0.6bln pa	+€2.3bln pa increase in CAPEX; OPEX increases Combined effect of CAPEX+OPEX of +€3.2bln pa
Support expenditures/household	+0.1% (€0.06bln pa) increase of renewable energy support	+23% (€14.0bln pa) increase of renewable energy support	+6% (€3.6bln pa) increase of renewable energy support	+0.3% (€0.2bln pa) increase of renewable energy support	+4% (€2.2bln pa) increase of renewable energy support

energy costs	expenditures	expenditures	expenditures	expenditures	expenditures
Gross value added	Value added increase of €0.3bln	Value added increase of €4.8bln	Value added increase of €1.4bln	Value added increase of €0.9bln	Value added increase of €2.1bln
Employment (including SMEs)	4,400 extra jobs SMEs: 3,500 extra jobs	6,000 extra jobs SMEs: 2,000 extra jobs	7,000 extra jobs SMEs: 5,000 extra jobs	3,000 extra jobs SMEs: 2,200 extra jobs	20,000 extra jobs SMEs: 13,000 extra jobs
Administrative costs	Administrative cost estimation on average €30mln pa higher than baseline	Administrative cost estimation on average €55mln pa higher than baseline	Administrative cost estimation on average €22mln pa higher than baseline	Administrative cost estimation on average €43mln pa higher than baseline	Administrative cost estimation on average €43mln pa higher than baseline
Extra-EU Imports	Marginal impact on Extra-EU imports (+0.1%)	66% (6.9Mtoe) reduction of solid biomass imports from non-EU countries 18% (1.0 Mtoe) higher Extra-EU imports of liquid biofuels	66% (6.9Mtoe) reduction of solid biomass imports from non-EU countries 4% (0.2 Mtoe) lower Extra-EU imports of liquid biofuels	Limited increase of Extra-EU imports (+1%, +0.2Mtoe)	8% (0.8Mtoe) reduction of solid biomass imports from non-EU countries 5% (0.3 Mtoe) lower Extra-EU imports of liquid biofuels

I.5. Conclusions

Final consumption of biomass for energy in the EU28 is estimated at 105 Mtoe in 2013, which corresponds approximately to two thirds of total renewable energy production. Under a baseline scenario, bioenergy consumption could increase to 146 Mtoe, representing still over half of total EU final renewable energy consumption. This is equivalent to a primary supply of biomass of 195 Mtoe (128 Mtoe in 2013, of which 4% was imported).

Five different policy options (below: 2, 3a, 3b, 4 and 5) for EU action on bioenegy sustainability post-2020 were analysed and their likely impact was assessed in relation to the baseline (policy option 1).

Policy option 2 (EU biomass criteria for heat and power) extends sustainability criteria for biofuels to both solid biomass and biogas, for heat and power production. A specific GHG saving threshold for heat and power applications is set at 70%, covering also the efficiency of the energy facility. These requirements are applied to plants above a certain size (base case: 4-5 MW thermal biomass input).

Overall, this option has minor impacts on the demand for biomass for energy compared to the baseline. The 70% threshold for GHG savings is not a limiting constraint for most heat and power based bioenergy value chains. Even though impacts on bioenergy deployment are expected to be minor, this option does provide minimum safeguards against biodiversity and carbon impacts related to direct land use change (deforestation), similar to the current sustainability criteria for biofuels, which may be of particular relevance for Extra-EU imports. It also creates a more uniform approach across Member States, reducing the risk for Intra-EU market trade flow inefficiencies. This option does incur additional administration costs, as biomass-based heat and power generators will need to demonstrate compliance with the sustainability criteria. The exact burden will depend on a variety of factors discussed in the last paragraph of this section.

Policy option 3a (SFM certification) builds on option 2 in terms of required GHG savings. The existing land criteria would apply only to agricultural biomass (independently of the final energy use), while a new criterion on Sustainable Forest Management (SFM) applies to all forest biomass consignment used for energy production.

Considering the amount of forest land that is currently certified, which is largely country or region dependent, the SFM requirement is expected to dramatically limit the availability of forest biomass for energy production, particularly from non-EU sources, a direct implication of the assumed restrictictions with respect to forest management (conservative with strong limitations with respect to harvest possibilities) and development of new extra-EU supply regions. The impact on the supply side, both domestic and imported is only partly offset by an increased use of agricultural biomass, causing an estimated 22% increase in land producing energy crops. Overall biomass demand would decrease by 16% compared to baseline in 2030. There would be a strong shift from renewable heat to non-biomass renewable electricity and biofuels. This would require considerably more capital expenditure in subsequent years, which is only partly offset by lower operating costs. In choosing this option to reach the 2030 targets the EU would incur additional costs of €10.0bln pa i.e. 23% higher support expenditures over baseline; GHG savings would be around 4.4% higher compared to baseline. Administrative costs for private market participants and public administrators would be the highest of all considered options.

- **Policy option 3b (risk-based approach for forest biomass)** is similar to option 3a as regards GHG emissions and sustainability criteria for agriculture biomass. However, a risk-based approach is applied to minimize the risk of unstainable woodfuel harvesting. Evidence of compliance with such requirement would be gathered first at national or sub-national level. Where this evidence is not available, operators would be required to provide evidence at the forest holding level.

In this study, this option is assumed to affect mainly extra-EU forest biomass imports with higher difficulties to provide evidence of compliance at national or subnational level. Therefore this option would lead to a 3% decline in overall (domestic and import) biomass demand compared to the baseline. The decrease of biomass imports is partly offset by an increased use of agricultural biomass, causing a 6% increase in land producing energy crops. There would also be a modest shift from biomass-based heat to both non-biomass renewable electricityand biofuels. This option would lead to additional costs of €3bln for meeting the EU 2030 RES target, i.e. 6% higher support expenditures over baseline. Furthermore, the GHG savings would be around 1.5% higher compared to baseline. Total administrative costs are lower than other options because forests within the EU are considered low-risk areas, with moderate efforts to show compliance.

Policy option 4 (energy efficiency requirement) builds on option 2, but adds a minimum energy efficiency standard (base case of 65%) for the conversion of biomass in new large-scale electricity and heat installations. In practice, only CHP installations would qualify for this requirement, so this would phase out new large-scale electricity-only dedicated biomass or co-firing installations, which only reach efficiencies of ~40%. Note, CHP needs are location specific in terms of Heating Degree Days (HDDs), both in terms of the average and variance.

This option would lead to a 1.5% decline in overall biomass demand, in particular for electricity production. This would be offset with a modest shift towards non-biomass RES-E and some more renewable heat solutions i.e. both bio-heat and other RES heat. This policy option brings about no improvements in terms of overall GHG performance compared to baseline. The reason for this is the sectoral shift anticipated by the decline of bio-electricity, offset by an increase of RES in heating & cooling. Despite the fact that low efficiency bio-based power supply is avoided under this option, the higher carbon intensity of generating electricity from fossil fuels drives the lack of improvement in GHG reduction.

This option causes a modest increase of CAPEX for renewable energy of €1.1bln pa which is partly offset by reduced OPEX. In choosing this option to reach the 2030 targets the EU incurs a nominal additional cost of €0.6bln pa compared to baseline and 0.3% higher support expenditures. Administrative costs for private market participants and public administrators would be higher than in option 2 (*EU biomass criteria for heat and power*). From private participants' side, this is explained because new CHP plants above 4 MW installed post-2020 need to demonstrate compliance with the energy efficiency requirement. From the public administration side is expected higher one-off and recurring costs because national laws need to be adapted to the energy efficiency criteria and there is more effort made by Public Administration in monitoring and verification activities.

Policy option 5 (stemwood cap) builds on option 2 and adds a cap for the use of stemwood for bioenergy at the MS level. It is assumed that wood use for residential heating (i.e fuel wood) would not be affected, since this use is typically not covered by bioenergy support schemes.

This option would lead to a 2.3% decline in overall biomass demand compared to the baseline, due to a decreased use of domestic and imported forest biomass. This is partly offset by an increased use of agricultural biomass, resulting in a 5% increase in land producing energy crops. There would also be a modest shift from biomass-based heat towards non-biomass RES electricity and biofuels. In choosing this option to reach the 2030 targets the EU would incur additional costs of €3.2bln pa compared to baseline and 4% higher support expenditures.GHG savings would be around 1.1% higher than baseline. Administrative costs for private market participants and public administrators are somewhat higher than in option 2 (*EU biomass criteria for heat and power*).

It is worth highlighting that there are significant trade-offs between the different options. Options 3a, 3b and 5 restrict the availability of biomass supply, particularly for forest biomass, with option 3a obviously being the toughest. To reach the 2030 targets, these options induce a (partial) shift to agricultural biomass with related land use impacts, as well as a shift from biomass-heat towards non-biomass renewable electricity (e.g. wind and solar power). A higher share of renewable electricity leads to higher GHG savings, but this comes with additional support expenditures. Option 4 (energy efficiency requirement) is different as it puts constraints on the end use, also resulting in a (small) decline of biomass use, but it leads to a shift from bio-electricity to more renewable heat; while this option phases out biomass applications with lower conversion efficiency, impacts on GHG savings or support expenditures of this policy option are minor.

All considered options would provide minimum safeguards against the risk of biodiversity or carbon stock losses. This is of particular relevance for Extra-EU imports. Introducing harmonized EU sustainability criteria would also reduce the risk of barriers to European biomass trade and impacts on the EU internal market. Administration costs associated to the compliance with the EU sustainability criteria are dependent on how the verification system is designed. Cost can be minimized through a number of measures, including building on national forest management laws (e.g. through the risk-based approach), use of existing market-based certification schemes, use of default values for accounting GHG impacts.

1 Objectives and methodological framework

1.1 Background

The EC has set ambitious climate and energy targets for 2030, among which an EU-level renewable energy target of at least 27%. Biomass use for energy is playing an important role in the EU28 and is expected to further increase by 2030. An issue heavily debated in the public space is whether sufficient sustainable biomass resources can be supplied, while also meeting competing uses. The EC is exploring additional actions the EU28 can take to ensure the sustainable and optimal use of biomass for energy, beyond 2020 towards 2030.

A consortium led by PwC, including VITO, Utrecht University, TU Wien, INFRO and Rütter Soceco was contracted to carry out a study for DG Energy of the EC with the objective of **developing plausible EU bioenergy supply and demand scenarios for 2030 and assessing the environmental and socio-economic impacts of possible future EU action to ensure bioenergy sustainability post-2020**. Hereafter this study will be referred to as '***BioSustain***'.

The study includes the following tasks:

- *Task 1* performed a review of recent literature to identify updated 2030 ***biomass supply capacities*** from forestry, agriculture and waste that could be available for the EU, through sustainable domestic production or imported from international markets.
- *Task 2* developed realistic 2030 EU ***biomass demand scenarios***, not only for energy, but also for other sectors of the bio-economy (industrial materials, biochemistry). These formed the baseline against which five alternative options are compared (in Task 5).
- *Task 3* was dedicated to a ***stakeholder consultation workshop***, allowing for validation of the modelling inputs and initial scoping of sustainability risks and possible additional action at EU level. In addition, the responses to a public consultation initiated by DG Energy on a sustainable bioenergy policy were analysed and taken into account.
- Based on tasks 1-3 and the findings of a fresh literature review, *Task 4* identifies ***sustainability risks*** related to biomass use post-2020 and assesses how existing EU and MS energy-related sustainability measures address the identified risks. The ***possible options for EU action*** are presented in order to minimize these risks.
- *Task 5* analyses the ***socio-economic and environmental impacts*** of a number of selected options for additional EU action. Impacts of each option are compared against the baseline scenario of Task 2, and assessed under a set of criteria, including environmental effectiveness, economic efficiency, and policy coherence.

Tasks 1 through 4 are explained elsewhere, they can be found in the Technical Annex of this report. This report summarises the results of Tasks 1 to 4, but the focus is on assessing the impacts of different options for additional EU action (Task 5).

The analyses carried out in this project were principally based on public information, as well as information provided by DG Energy. A model framework is used to assess the future of bioenergy supply and demand within the EU28, its MS's biomass trade flows, and to gauge most of the impacts of the identified policy options. The framework combines specialised models with complementary scopes and strengths, allowing a quantitative assessment of a broad set of impacts of bioenergy use.

Limitations to the study and modelling include:

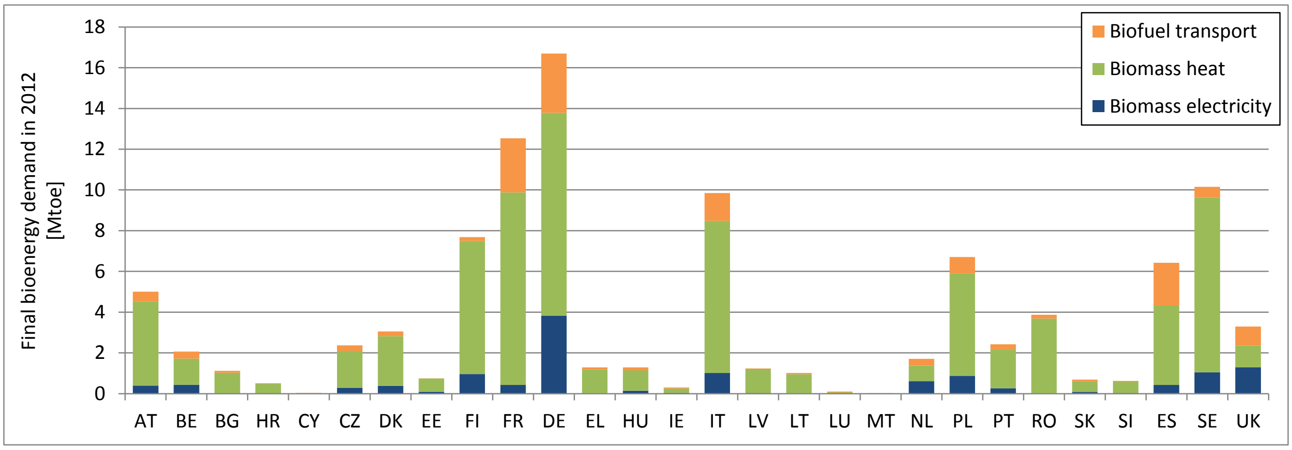
- *Modelling is constrained to the EU energy system.* In the assessment of biomass supply scenarios, amounts of biomass required in other biomass markets such as food and feed and materials (including novel industrial use for biochemical production) were considered not available for EU energy use, so in fact these other markets are prioritised over energy use. Actual competition effects between energy and other markets are not covered in the modelling. Availability of extra-EU biomass imports is also exogenous to the model.

- *Impacts of sustainability regulations on the bioenergy supply are handled exogenously to our modelling system.* The assumptions used in this study to determine the impact of sustainability requirements on biomass supply potentials may not fully reflect the regional context or the design of sustainability requirements (where details can make a big difference). This is particularly relevant for the risk-based approach related to forestry biomass, and calculated impacts for this policy option therefore have a relatively high uncertainty level.
- *Impacts of sustainability regulations affecting only large-scale bioenergy plants.* According to the assumption made for assessing the policy options, as default only large-scale plants are affected by certain sustainability requirements, whereas small end-users are not affected. Green-X classifies all plants above 5 MW (thermal capacity) as large-scale. On the other hand, the current policy debate refers to a 20 MW threshold. As a consequence, the Green-X modelling may overestimate the impacts of applying sustainability regulations since it considers a larger portion of the market to be affected by the regulation. Currently plants between 5 and 20 MW represent around 16% of cumulative installed capacities of all bioenergy plants consuming wood chips at EU level.

1.2 State of play of bioenergy supply and demand and trends to 2020

Today, biomass use for energy purposes (bioenergy) contributes 1,342 Mtoe or about 10% to the global total primary energy supply (TPES). In the EU28 bioenergy represented 128 Mtoe or 8 % of gross inland consumption in 2013 and 105 Mtoe (10%) of final energy consumption. Bioenergy is the dominant RES today, representing two thirds of both 2005 and 2011 renewable energy production in the EU28, being produced from solid, gaseous and liquid biomass sources. Heat is still the largest sector of final bioenergy consumption at 75% of total final bioenergy in the EU28, followed by electricity (13%) and transport fuels (12%). Solid biomass main end-use is the residential sector (ie forest resources), and this represents the largest share (90.8 Mtoe gross inland renewable energy consumption), followed by liquid biomass (14.4 Mtoe), biogas (13.5 Mtoe) and organic waste (9.1 Mtoe). However, the contribution of bioenergy to demand varies across the MS's as shown in Figure 1-1, displaying a breakdown of final bioenergy demand by sector for each MS.

Figure 1-1 Sectoral breakdown of final bioenergy demand in 2012 by MS

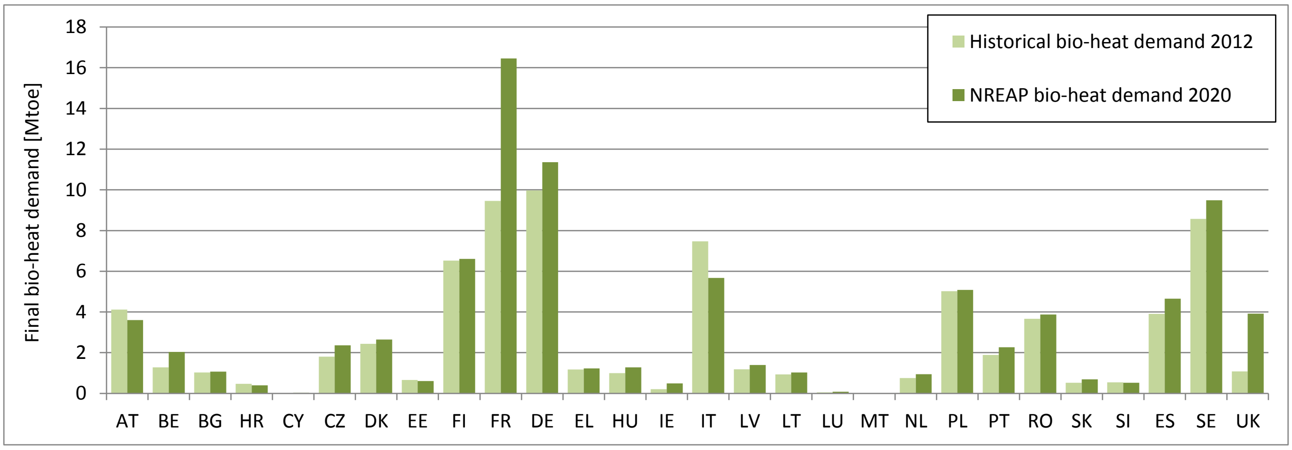


Source: Eurostat, Fraunhofer ISI

Bioenergy demand grew rapidly between 2005-2011, averaging ~6% per annum. Lower growth rates will be sufficient to meet MS 2020 deployment targets.

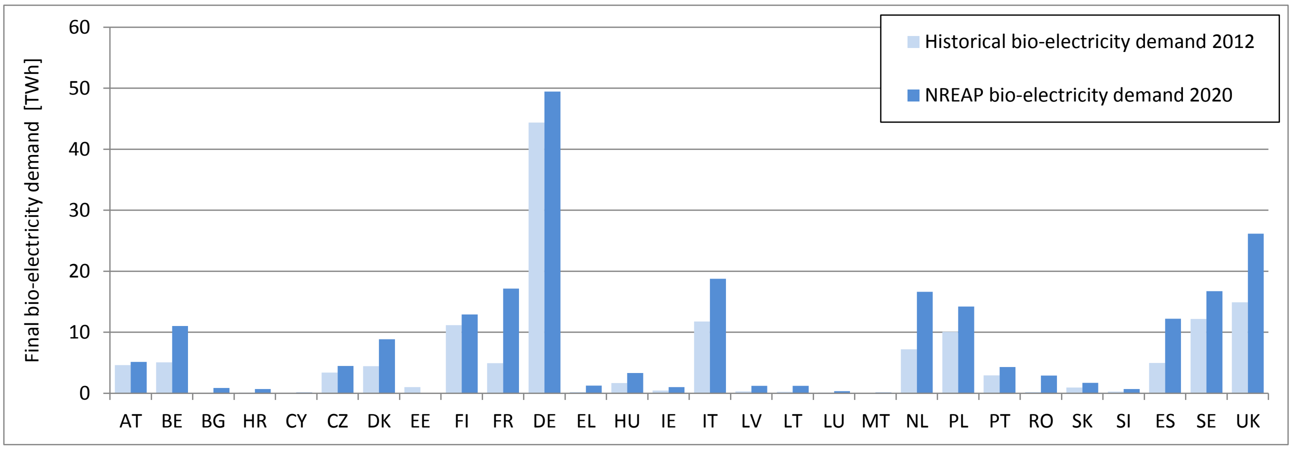
An examination of 2020 projections confirms that biomass is also key to meeting the EU's 2020 RES target. Under the National Renewable Energy Action Plans (NREAPs), biomass for heating & cooling, electricity and transport will supply about 53% of the required RES volumes for meeting the 20% by 2020 (128 Mtoe out of 244 Mtoe). The majority of this comes from solid biomass ~75% (94 Mtoe). Figure 1-2 for bio-heat and Figure 1-3 for bio-electricity compare 2012 bioenergy demand with expectations for 2020, for the electricity sector and for heating & cooling demand, by NREAP.

Figure 1-2 Final bio-heat demand in 2012 compared to expectations for 2020



Source: Eurostat, Fraunhofer ISI and NREAPs

Figure 1-3 Final bio-electricity demand in 2012 compared to expectations for 2020



Source: Eurostat, Fraunhofer ISI and NREAPs

1.3 Biomass supply scenarios

The potential energy production from biomass is supply and demand driven, affected by the various policies in different sectors of the economy. In order to ensure a sustainable supply of biomass for energy, we need to understand the supply side of the market, from forest, agriculture and waste sources as well as biomass demand for other uses, including food, feed, fibre and biochemicals. The assessment undertaken in Task 1 (biomass supply capacities) and Task 2 (biomass demand scenarios) of BioSustain provide useful insight into both the complexity and the trade-offs in biomass supply and demand, across the various sectors. The individual MS biomass feedstock situations are assessed and supply capabilities derived, including an analysis of industrial i.e. non-energy demand, for forestry-based biomass.

The approach and outcomes are presented here, summarising the technical background. The full technical background report is in 'Technical Annex A: EU biomass supply curve and industrial sector demand through 2030'.

The results of this assessment provide the basis for all subsequent analysis within this project and have been fully incorporated in subsequent modelling. For example: to update the existing bioenergy cost-resource curves used in the energy system Green-X Model.

1.3.1 Approach for reviewing biomass supply curves for energy use

To assess the future potential of bioenergy, realistic 2030 biomass supply scenarios have been developed building on a review of the sustainable biomass supply from agriculture, forests and waste that could be achieved in the EU, whether sourced from domestic sustainable production or imported. In addition, competing demand in forest markets and novel industrial use for biochemicals etc are assessed in order to identify additional demand for biomass.

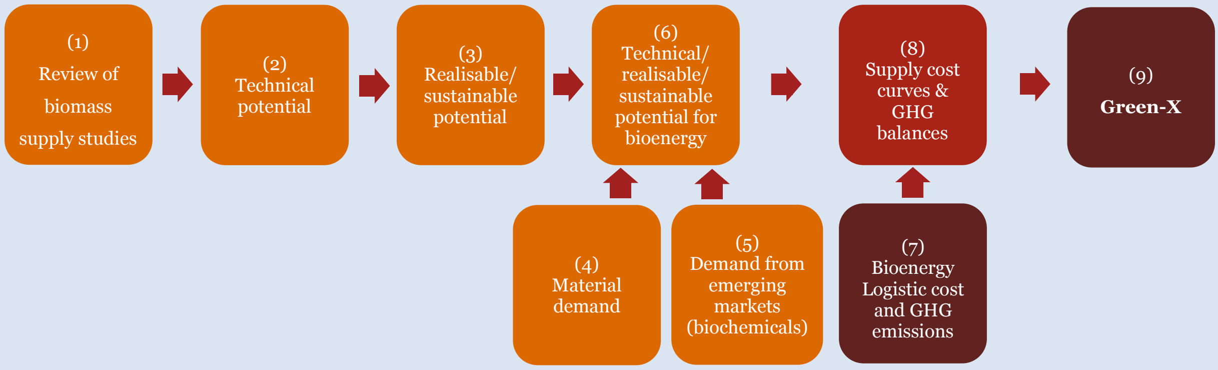
Box 1 describes the approach to support the design of plausible biomass supply scenarios to 2030 and update the existing biomass cost-resource curves used in the energy system model Green-X. A key element of the overall approach is the stakeholder workshop as outlined in Box 1.

Box 1 General approach to determine the biomass supply potential available for bioenergy

Based on an up-to-date review of available literature *(step 1,*

Figure 1-4*)*, technical supply capacities of biomass are derived, indicating the (technical) upper boundary for the supply of biomass in Europe *(step 2)*. When constraints are taken into consideration (e.g. biomass management practices and sustainability concerns), technical potentials are reduced and, consequently, sustainable achievable production can be indicated *(step 3)*. A biomass demand assessment from Industrial sector *(step 4)* and from Emerging markets (biochemicals) *(step 5)* is then undertaken, complementing the prior step. In our analysis, such demand has a higher price or value than for energy use and, therefore is subtracted from overall supply availabilities to calculate the feedstock remaining for bioenergy use *(step 6)*. Finally, costs and GHG emissions concerning biomass feedstock supply are calculated taking Intra-EU and Extra-EU trade routes into account *(step 7 and 8)*. Supply cost curves and the associated GHG balances are input to the biomass trade module in the energy system model Green-X (9) described in section 1.4.1.

Figure 1-4 General approach to determine the supply potential of biomass for bioenergy (adapted from BioTrade2020+)



Imports of solid biomass from Extra-EU

Intermediate results of the IEE project BioTrade2020+[8] for case studies of the US Southeast, Brazil and Ukraine were used to determine the export potential of solid biomass to the EU. To determine the net sustainable export potential for export to the EU, BioTrade2020+ used a common method as shown in Figure 1-5.

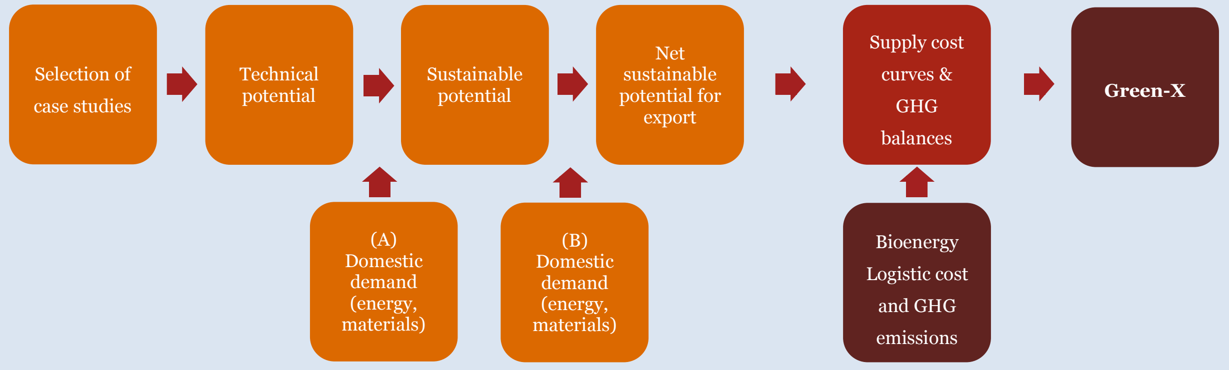
In the BioTrade2020+ project, the current and future export potential is determined as follows. First, the technical potential is determined from the selected case study regions, e.g. how much corn stover might technically be available after harvest for all end uses. In the next step, we identify how much of the technical supply can be used taking into account various sustainability constraints. These are defined as a loose and strict set of criteria. The loose set of criteria do include the sustainability criteria as laid down in the RED (i.e. exclusion of highly biodiverse and carbon-rich lands, calculation of GHG footprints), and additional (specifically for residues) criteria regarding soil protection (erosion and soil organic carbon). The strict set of criteria includes various additional environmental and social sustainability criteria, but these were not available at the time. Next, the current local use for industrial and (traditional and modern) bioenergy uses were determined and deducted from the technical potential (Option B). This implies that sustainability criteria are only applied to exported biomass. This is considered more realistic because EU policy makers cannot extend these criteria to all biomass (option A).

In addition, an estimation is made as to whether the existing local markets and infrastructure could actually be used to mobilize the gross available biomass potential e.g. the presence of mechanical harvesting machinery, presence of chipping/pelletisation plants, road and rail infrastructure, etc resulting in the net available export potential. Finally, the cost-supply curves for the gross available biomass potential to the EU is determined, including GHG footprints. This procedure is carried out for the current situation 2015. For each case study two scenarios are applied: (1) a business as usual scenario (BAU), in which all current trends (e.g. agricultural yields, food demand, local biomass use, etc.) are extrapolated to 2020 and 2030; (2) a High Trade (or optimistic) scenario, specific fmarket participants are identified that – if changed – could increase the export potential (e.g. increasing agricultural yields by better management). The BAU scenario is used for the ‘Reference supply scenario’ in BioSustain. The High Trade scenario is used for the ‘Resource supply scenario’ in BioSustain.

There are two important limitations to the approach used. First, domestic demand is always prioritised over export. Actual price discovery in domestic markets, for example between local pulpwood and export markets, is therefore not taken into account. The market will sell to the best netback price. Secondly, the highest value products are prioritised to domestic markets and are assumed not to be available for wood pellet production for export. Because of increased wood demand in the US Southeast in the BAU scenario of BioTrade2020+, stemwood is no longer available for wood pellet production by 2030. In the context of more recent developments, this seems however unlikely to happen.

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

Figure 1-5 Approach to determine the net sustainable potential for import of solid biomass from third countries applied in BioTrade2020+ (Mai-Moulin et al. 2015)



The supply of sustainable wood sources is not a fixed point but is represented by a "corridor" of three options society may take within given borders. The corridor describes the options for sustainable utilisation, quantified by three realisable supply scenarios.
The result is a corridor of sustainable utilization options for the following scenarios:

- ***Restricted***: EU wood availability under the condition of stronger utilisation restrictions and larger set aside areas. Higher global competition for Extra-EU solid biomass and lack of investments in infrastructure to mobilize alternative woody biomass. Low export capacity of liquid biofuels outside the EU.
- ***Reference***: EU wood availability is given under today's circumstances. Extra-EU solid biomass development follows a BAU trend. Medium export capacity of liquid biofuels to the EU.
- ***Resource***: maximum possible utilisation of wood in the EU under long-term sustainable conditions. Strong development of supply and infrastructure of Extra-EU solid biomass, perennial crops cultivated for export markets. High export capacity of liquid biofuels to the EU.

Extra-EU supply scenarios of liquid biofuels and solid biomass have been aligned to the forest supply scenarios. Supply potentials of agriculture biomass (i.e. energy crops and agricultural residues) and organic waste change in time, but are assumed similar between the three different supply scenarios.

A detailed list of the constraints and how they were applied by scenario, is given in Technical Annex A.

Box 2 Stakeholder workshop: a critical reflection of the concept and draft outcomes

As part of the BioSustain project, a stakeholder workshop was held on 7 December 2015 in Brussels. The workshop was hosted by the EC and was attended by 69 participants, including sector associations and market participants in the field of agriculture, forestry, waste processing, bioenergy and biofuel production, wood processing industry, paper industry, as well as policy makers at national and EU level, academia, research organisations, NGOs and other organisations. The objectives of the stakeholder workshop were to present preliminary findings on biomass supply and demand scenarios for EU energy and non-energy use by 2030; discuss and validate these findings by experts and stakeholders which have not been involved in the study so far; introduce the next steps on identifying potential sustainability risks and map EU and national mitigation actions.

The results of the workshop were included in the study. In terms of *supply and demand scenarios* the main discussions concerned the assumptions behind the supply curves and their component assumptions, e.g. the amount of residues that should be left in the forest, growth projections of wood industries, the amount of land available for energy crops, the amount of agricultural residues which should be left in the field, the most likely trade partners for solid biomass with the EU, how waste policies will influence biomass waste supplies, and the potential interaction between bioenergy and biochemical markets.

In terms of *sustainability risks and possible mitigation actions*, a panel debate brought various interesting points forward that were used for the further identification of risks, policy gaps and potential policy options (see chapter 2). Points brought forward concerned the multifunctionality of forests, forest management systems, comprehensive carbon accounting systems, aim for high efficiency applications, 'clever, but not rigid' way of cascading recognizing the long-term storage of carbon in materials, promote the investment climate for biochemicals and other biomaterials, common sustainability criteria at EU level, build on existing national regulations, regional assessments with risk-based approach, put efforts in mobilisation of biomass, a framework of carbon pricing, among other.

'Technical Annex B: Stakeholder Workshop - Summary of report and Background Paper' comprises the key points raised during the workshop and the background paper, which gave an overview of preliminary findings and topics discussed during the stakeholder workshop.

1.3.2 Results of the assessment of biomass supply capabilities

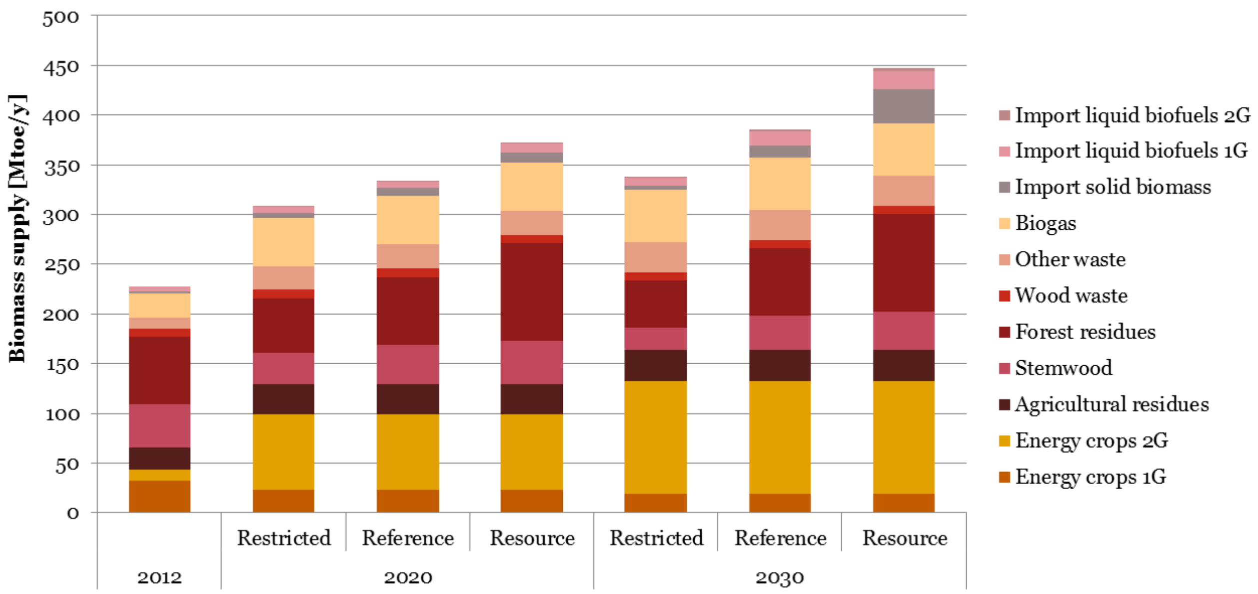
This section presents the outcomes of the assessment, describing current biomass uses and reviewing current and future biomass supply capabilities from MS production and Extra-EU imports.

Total potential supply of biomass for energy use in the EU28 in 2012, 2020 and 2030

The current estimated supply potential of biomass for energy from forest, agriculture and waste sectors as well as Extra-EU imports is well above today's primary production of biomass for energy in the EU28 (123 Mtoe in 2013) and Extra-EU imports (~5 Mtoe in 2013). In the longer term, supplies (under all three restricted, reference and resource scenarios) are clearly higher than the amounts that will be required for bioenergy. In practice, supply of agricultural biomass was estimated at 211 Mtoe, of which only 22-30% (45 to 64 Mtoe) is used in the baseline scenario for 2030. In terms of forestry biomass, the consumption in 2030 is the range of 76-110 Mtoe, which is very close to the total supply (79 in restricted scenario to 146 Mtoe in the resource scenario), therefore forestry biomass potential is expected to be almost completely used. In terms of waste biomass, it is expected that 78% of the potential supply (23 Mtoe compared to 29 Mtoe) will be consumed as bioenergy in 2030.

However, it should be noted that part of this supply potential might be difficult to mobilize. In particular, additional supply of stemwood and forest residues depends on forest management constraints. The domestic supply in the EU28 in 2030 ranges between 338 Mtoe in the Restricted scenario to 391 Mtoe in the Resource scenario. The future share of solid biomass and liquid biofuels supply from Extra-EU sources ranges between 4% (13 Mtoe) in the Restricted scenario to 14% (56 Mtoe) in the Resource scenario, compared to 4% in 2013 (5 Mtoe).

Figure 1-6 Overview of estimated biomass potential for bioenergy in the EU28 in 2010, 2020 and 2030 in terms of primary energy



Biogas and import of liquid biofuels are shown in final energy units.
1G: food- and feed-based energy crops, biofuels
2G: lignocellulosic energy crops, biofuels

Forest biomass

Forest biomass can be divided into (1) primary forest biomass - stemwood, other industrial roundwood and primary forest residues e.g. logging residues, (2) secondary forest residues - wood processing industrial residues, like sawdust, bark and black liquor, and (3) wood wastes - construction and demolition wood, post-consumer wood.

The total growing stock of forest biomass in the EU is estimated by around 21,000 Mm³ of solid wood equivalent (swe) (or 4,400 Mtoe)9, with a theoretical annual increment of total biomass of 1,277 Mm³ swe overbark10 (268 Mtoe) in the EU. However, various technical, environmental and social constraints and conditions reduce the total achievable supply potential for all uses (energy and materials) to about 710 Mm³ swe (149 Mtoe).

Total industrial non-energy demand for primary and secondary forest biomass i.e. residues and recycled material, is projected to increase from 437 Mm³ in 2010 to 514 Mm³ in 2030. The total available primary and secondary forest biomass is calculated at 1,020 Mm³ in 2010 to 1,074 Mm³ (swe) in 2030 in the reference scenario. The 20 year primary and secondary growth rates are 583 (e.g. 1,020-437) and 559 Mm³ (swe). At least 350 Mm³ are already used for bioenergy in 2010 (EUwood report, Mantau et al., 2010). The additional potential bioenergy demand is roughly 200 Mm³ in the period 2020 - 2030, mostly in the form of forest residues and landscape care wood. This is a potential supply under the named constraints and not necessarily available to markets. In the Restricted scenario this potential supply could be around 150 Mm³ less while under the Resources scenario it may be about 150 Mm³ higher. The differences between scenarios are due to the use of forest residues. However, mobilisation of these depends mainly on technical solutions, because of the monetary focus on the high-value stem and high cost of manual collection of residues. Furthermore, there can be high environmental restrictions on the use of residues. The environmental effects of residue utilisation are discussed in relation to the extraction of nutrients and deadwood that may vary

[9] Conversion factor swe: 0.210 Mtoe / Mm^3
[10] Overbark is used when the volume of wood also includes bark. If bark is excluded, the qualification underbark is used.

by forest stand. The three supply scenarios: Restricted, Reference and Resource, assess different strategies of forest biomass mobilisation and within the corridor of sustainable biomass supply.

Coniferous stemwood – softwood - is almost completely for industrial or manufacturing purposes, leaving between 1.0 Mm3 (Restricted) and 44 Mm3 (Resource) available for energy in 2030. Non-coniferous stemwood – hardwood - is theoretically available ranging from 60-110 Mm^3. However, the mobilisation of high value assortments for energy use is more problematic, because prices for high-grade hardwood are generally above the energy value netback from biomass plants. Primary forest residues are the largest reserve for woody biomass for energy, ranging widely from 29-265 Mm3. Bark is harvested from stems and its potential is, therefore, directly connected with the mobilisation of stemwood, between 42-49 Mm3.

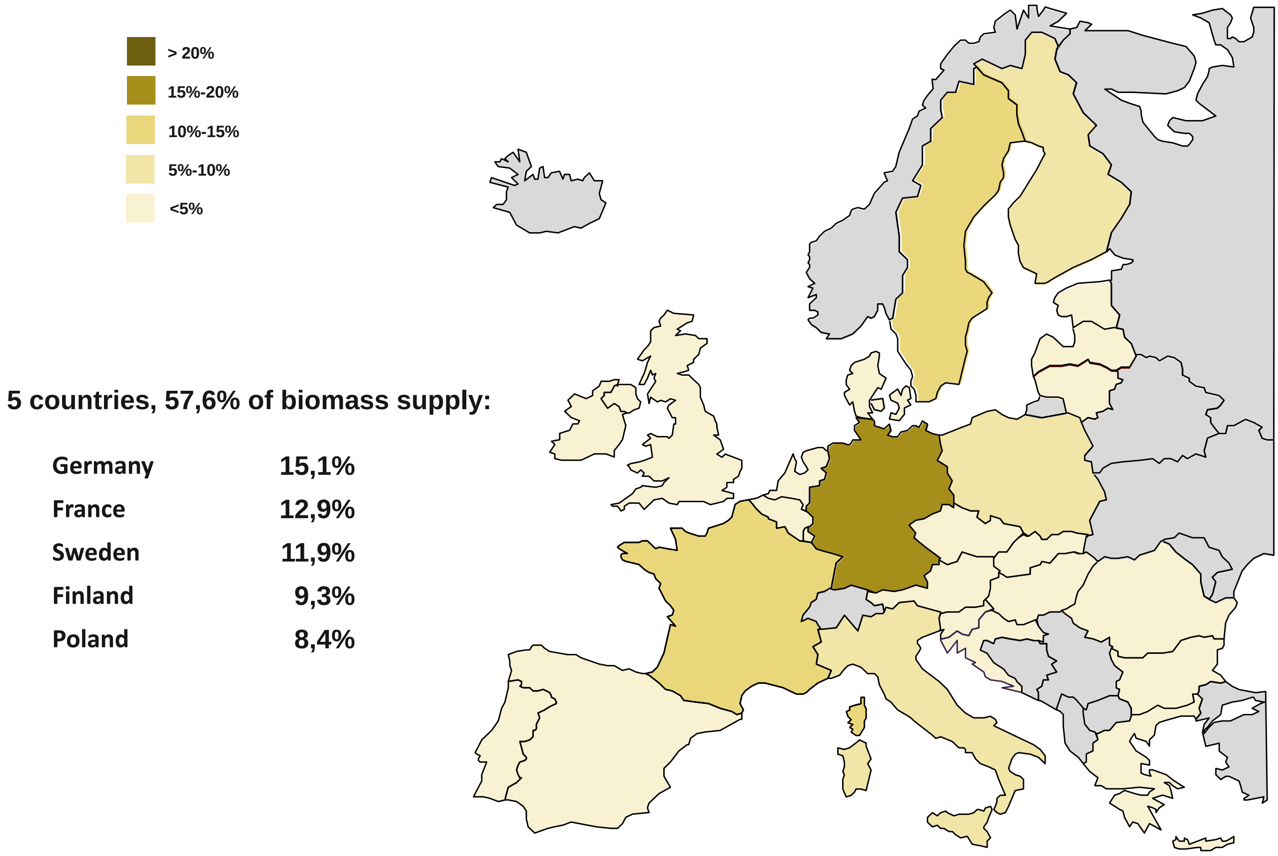
Landscape care wood has an interesting potential especially for communities which often own these resources. However, a large proportion is garden wood, often used by households as firewood.

Post-consumer wood is a significant resource as well, declining from 45 Mm3 in 2010 to 26 Mm3 by 2030. Figures decrease in relation to higher recycling rates of this material. In countries with good collection systems, post-consumer wood is already widely used, while in other countries it is not yet available.

Secondary forest residues like black liquor are already completely used for energy today; sawmill residues are to some extent used for energy, but mainly for material uses with 67 Mm3 (82%) in 2010 increasing to 82 Mm3 (88%) in 2030.

The largest share of forest biomass supply - stemwood, primary forest residues, secondary forest residues - in the EU28 is in Germany (15% by 2030) followed by France, Sweden, Finland and Poland. Together, these five MS’s will make up ~60% of forest biomass supply capacity in the EU28 by 2030 (Figure 1-7).

Figure 1-7 Forest biomass (stemwood, primary forest residues, secondary forest residues) supply potential share per MS (2030)



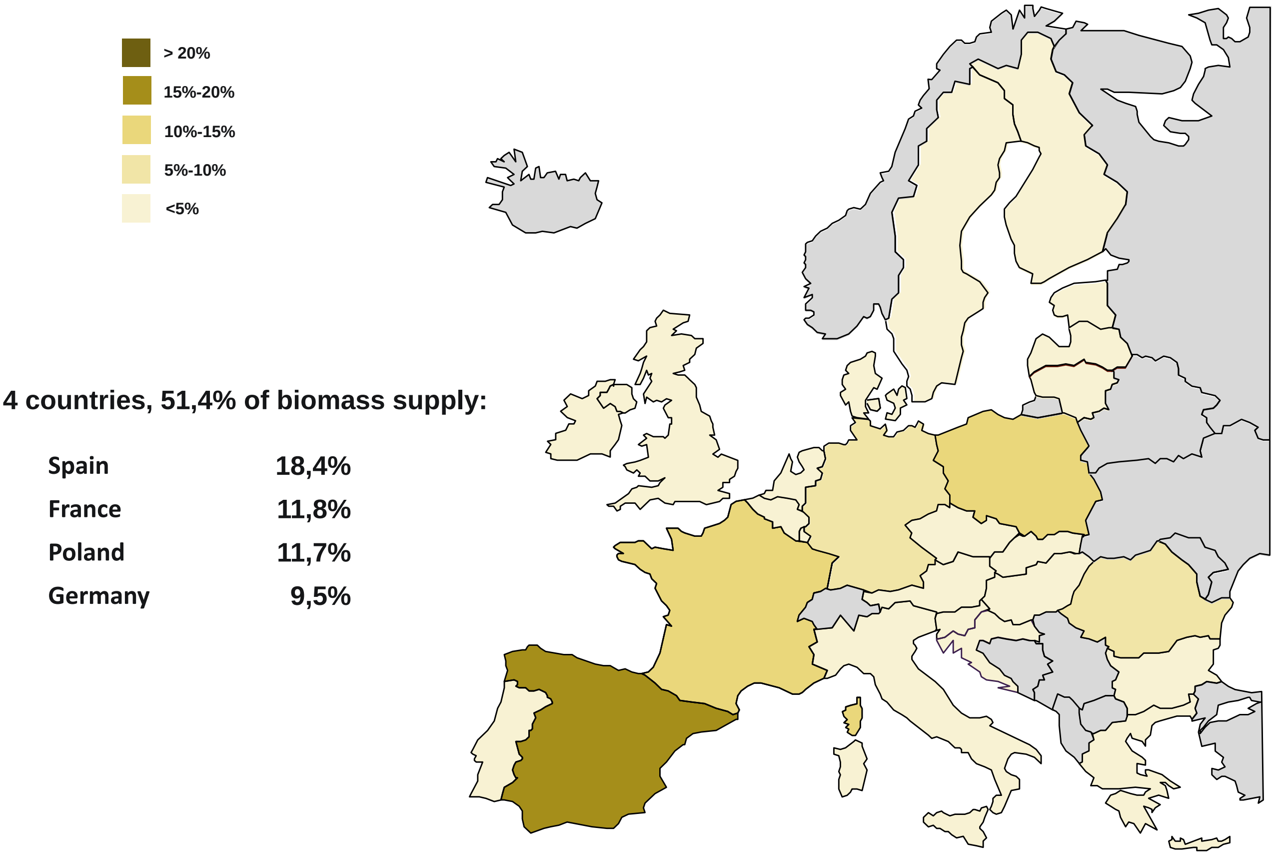
Energy crops

Energy crops are grown solely for bioenergy production. They can be classified by harvesting frequency into annual crops and perennial crops; they are neither food- nor feed-crops being indigestible lingo-cellulosic energy crops. They are most often perennial grasses (for example, miscanthus or switchgrass) or short rotation coppice (for example, poplar or willow). Many food-and feed-crops are only partially used for bioenergy purposes and are annual crops (for example wheat, sugar beet or rapeseed). Others like palm and sugarcane are perennial.

The total Utilised Agricultural Area (UAA) in the EU28 totals 177 Mha in 2013. Arable land accounts for the largest area (106 Mha, 60%), permanent cropland cultivated with perennial crops covers 12 Mha (~7%) and permanent grassland was at 58 Mha, the remaining 33% . In 2012, total arable land used for biofuel feedstock cultivation in the EU28 was ~4.5 Mha. In addition, another category is crops cultivated for co-digestion (also called anerobic digestion) with a growing but currently insignificant share (1 Mha in Germany).

Land which might become available for bioenergy is projected to be 23 Mha in 2020 and largely unchanged at 24 Mha by 2030 (18% of total arable land, 12% of utilized agricultural area). The total supply potential of dedicated energy crops in the EU is estimated to increase from 39 Mtoe in 2010 to 131 Mtoe in 2030. In particular, high yield lignocellulosic crops (grassy crops, short rotation coppice) have the largest potential, increasing from 11 Mtoe in 2012 to a projected 113 Mtoe in 2030. Figure 1-8 shows the supply percentages of agricultural biomass (energy crops, agriculture residues, manure) with four countries Spain, France, Poland and Germany comprising 50%+ of MS biomass supply in the EU28.

Figure 1-8 Agricultural biomass (energy crops, agriculture residues, manure) supply potential share per MS (2030)



Agricultural residues and manure

Agricultural residues can be divided into primary crop residues (or harvest residues) that are produced on the field (for example straw, prunings, cuttings), secondary crop residues that are produced from processing of harvested products (for example, bagasse or rice husks) and animal farming residues (manure).

Straw (US: stover) currently has the largest potential of agricultural residues, but has a very low energy density making it very expensive to transport significant distances. Its supply availability is residual to the removal rate over that required to maintain soil quality and to the local high value uses of the residues (such as for animal bedding); fmarket participants are driven by the colocation of animal and crop husbandry. The potential for primary harvest residues dependent on the development of cellulose fermentation advances – we assume constant from 2020-2030.

The largest growth in terms of realisable agricultural biomass supply for energy is most likely agriculture biogas, increasing from 15 Mtoe in 2010 to 40 Mtoe in 2030. Animal manure is the largest supply source of agriculture biogas (47%), followed by pasture residues (28%) and grain crop residues such as wheat and maize (18%).

Organic waste

After forestry and agriculture, organic waste is the third main category of biomass that can potentially be used for energy generation. An important share of that waste is of biological origin (paper, wood, food waste, garden waste).

The main waste categories, as reported in Eurostat, consisting partly or entirely of organic material are: (1) paper and cardboard wastes, (2) animal and mixed food waste, (3) vegetable wastes, (4) household and similar wastes, (5) common sludges and (6) wood wastes. Wood waste is not included in this assessment as it is already covered in the assessment of forestry biomass.

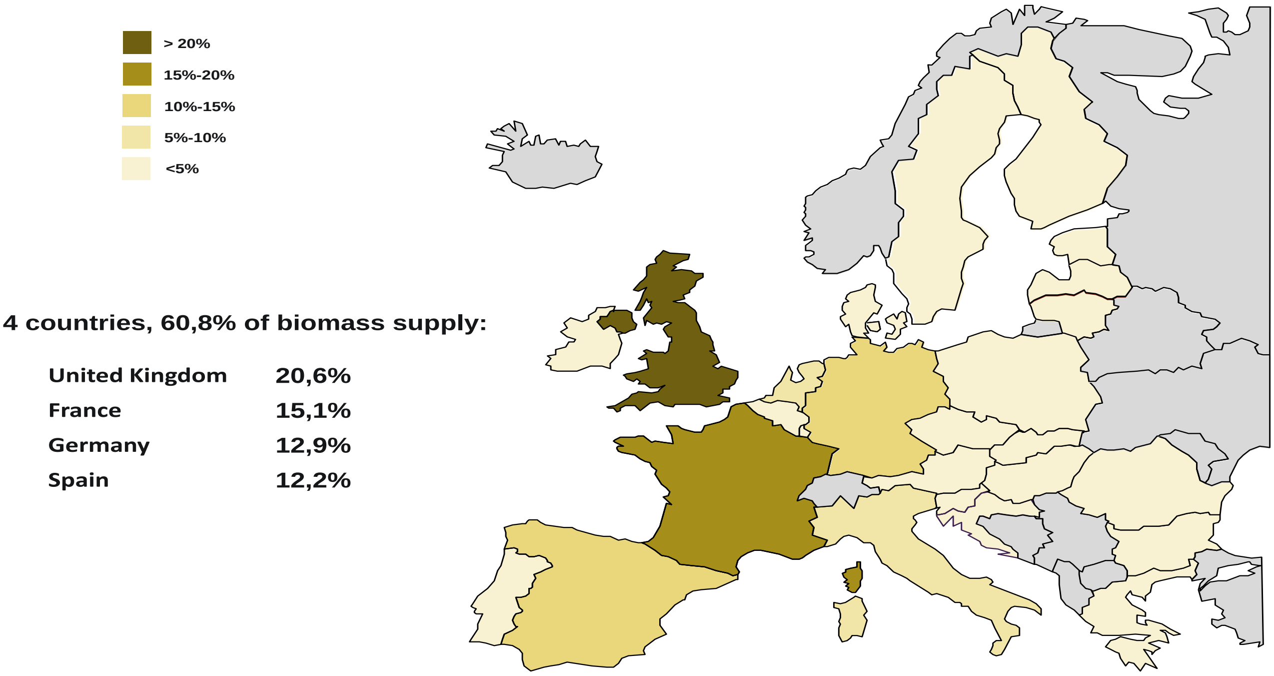
A substantial growth of bioenergy from waste is possible, from current levels around 11 Mtoe in 2012, up to around 25-30Mtoe in 2030, which is more than double current use. The main potential for waste biomass in the next decades still lies in the incineration (and energy recovery) of mixed household and similar waste in waste-to-energy plants (~14 Mtoe/y). The potential of other separated fractions generally varies between 3-5 Mtoe each. Used animal fats and vegetable oils are already and important feedstock for 'advanced' biodiesel. A substantial share (> 1 Mtoe/pa) is already used for this application today, used cooking oils are already traded between countries for this purpose.

Trends in waste management i.e. waste generation, recycling targets, share of landfill, have a substantial impact on total potentials. These have been taken into account, both in the baseline scenarios and in sensitivity runs performed for this study by applying stronger waste management evolutions compared to the baseline scenario - reduced MSW generation, higher landfill reduction, higher waste separation, decoupling of sector waste from GDP growth. Some of these effects increase the energy potential e.g. reduced landfill, other reduce the potential (e.g. reduced waste generation, higher waste separation). When combining the different effects, the energy potential could reduce by ~5 Mtoe, by our calculations.

The potential for paper and cardboard is very low - about 3% of recovered material or 0.18 Mtoe in 2012, 0.33 Mtoe in 2030, as most of those fractions will go to recycling. Material recycling - e.g. paper recycling, is excluded from the energy potential. Recovery options for separated waste biomass fractions such as vegetal waste or mixed animal and food waste consist of a balance of material applications - e.g. oleochemicals, but also soil improvers such as compost, and energy applications. There may be a trend to convert current compost facilities to pre-digestion and post-composting. Four countries, UK, France, Germany and Spain provide over 60% of biomass from waste sources in the EU28 by 2030 as shown in

Figure 1-9.

Figure 1-9 Biomass waste (organic fraction of municipal solid waste, sewage gas, landfill gas) supply potential share per MS by 2030.



Biomass demand for novel materials - biochemicals and biopolymers - to 2030

Biomass demand for novel industrial materials such as biochemicals is expected to have a higher price to biomass producers and is therefore subtracted from overall supply possibilities to calculate the feedstock surplus available for bioenergy use.

There are different ways of using biomass for the production of chemicals. Bio-based surfactants and solvents, - mostly based on vegetable oils, animal fats, sugar or starch, are currently the most important bio-based applications in chemistry. However, highest growth rates, between 10-15% CAGR, are expected in biopolymers and bio-based plastics.

The projected bio-based chemical industry raw material demand in 2030 is estimated as 5-10 Mtoe, which is still much lower than biofuels or bioenergy.

Biopolymer demand in the EU by 2030 is estimated in the range of 2-3 Mtoe. Current raw materials are mainly sugar, starch and cellulose for some specific chemicals. This is expected to be stable in the near future, although a shift to 2nd generation pre-treatment processes – such as producing sugars from lignocellulose can be anticipated, but at a slower pace than for biofuels.

Under certain assumptions - 80% sugar/starch input; 20% lignocellulose input - biopolymers would induce a resource demand of 4.0Mmt of sugar or starch and 1.5-2.0Mmt of lignocellulose.

Bear in mind that these figures are for the European market demand of bio-plastics, which may evolve differently from production. If current trends continue a substantial part of the production will be outside Europe, especially in South America and Asia).

Another application of biomass resources in materials would be in bio-composites, which are around 50% bio-based. A forecast indicates that more than half of the EU's 2.4Mmt pa of composite production could be bio-composites by 2030, consuming around 0.5Mmt of woody biomass and 0.2Mmt of natural fibres, both are inconsequential volumes.

Table 1-1 Overview of main assumptions of the extra-EU supply scenarios of solid biomass and supply by 2030 (Mtoe/a pellets).

Supply region	2030		
	Reference	Restricted	Resource
US Southeast	Based on BioTrade2020plus[a] (BAU scenario). Low domestic production and increased demand in competing sectors (domestic bioenergy, panels, pulp and paper) reduces the future export potential of stemwood to almost zero.	Similar to Reference scenario, but no growth in mobilisation of forest residues. The main reason is the exclusion of wood residues that are generated form pre-commercial thinning operations, but also land clearing activities. These other removals might not meet more strict SFM criteria (e.g. FSC), that require replanting after land clearing.	Based on BioTrade2020plus[a] (High Trade scenario). The high production rate results in an increased sustainable export potential of stemwood and forest residues.
Total	4.11 Mtoe	1.10 Mtoe	10.74 Mtoe
Stemwood	0.10 Mtoe	0.10 Mtoe	4.06 Mtoe
Forest residues	4.02 Mtoe	1.01 Mtoe	6.67 Mtoe
Brazil	Based on BioTrade2020plus[a] (BAU scenario). Agricultural- and forestry production and consumption evolves at the current pace, yield increases follow historic trends. Pellet mill capacity is assumed to remain 910 kt/y beyond 2020 as a result of lacking investments.	Currently, Brazil is hardly exporting solid biomass for energy. The restricted scenario assumes no developments in this region to 2030.	Based on BioTrade2020plus[a] (High Trade). Beyond 2020, a compound annual growth rate of 42% was assumed, based on pellet mill capacity growth in the US Southeast between 2013 and 2013. In 2030, the total pellet production capacity increases to 30.5 Mt/y (12.5 Mtoe).
Total	0.37 Mtoe	0.02 Mtoe	12.09 Mtoe
Forest residues	0.37 Mtoe	0.02 Mtoe	9.04 Mtoe
Agricultural residues			3.06 Mtoe
Ukraine	Based on BioTrade2020plus[a] (BAU scenario). Little improvements in yields and cropping intensity are expected.	The Restricted scenario assumes no exports of wood pellets from Ukraine.	Based on BioTrade2020plus[a] (High Trade scenario) with steady yield and cropping intensity improvements, an increased potential for energy crops (switchgrass) from the moment the land becomes available.
Total	0.85 Mtoe	0.00 Mtoe	5.04 Mtoe
Forest residues	0.04 Mtoe		0.04 Mtoe
Agricultural residues	0.82 Mtoe		2.56 Mtoe

Energy crops			2.44 Mtoe
Canada	Based on estimated wood biomass flows in Western Canada by 2025 (Pöyry, 2014) who estimate that wood pellet production will increase moderately from 1.9 Mt/a today to 3.8 Mt in 2025. No growth assumed after 2025.	Wood pellets from stemwood from primary forests are excluded due to strict limitations on harvesting possibilities. Note that this highly conservative given the high share of publicly owned and SFM certified forests in Canada[b].	Similar to Reference scenario.
Total export potential, of which:	1.57 Mtoe	1.06 Mtoe	1.57 Mtoe
Stemwood	0.50 Mtoe	0.00 Mtoe	0.50 Mtoe
Forest residues	1.06 Mtoe	1.06 Mtoe	1.06 Mtoe
Northwest Russia	Based on estimated wood biomass flows in Western Canada by 2025 (Pöyry, 2014) who estimate that wood pellet production will increase moderately from 1.4 Mt/a today to 1.9 Mt in 2025.No growth assumed after 2025.		
Total	1.22 Mtoe	1.22 Mtoe	1.22 Mtoe
Stemwood	0.38 Mtoe	0.38 Mtoe	0.38 Mtoe
Forest residues	0.84 Mtoe	0.84 Mtoe	0.84 Mtoe
Australia, New Zealand, SE Asia	Wood pellets form stemwood and forest residues from Australia and New Zealand and agricultural residues (palm kernel shells, PKS) from SE Asia as projected by Lamers et al (2014). No growth between 2020 and 2030.		
Total, of which:	1.44 Mtoe	0.83 Mtoe	1.44 Mtoe
Stemwood	0.53 Mtoe	0.53 Mtoe	0.53 Mtoe
Forest residues	0.29 Mtoe	0.29 Mtoe	0.29 Mtoe
Agricultural residues (PKS)	0.61 Mtoe	0.00 Mtoe	0.61 Mtoe
Sub-Saharan Africa	Wood pellets form short rototation energy crops on surplus available crop land (based on Biomass Policies, Fritsche et al. 2014).	The lack of actual investments in biomass supply as well as infrastructure to mobilize and export biomass makes supply highly uncertain. Assumed to be zero in the Restricted scenario.	Similar to Reference scenario.
Total	2.33 Mtoe	0.00 Mtoe	2.33 Mtoe
Energy crops	2.33 Mtoe	0.00 Mtoe	2.33 Mtoe
Total	**11.89 Mtoe**	**4.23 Mtoe**	**34.42 Mtoe**

a Case study reports are available per region: http://www.biotrade2020plus.eu

b See for example IEA Bioenergy Task 40: http://task40.ieabioenergy.com/wp-content/uploads/2013/09/t40-sustainable-wood-energy-2014.pdf

1.4 Development of bioenergy demand scenarios and approach for assessing related impacts

To assess the future of EU28 bioenergy supply and demand, biomass trade flows, and to the impact of the various policy options, a modelling framework is used, combining specialised models with complementary scopes and strengths. This section introduces this unique modelling system tailored to assess a broad set of impacts of bioenergy use in a quantitative manner. It describes in detail the overall approach taken, including a discussion of the scenarios analysed and of related key assumptions.

1.4.1 Modelling framework

To forecast bioenergy supply and demand, and assessment the impact of the identified policy options, a modelling framework is used combining the energy system **Green-X** model, the geospatial **ArcGIS Network** model and the **MULTIREG** model, as complementary tools for assessing socio-economic impacts. More details regarding this framework can be found in 'Technical Annex C: Modelling framework'.

The Green-X model[11] is a specialized energy system model, geographically bounded to the European Union and its neighbours, which has been used in several impact assessments and research studies on RES. The core strengths of this tool are its detailed representation of renewable resources and technologies, and its comprehensive incorporation of energy policy instruments, including also sustainability criteria for bioenergy as developed in the BioBench study (Pelkmans et al., 2012). This allows various policy design choices to be assessed for their resulting costs, expenditures and benefits, as well as environmental impacts.

Identified potentials for bioenergy supply (including domestic and imported supply) combined with trends concerning biomass demand for material use as discussed above (cf. section 1.3) as well as information on related costs serve as basis for the modelling works. To incorporate biomass trade flows in the Green-X database and the subsequent model-based analysis, a well-established linkage between the Green-X model database and Utrecht University's geospatial network model has been used as will be outlined in section 1.4.3. The extended database includes, for example, feedstock specific costs and GHG emissions for cultivation, pre-treatment e.g. chipping, palletisation, and country-to-country specific transport chains.

Finally, the techno-economic policy assessment done by the use of Green-X is complemented by a brief analysis of socio-economic impacts, indicating how GDP and employment are affected throughout changes in bioenergy use across scenarios. The outputs of Green-X have consequently served as input for the MULTIREG model –a multi-national, multi-sectoral input-output model being capable of assessing the impacts of technical and structural change in the EU economy related to biomass use.

Within the following sections, the characteristics of each of the models are described and their use within the project is clarified.

1.4.2 Energy system modelling: the Green-X model

The Green-X model is a specialized energy system model, geographically bounded to the European Union and its neighbours, that has been used in several impact assessments and research studies related to RES. The core strengths of this tool are its detailed representation of renewable resources and technologies and its comprehensive incorporation of energy policy instruments, including also sustainability criteria for bioenergy, cf. Box 3. This allows various policy design choices to be assessed with respect to resulting costs, expenditures and benefits, as well as environmental impacts.

[11] More information available at www.green-x.at

Overview of the Green-X model

The Green-X model was developed by the Energy Economics Group (EEG) at TU Wien under the EU research project "Green-X - Deriving optimal promotion strategies for increasing the share of RES-E in a dynamic European electricity market" (Contract No. ENG2-CT-2002-00607). Initially focussed on the electricity sector, this modelling tool, and its database on both RES) and costs, has been extended to incorporate renewable energy technologies across all energy sectors. The model is privately owned by TU Wien, but a public demo version is available to allow for a simplified use and to a better understanding of the functionality.

Green-X covers the EU28 geographically, but also covers the Contracting Parties of the Energy Community (West Balkans, Ukraine, and Moldova) and selected other EU neighbours (Turkey, North African countries). It allows for detailed assessments of supply and demand of RES as well as of associated costs such as capital expenditures, additional generation cost of RES compared to conventional generation, consumer expenditures due to applied supporting policies, benefits e.g. avoidance of fossil fuels and corresponding carbon emission savings. Results are calculated at both a MS and technology-level on an annual basis. The time-horizon allows for in-depth assessments up to 2050. The Green-X model develops MS specific dynamic cost-resource curves for all key RES technologies across all energy sectors. Besides the formal description of RES capacities and costs, Green-X provides a detailed representation of dynamic aspects such as technological learning and technology diffusion.

Through its in-depth energy policy representation, the Green-X model allows an assessment of the impact of applying combinations of different energy policy instruments e.g. quota obligations based on tradable green certificates, guarantees of origin, premium feed-in tariffs, tax incentives, investment incentives, impact of emission trading on reference energy prices, at both MS or EU28 level in a dynamic framework. Sensitivity investigations on key input parameters such as non-economic barriers influencing the technology diffusion, conventional energy prices, energy demand developments or technological progress e.g. technological learning typically complement a policy assessment.

The Green-X Model allocates biomass feedstock to feasible technologies and sectors in a fully internalised calculation procedure. For each feedstock category, technology choices and their corresponding demands are ranked based on the feasible revenue streams as might be available to a potential investor under the conditioned, scenario-specific energy policy framework that may change annually. Recently, a module for Intra-EU trade of biomass feedstock has been added to Green-X which operates on the same principle as that outlined above, but at a European rather than at a MS level. The Green-X model was expanded during 2011 to allow an endogenous modelling of sustainability regulations for the energetic use of biomass. This comprises specifically the application of GHG constraints that exclude technology-feedstock combinations which do not comply with conditione thresholds.

Box 3: Approaches used in modelling biomass sustainability measures

Examples of default approaches used for modelling sustainability measures are listed below. They are illustrative, details were adapted over the course of BioSustain:

- For modelling requirements on *minimum supply chain GHG emissions* the following approach will be followed: GHG emissions for assessed biomass pathways are based on calculations by the Joint Research Centre (JRC) and complemented by transport-related emissions derived from the logistic model.
- *Sustainable forest management (SFM)* is assumed to be a proxy of all national regulations introducing biodiversity and ecosystem services criteria for forest biomass. Therefore, compliance costs of these regulations are assumed being equal to compliance with SFM certification schemes, including costs resulting from both compliance with SFM requirements and chain of custody certification.

For these, data from literature is used to estimate average costs. A premium per MWh of primary feedstock will go into modelling.

- *Minimum conversion efficiency standards* have been introduced in various countries as a condition for receiving financial support. Typically, they implicitly promote biomass use in CHP plants rather than electricity-only facilities or they promote biomass use in efficient heating installations. Thus, model implementation is done by limiting financial incentives to efficient biomass supply streams in countries that make use of such standards.
- To model *national regulations introducing air emission limits higher than EU standards*, literature data is used to estimate the additional investment costs for biomass conversion plants to comply with these regulations in the respective countries.
- *Measures to reduce iLUC* will be modelled based on policy scenario assumptions that will restrict the supply of food- or feed-based biofuel crops.

About the use of Green-X in the BioSustain project

Within BioSustain, modelling of future supply and demand of bioenergy and other renewables in the energy sector has been done by using the Green-X model. In this context, Green-X provides a broad set of results concerning environmental issues: avoidance of fossil fuels and of GHG emissions following a supply chain approach, and economic impacts: CAPEX, OPEX, support expenditures.

Development of baseline scenarios for bioenergy demand

Within the project, Green-X is used to quantitatively model the following bioenergy demand scenarios up to 2030:

- a reference scenario in accordance with the EU outlook for energy and transport up to 2050 (i.e. PRIMES reference scenario), assuming for example a (gradual) phase-out of RES support beyond 2020 and, consequently, non-compliance with 2030 energy and climate targets.
- a RES policy scenario in accordance with the EC CEP agreement on 2030 energy and climate targets, aiming at 40% GHG reduction and (at least) 27% RES and energy efficiency by 2030. This case is subsequently named Green-X EUCO27 scenario and is used throughout this study as the benchmark for analysing the impacts of policy options to safeguard sustainability of bioenergy supply and use. The underlying policy concept for incentivising RES can be characterised as a least-cost approach, enhancing an efficient use of bioenergy and other RES to meeting 2030 RES goals in a cost-effective manner, see Box 4. Specifically for biofuels in transport, a continuation of current policy practices is envisaged post-2020, in accordance with the calculation done by the PRIMES model in related works.

Box 4: A least-cost approach to allocate investments in RES technologies post-2020

The selection of RES technologies in the period post-2020, within the default RES policy scenario as well as within all related scenarios concerning sustainability policy choices - follows a least-cost approach. This means that all additionally required future RES technology choices, including bioenergy, are ranked in merit-order, and the economic viability drives which choices are made to achieve the 27% RES target. In other words, a least-cost approach is used from a European perspective to determine investments in bioenergy and other RES post-2020 across the EU28. This allows us to fully reflect competition across technologies, countries (including differing financing conditions etc.) from a European perspective. Support levels and related expenditures follow then the marginal pricing concept where the marginal technology option determines the support level, like in the ETS or in a quota or certificate trading regime, or similar to the concept of liberalised electricity markets.

A sensitivity analysis is carried out on the following parameters:

- *Availability of biomass feedstock for the energy sector:* Aim is to assess the impacts of changing assumptions concerning bioenergy feedstock potentials, reflecting the uncertainty in the availability of forestry biomass feedstock for the energy sector (EU and Extra-EU potentials), respectively. For doing so, three different datasets on bioenergy feedstock potentials are applied, reflecting distinct levels of availability of forestry biomass includes competition between energy and material use, combined with distinct trends concerning Extra-EU solid biomass potentials available for import to Europe.

  More precisely, the default dataset on feedstock potentials reflects a "reference" case with respect to biomass feedstock that is left over for energy uses (i.e. in accordance with the "reference" scenario concerning biomass feedstock, see section 1.3) and a reference trend concerning Extra-EU biomass potentials that can be imported to Europe (see section 1.3). Within the sensitivity assessment this dataset will be replaced by a low potential case (i.e. the "restricted" scenario concerning supply potentials) and a high potential case (i.e. the "resource" scenario).

- *Energy efficiency / energy demand:* For the RES policy scenario the impact of accompanying energy efficiency measures is assessed. More precisely, we analyse how overall RES deployment and specifically bioenergy demand is affected by a move towards stronger energy efficiency measures (i.e. 30% instead of 27%).

An overview on assessed scenarios with respect to baseline developments is given in **Error! Reference source not found.**.

Table 1-2 Overview of cases assessed for baseline trends

Scenario acronym:	**Policy option 1, reference scenario, REFERENCE scenario**	**Policy option 1, EUCO27 scenario, REFERENCE scenario**	**Policy option 1, EUCO30 scenario, REFERENCE scenario**	**Policy option 1, EUCO27 scenario, RESTRICTED scenario**	**Policy option 1, EUCO27 scenario, RESOURCE scenario**
Policy option (sustainability):	Policy option 1	Policy option 1	Policy option 1	Policy option 1	Policy option 1
Case-specific policy assumptions:	Reference scenario (in accordance with PRIMES reference), no additional EU action on sustainability	EUCO27 scenario, **no additional EU action** on sustainability	EUCO30 scenario, **no additional EU action** on sustainability	EUCO27 scenario, **no additional EU action** on sustainability	EUCO27 scenario, **no additional EU action** on sustainability
Dataset on bioenergy potentials:	**REFERENCE**	**REFERENCE**	**REFERENCE**	**RESTRICTED**	**RESOURCE**
RES target 2030:	No (reference)	27%	27%	27%	27%
Energy efficiency target 2030:	No (reference)	27%	30%	27%	27%

Key input parameters

In order to ensure maximum consistency with existing EU scenarios and projections, the key input parameters of the scenarios presented in this report are derived from PRIMES-EUCO27 modelling and from the Green-X database with respect to the potentials and cost of RES technologies. Table 1-3 shows which parameters are based on PRIMES, on the Green-X database and which have been defined for this study. The PRIMES scenarios used for this assessment are the latest EC *reference scenario* (EC, 2016) and climate mitigation scenarios that build on an enhanced use of energy efficiency and renewables in accordance with the Council agreements taken for 2030 (PRIMES EUCO27 and EUCO30 scenario).

Table 1-3 Main input sources for scenario parameters

Based on PRIMES	Based on Green-X database	Defined for this assessment
Primary energy prices	Renewable energy technology cost (investment, fuel, O&M)	Renewable energy policy framework
Conventional supply portfolio and conversion efficiencies	Renewable energy potentials	Reference electricity prices
CO_2 intensity of sectors	Biomass trade specification	
Energy demand by sector	Technology diffusion / Non-economic barriers	
	Learning rates	
	Market values for variable renewables	

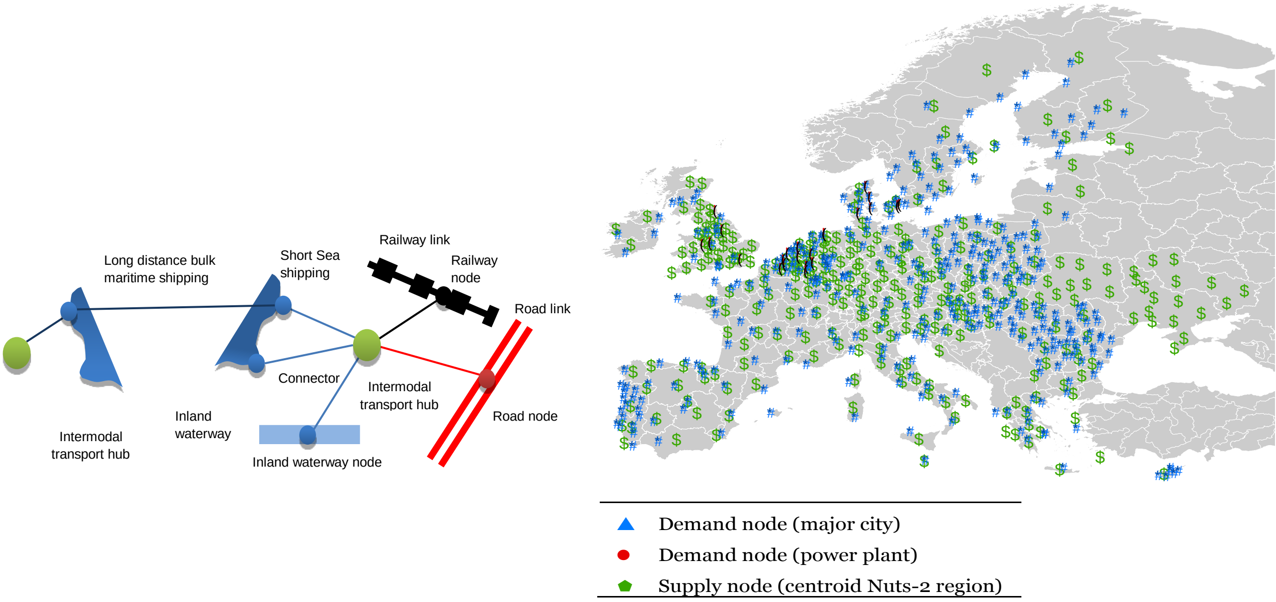
1.4.3 Modelling biomass transport chains in and to Europe: the geospatial network model

In order to identify likely trade routes of solid biomass and to quantify the specific costs and GHG emissions of the logistic chains of solid biomass trade, a geospatial network model was developed in the ArcGIS Network Analyst extension by the Copernicus Institute at Utrecht University. The model includes an intermodal network with road, rail, inland waterways and short sea shipping in Europe and ocean shipping routes for Extra-EU supply chains. The networks are connected via transhipment hubs, where biomass can be transferred to other transport modalities (for instance, from truck to ship).

The model optimises for least cost and associated GHG emissions from demand to supply regions. Total cost and GHG emissions depend on the routes taken, transport modes used and number of transfers between different transport modes.

For illustrative purposes, Figure 1-10 (left) depicts an example of a transhipment hub in a region including all transport modalities, such as Rotterdam. Note that in most regions only road and rail networks are available. Transport costs are calculated between each supply node (the geographic centres of NUTS-2 regions) and each demand node. Demand nodes include coal fired power plants that can co-fire biomass or coal power plants that are fully converted to biomass, for example Drax in the UK, and major cities in Europe. Large power plants are included to represent the developed infrastructure in Northwest Europe to supply wood pellets. These power plants are often located near seaports or inland waterways. Cities are considered representative for decentralized demand of biomass with more complex supply chains. The power plant capacity (MWe) and population per city were used to allocate demand per demand node.

Figure 1-10 The network model approach (hub-spoke) (left) and EU origins and destinations (right)



1.4.4 Assessment of socio-economic impacts: the MULTIREG model

The analysis of socio-economic impacts aims at deriving a rough estimate of the impacts of policy measures on gross value added as a contribution to GDP, employment and specifically employment in small and medium enterprises (SME). It builds on the results of the Green-X model and combines technology-specific data with economic modelling. For that purpose the MULTIREG model – i.e. a multi-national, multi-sectoral input-output model being capable of assessing the impacts of technical and structural change in the EU economy related to biomass use – is used.

Overview of the MULTIREG model

The MULTIREG model is a multi-national, multi-sectoral input-output model that covers each of the EU MSs and the Rest of the World as an aggregate. The main database of MULTIREG is an inter-country input-output table that captures economic transactions within and between countries at the industry level. This includes transactions between industries (intermediate inputs) and final demand (household consumption, government consumption, investment and exports). Trade between countries is represented explicitly by product group and by trade partner. This setup allows tracing supply chains across country borders, which is an important feature of the modelling approach. Furthermore, data on sectoral employment and employment in SME are included. The sectoral level of disaggregation allows distinguishing 59 industries at the NACE 2-digit level. The database of the MULTIREG model is derived from the recently published and EU-funded World Input-Output Database (WIOD) and additional data from Eurostat.

The outputs of MULTIREG are impacts on gross value added as a contribution to GDP, employment and employment in SME. The results on employment in SME exclude direct effects for operation of RES facilities, since data on their size classes are not available. Economic and employment impacts are calculated for each RES technology, each EU MS and each of the 59 industries.

Use of MULTIREG in the BioSustain project

Within BioSustain, the MULTIREG model is used to perform a brief estimation of the impacts of policy measures on gross value added as a contribution to GDP, employment and specifically employment in small and medium enterprises (SMEs). MULTIREG builds on the results of the Green-X Model and combines technology-specific data with economic modelling.

The analysed policy measures lead to shifts within the use of RES technologies. Since the 27% RES target still applies, the impact on the use of conventional energy technologies is small and thus not included in the assessment. On one hand, the measures mainly lead to changes of investment, O&M and fuel expenditures for RES deployment and use, and on the other hand, to policy support expenditures. These economic impulses trigger further economic impacts, which can be subdivided into the following effects:

- the direct effect on the RES sector, that comprises operation of RES facilities (e.g. bioenergy plants, wind power plants) on one hand and dedicated technology, service and fuel suppliers (e.g. engineering companies, technology and component manufacturers or installation companies) on the other hand;
- the indirect effect on the upstream supply chains of the RES sector; the direct and indirect effects are aggregated to the deployment effect;
- the income effect, that is induced by consumption of persons employed in the RES sector and upstream industries and includes the direct and indirect impacts of manufacturing of the goods and services consumed;
- the budget effect, which is induced by policy support expenditures. It is assumed that support expenditures are in the end financed by private households by increasing energy or other product prices, by additional taxes to compensate public subsidies or by reduced capital income from companies carrying the support expenditures. Increasing support expenditures are thus assumed to reduce the real income of households and consequently their general expenditures for goods and services. As a further consequence, this reduces the production of goods and services in the supply chain industries.

These effects are calculated for the baseline case and each policy option. The net impact of each policy option results as the deviation from the baseline case. The results refer to the annual average of the years 2021 - 2030.

In order to estimate the deployment effect, the investment, O&M and fuel expenditures for RES deployment are distributed to cost components and then to supplying industries, based on technology-specific data on cost structures. These data are fed into the MULTIREG model to calculate the deployment effect of RES deployment. The income and the budget effects are also calculated with MULTIREG.

Socio-economic impacts are modelled as differences between policy options and the reference case without additional sustainability criteria for biomass use.

1.5 Calculation of supply chain GHG emissions and related savings

GHG emissions of liquid biofuels and solid and gaseous bioenergy pathways are calculated following the methodologies of Annex V of the EU Renewable Energy Directive (EC 2009), Annex I of COM2010(11) and SWD(2014)259. Defining the exact height/range of the C-footprint per type of feedstock and originating region is extremely difficult and proved not feasible based on available literature and data sources. Possible emissions or credits from carbon stock changes are therefore not included. Emissions of biomass supply chains are combined with conversion efficiencies to electricity, heat and fuels in Green-X to calculate total pathway emissions and to address for GHG criteria (threshold values).[12]

Solid and gaseous biomass

GHG emissions and typical savings for electricity and heat are depicted in Figure 1-11 for European pathways and Figure 1-12 for imported solid biomass from Extra-EU countries. The results are calculated for trade between each individual MS per type of feedstock and as such implemented in the Green-X model. For readability, only the ranges are depicted here.

GHG savings are calculated in these graphs assuming an efficiency of 85% for heat and 32% for electricity, representing typical values as used in Green-X modelling for bioenergy installations. For CHP an average electric efficiency of 28% is assumed whereas for the combined heat supply an efficiency of 32% is presumed.[13] Generally, these values are higher than the efficiencies assumed in COM(2010) 11 and SWD(2014) 259, representing a conservative indication of default and typical values. The pathways used in this study link to JRC's report on Solid and gaseous bioenergy pathways as follows (Giuntoli *et al.*, 2015):

- EU/Extra-EU Forest residues: A. Woodchips from forest logging residues (Pathway no. 1)
- EU/Extra-EU Stemwood: D. Woodchips from stemwood (Pathway no. 4)
- EU/Extra-EU Wood industry residues: C. Pellets from wood industry residues (Pathway no. 7)
- Agricultural residues:
  - EU Straw, domestic: A. Agricultural residues with bulk density <0.2 tonne/m3 (Pathway no. 11)
  - EU Straw, exported: C. Straw pellets (Pathway no. 13)
  - Extra-EU Brazil: D. Bagasse pellets/briquettes (Pathway no. 14)
  - Extra-EU Southeast Asia: F. Palm kernel meal (Pathway no. 16) (open pond and closed pond)
- Grassy crops:
  - EU Domestic: E. Miscanthus bales
  - EU Export: E Miscanthus bales
- Short rotation coppice (SRC)
  - EU: B2. Woodchips from SRC – Poplar (pathway no. 2b-c)
  - Extra-EU: B1. Pellets from SRC – Eucalyptus (Pathway no. 6a)

The calculated emissions of solid bioenergy pathways are different from the reported values by JRC (Giuntoli *et al.*, 2015) for the following aspects:

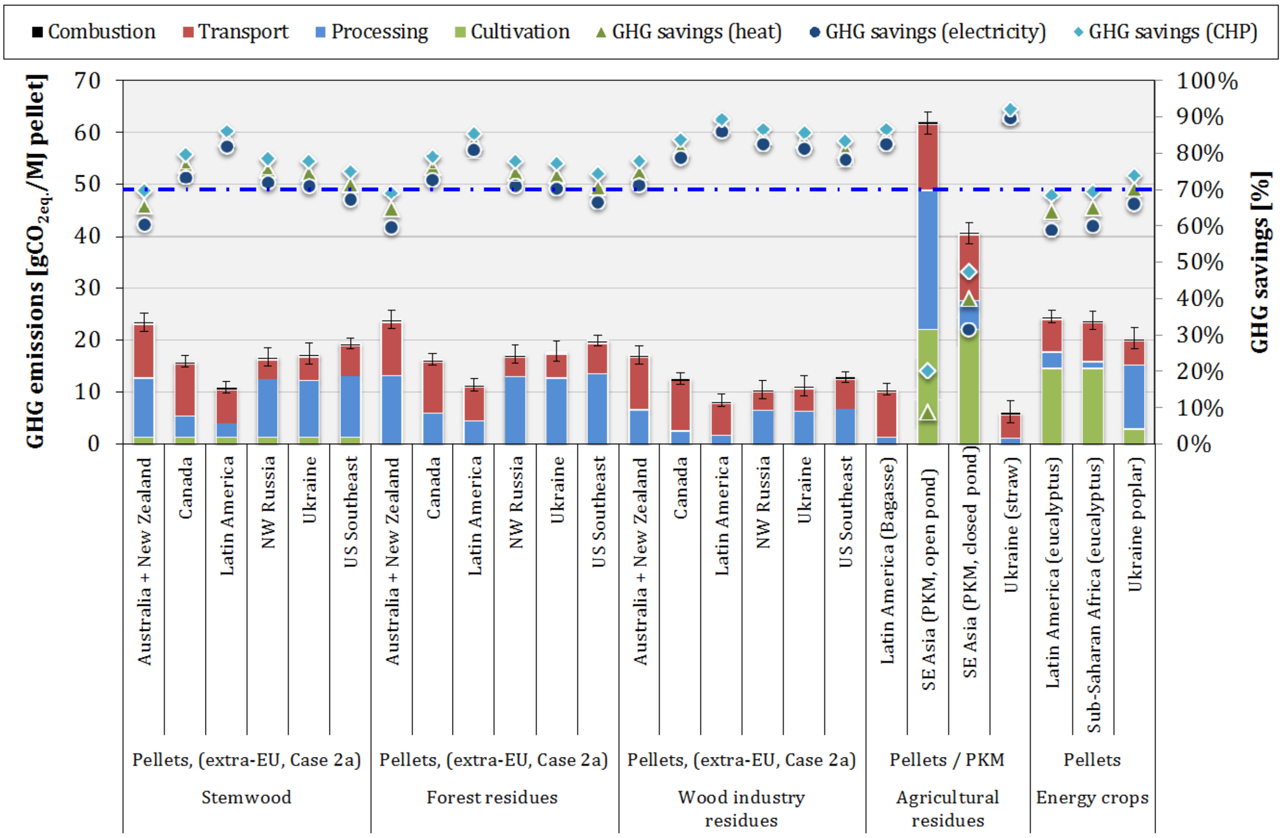
- Country specific electric emission coefficients were used instead of the EU28 standard value. These were derived from the additional standard values from the BIOGRACE II tool (BIOGRACE II, 2015);

[12] Please note that in modelling GHG savings are calculated endogenously with the Green-X model, using distinct conversion efficiencies by plant type and thereby considering expected improvements for new installations thanks to technological progress.

[13] Note that this does not represent the technical conversion efficiency of heat supply in case of CHP that is typically significantly higher. Thus, it is the combination of the coupling factor between electricity and heat supply, describing how often heat is used during times of electricity supply, and the technical conversion efficiency for the heat part.

- Transport chains of international bioenergy pathways are calculated based on country-to-country specific trade routes derived by use of the geospatial ArcGIS Network model.
- Grassy crops were eliminated from the JRC study due to lack of reliable data because the market of miscanthus cultivation is not yet well developed (Giuntoli *et al.*, 2015). For the purpose of the BioSustain project, the eliminated results are included because grassy crops are key feedstocks in the Green-X model.

Figure 1-11 GHG emissions and typical GHG savings[14] for domestic and ranges of Intra-EU solid biomass*



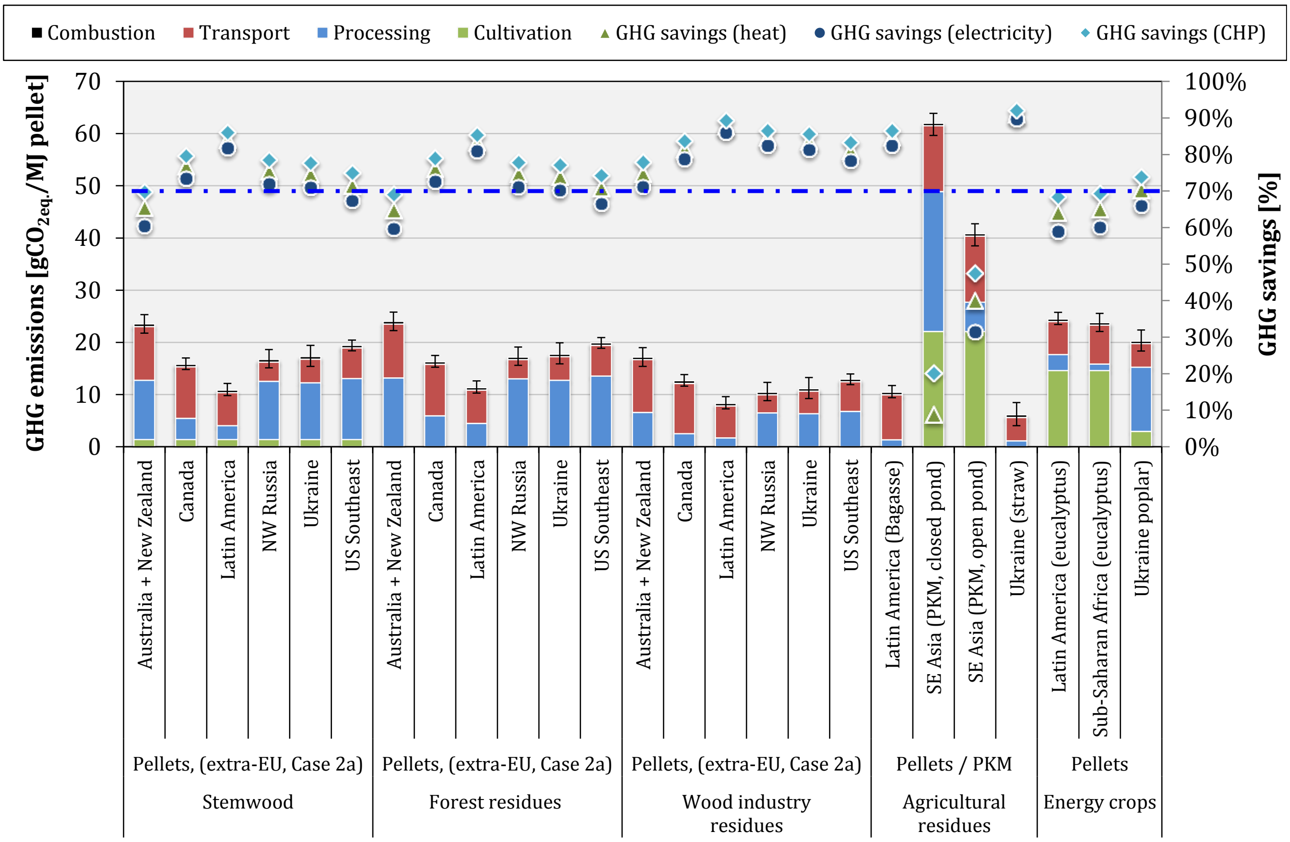
* *Adapted from JRC (Giuntoli et al., 2015) with specific transport chains and conversion efficiencies aligned with Green-X Model.*

Because of the low bulk density of straw and miscanthus bales, these feedstocks are assumed to be pelletised if exported. Due to handling difficulties, wood industry residues such as sawdust are also assumed to be pelletized for both domestic uses and exports. All other wood sources are assumed to be transported as wood chips. Given the low bulk density of wood chips, this could lead to higher emissions if transported over long distances compared to transport of wood pellets. This is the main reason why the ranges between lowest and highest emissions from exported wood chips are higher than exported wood pellets or agri-pellets.
The GHG emissions of solid biomass imported from outside the EU are generally higher those from domestic biomass. However, large bulk ocean carriers are relatively efficient compared to road or rail transport. In some cases, GHG emissions of overseas imported biomass pathways are lower than solid biomass traded between MS's.

[14] GHG savings are calculated under COM(2010)11: $GHG\ savings = \frac{FFC - GHG\ bioenergy}{Fcc} * 100$ where $FFC_{electricity}$ (fossil fuel comparator) = 186 g CO_2eq / MJ_{el} and FFC_{heat} = 80 g CO_2eq/MJ_{heat}. Please note that GHG savings depend on the actual system efficiency, as calculated with the Green-X model.

Emissions from palm kernel meal (PKM), a co-product from palm oil production are allocated under the RED method (energy content, wet LHV). Wastewater from palm oil processing results (palm oil mill effluent, POME) is often treated in open ponds leading to high methane emissions. These emissions can be reduced substantially if processed in a closed pond. Both pathways, as calculated by JRC, are depicted in Figure 1-12.

Figure 1-12 Average GHG emissions and typical GHG savings[15] for Extra-EU solid biomass*

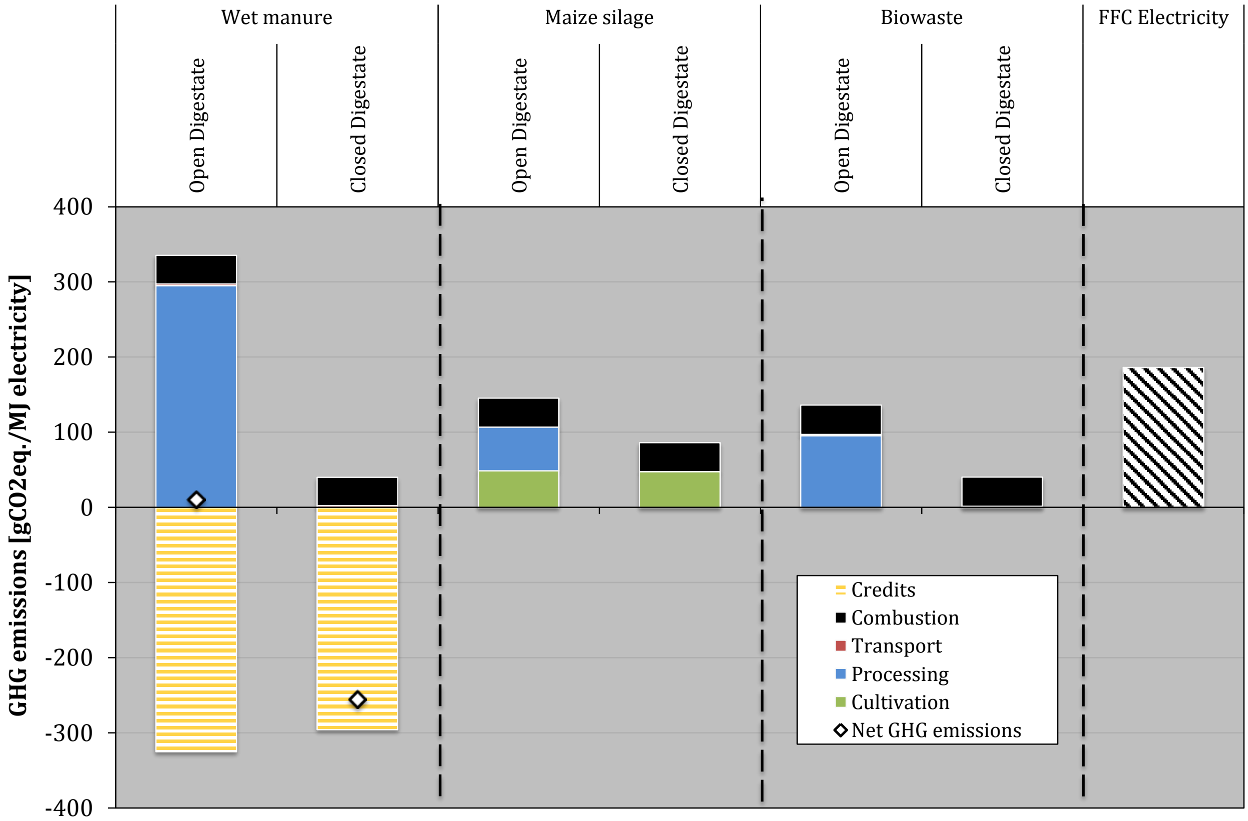


Error bars show the ranges between EU MS's.
**adapted from JRC (Giuntoli et al., 2015) with specific transport chains and conversion efficiencies aligned with Green-X Model*

GHG emissions of gaseous bioenergy pathways from co-digestion (manure and maize) and waste do not entail international transport and are directly derived from JRC as shown in Figure 1-13. Note however that the typical values are used. For the calculation of the default values shown below, emissions from processing, transport and fuel use are increased with 20% compared to the default values (Giuntoli *et al.*, 2015).

[15] GHG savings are calculated under COM(2010)11: $GHG\ savings = \frac{FFC - GHG\ bioenergy}{Fcc} * 100$ where $FFC_{electricity}$ (fossil fuel comparator) = 186 g CO_2eq / MJel and FFC_{heat} = 80 g CO_2eq/MJ_{heat}.

Figure 1-13 Default GHG emissions for electricity production from non-upgraded biogas (Giuntoli *et al.*, 2015)



Liquid biofuels

Emissions from liquid transport fuels are based on JRC, as presented in the EU RED for current production systems. Future improvements and associated emissions and GHG savings are derived from COWI (COWI Consortium, 2009) as shown in Table 1-4 and based on the following assumptions:

- N_2O Emissions from N-fertilizer plants will be reduced with 90% by application of end-of-pipe technologies;
- 25% reduction in CO_2 emissions from N-fertilizer production by 2020;
- 5% reduction in GHG emissions other than related to N-fertilizer consumption by 2020;
- 10% reduction in CO_2 emissions from biofuel processing by 2020.

Please note that in the Green-X model it is assumed that further improvements in terms of GHG performance can be achieved for selected biofuel pathways in the period post-2020, allowing coping with higher GHG thresholds that come into force for all new installations from 2020 onwards.

2 Baseline scenario

2.1 Bioenergy supply and demand projections to 2030

This section presents the outcomes of the model-based analysis concerning baseline trends in the renewable energy sector at EU level, and specifically on the role of bioenergy. The baseline scenario, i.e. the Green-X EUCO27 scenario, where the underlying *reference* dataset is currently available bioenergy supply and demand is used. For this scenario, detailed outcomes are presented concerning developments over time and on various subjects. The results of other cases are for comparative reasons are included in the summary tables.

2.1.1 Trends in overall final bioenergy demand, by energy sector

Table 2-1 shows a breakdown of RES and bioenergy demand by 2030 in terms of final energy consumption, indicating the contribution of bioenergy and other RES in meeting the 2030 RES target (ie EUCO27: part of which is that at least 27% RES share in gross final energy consumption) for all assessed cases under baseline conditions. Complementary to this, in Figure 2-1 a detailed look at the dynamic development in the period up to 2030 is taken for the default baseline case, i.e. the Green-X EUCO27 scenario. More precisely, the upper graph in Figure 2-1 shows the development of RES and bioenergy demand in absolute terms, i.e. the derived electricity, heat and transport fuels stemming from bioenergy and other RES in Mtoe. The respective shares in sectoral demands and in overall gross final energy demand is depicted in the lower graph in Figure 2-1.

Despite the continuous increased use of bioenergy up to 2030, specifically in heating & cooling and in the electricity sector, their percentage share in final energy production coming from renewables is declining modestly (cf. Figure 2-1 (bottom)) from around 61% by 2014 down to about 50% by 2030. This is a consequence of the strong increased use of other RES like wind and solar in the years to come, consistent with previously observed trends of their deployment. **The underlying policy concept of the Green-X EUCO27 scenario is to follow a least-cost approach for incentivising the required RES deployment for meeting 27% RES by 2030.** This has implications on the projected future development of the various RES technologies. Under these framework conditions, demand for bioenergy is expected to grow but the relative share in total RES may decline. A limited availability of bioenergy feedstock in the forestry sector, as assumed under the “restricted” scenario, would accelerate this trend. This limits the contribution of bioenergy to overall RES supply to 42% by 2030 whereas in the opposite case, assuming increased availability of forestry biomass and of Extra-EU imports i.e. the “resource” scenario of bioenergy supply possibilities, the share of bioenergy would remain constant post 2020, at around 53%.

In terms of sector specific developments, the strongest contribution of bioenergy in terms of final energy is for heating & cooling, followed by electricity and the transport sector. These trends remain intact under changing framework conditions of biomass supply and demand trends. The largest increase other renewables use is expected to take place in the electricity sector. Here mainly wind and solar contribute to increase the RES share in gross electricity consumption from 37%-48%, from 2020-2030.

A closer look at bioenergy developments in the individual MS’s shows the following trends:

- By 2030, the highest share of bioenergy in overall final energy demand will be in the Baltic States and Scandinavian countries - Finland and Sweden. Bioenergy is a key source in these countries for heating but there are differences between them in the roles of derived heat and direct use. In Sweden and Finland derived bioheat from CHP plays a key role today and in the future, while in the Baltic Staes it is the direct use of bioenergy at household and industry level that drives the strong contribution of bioenergy to overall energy demand.

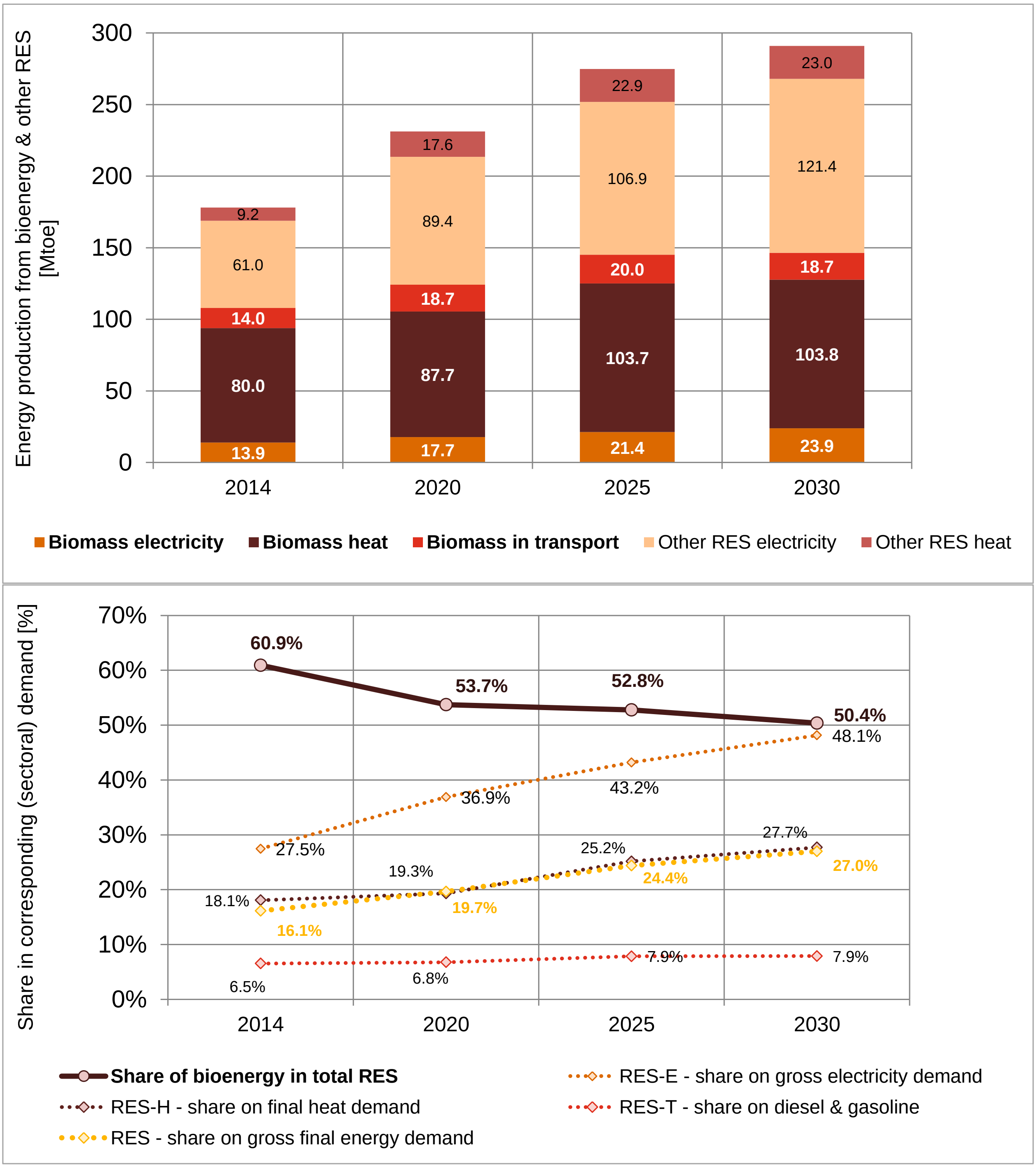
- The list of countries gets longer if the share of bioenergy in total new RES installations in the period post-2020 is considered. Similar to the Baltic States, Finland and Sweden - Belgium, Bulgaria, the Czech Republic, Hungary, Slovakia, Slovenia and Romania will have bioenergy dominating their renewables expansion in the next decade. Bioenergy is expected to contributes more than two thirds of generation by 2030, largely new installations built after 2020.
- In absolute terms, if the produced energy stemming from biomass is accounted for, Germany ranks first, followed by France, Finland, Sweden and Poland. In each of these countries, bioenergy is expected to contribute more than 10 Mtoe by 2030.
- In contrast to the above, the lowest bioenergy share in final energy demand by 2030 is expected for Malta, Cyprus and Luxembourg. Here domestic bioenergy supply potentials appear more strictly limited and the lack of domestic resources will only to a small extent be offset through biomass imports from other EU countries or from abroad.
- For electricity supply, bioenergy is expected to achieve the strongest increase in the forthcoming decade in the UK and in Poland. In each of these countries more than 10 TWh of electricity generation by 2030 stems from new bioelectricity installations (built post-2020).

Table 2-1 RES and bioenergy demand in terms of final energy by 2030 – electricity, heat and transport fuel production from RESs under baseline trends

Energy production from RES by 2030	Case:	Policy option 1, reference scenario, REFERENCE Supply Potentials	Policy option 1, EUCO27 scenario, REFERENCE Supply Potentials	Policy option 1, EUCO30 scenario, REFERENCE Supply Potentials	Policy option 1, EUCO27 scenario, RESTRICTED Supply Potentials	Policy option 1, EUCO27 scenario, RESOURCE Supply Potentials
Electricity sector						
Biogas	Mtoe	5.3	5.5	5.5	5.7	5.4
Solid biomass	Mtoe	14.6	15.6	15.5	14.8	16.7
Biowaste	Mtoe	2.8	2.8	2.8	2.8	2.8
Bioenergy electricity	**Mtoe**	**22.7**	**23.9**	**23.8**	**23.3**	**24.9**
of which CHP	Mtoe	16.5	17.2	17.3	16.5	18.1
Other RES electricity	Mtoe	110.8	121.4	118.8	138.7	115.5
RES-E total	**Mtoe**	**133.5**	**145.4**	**142.6**	**161.9**	**140.4**
Heat sector						
Biogas (derived heat)	Mtoe	2.7	2.8	2.8	2.9	2.8
Solid biomass (derived heat)	Mtoe	21.9	23.4	23.5	21.9	24.9
Biowaste (derived heat)	Mtoe	4.1	4.2	4.2	4.2	4.2
Bioenergy (derived heat)	Mtoe	28.8	30.4	30.5	28.9	31.8
Bioenergy (direct use)	Mtoe	65.8	73.5	70.6	50.1	86.0
Bioenergy heat	**Mtoe**	**94.6**	**103.8**	**101.0**	**79.1**	**117.8**
Other RES heat	Mtoe	20.8	23.0	22.5	29.9	21.4
RES-H total	**Mtoe**	**115.5**	**126.8**	**123.6**	**108.9**	**139.2**
Transport sector						
1st generation biofuels	Mtoe	10.2	7.2	7.2	7.7	7.0
2nd generation biofuels	Mtoe	5.1	6.1	5.2	7.3	6.7
Biofuel import	Mtoe	2.0	5.4	4.9	5.6	2.8
Bioenergy in transport	**Mtoe**	**17.4**	**18.7**	**17.3**	**20.6**	**16.5**
RES-T total (excl. electricity)	**Mtoe**	**17.4**	**18.7**	**17.3**	**20.6**	**16.5**

Summary: RES vs bioenergy						
Bioenergy total	**Mtoe**	**134.7**	**146.5**	**142.2**	**122.9**	**159.2**
RES total	**Mtoe**	**266.3**	**290.9**	**283.5**	**291.4**	**296.1**
RES share on related demand						
RES-E - share on gross electricity demand	%	44.1%	48.1%	48.8%	53.6%	46.5%
RES-H - share on final heat demand	%	23.4%	27.7%	28.9%	23.8%	30.4%
RES-T - share on final transport fuel demand	%	5.2%	5.9%	5.6%	6.5%	5.2%
RES-T - share on diesel & gasoline	%	6.7%	7.9%	7.5%	8.7%	6.9%
RES - share on gross final energy demand	**%**	**23.6%**	**27.0%**	**27.5%**	**27.0%**	**27.5%**
Share of bioenergy in total RES	**%**	**50.6%**	**50.4%**	**50.2%**	**42.2%**	**53.8%**

Figure 2-1 RES and bioenergy demand in the period 2020 to 2030 in the Green-X EUCO27 scenario



In absolute terms (top) and in relative terms, as share of corresponding sectoral demands (bottom)

2.1.2 Trends in bioenergy supply

This section focuses on expected trends in bioenergy supply. As a starting point, Table 2-2 provides a breakdown of available bioenergy supply potentials and their expected use by 2030 for all assessed cases under baseline conditions. After that, details on the dynamic development of total bioenergy supply and by energy sector for this study's focal period 2020-2030 are shown in Figure 2-2 for the baseline case, i.e. the Green-X EUCO27 scenario. The upper graph in Figure 2-2, indicating at aggregated level a breakdown of bioenergy supply, contains in addition to the modelling outcomes on future bioenergy supply also data on the current status (2014).

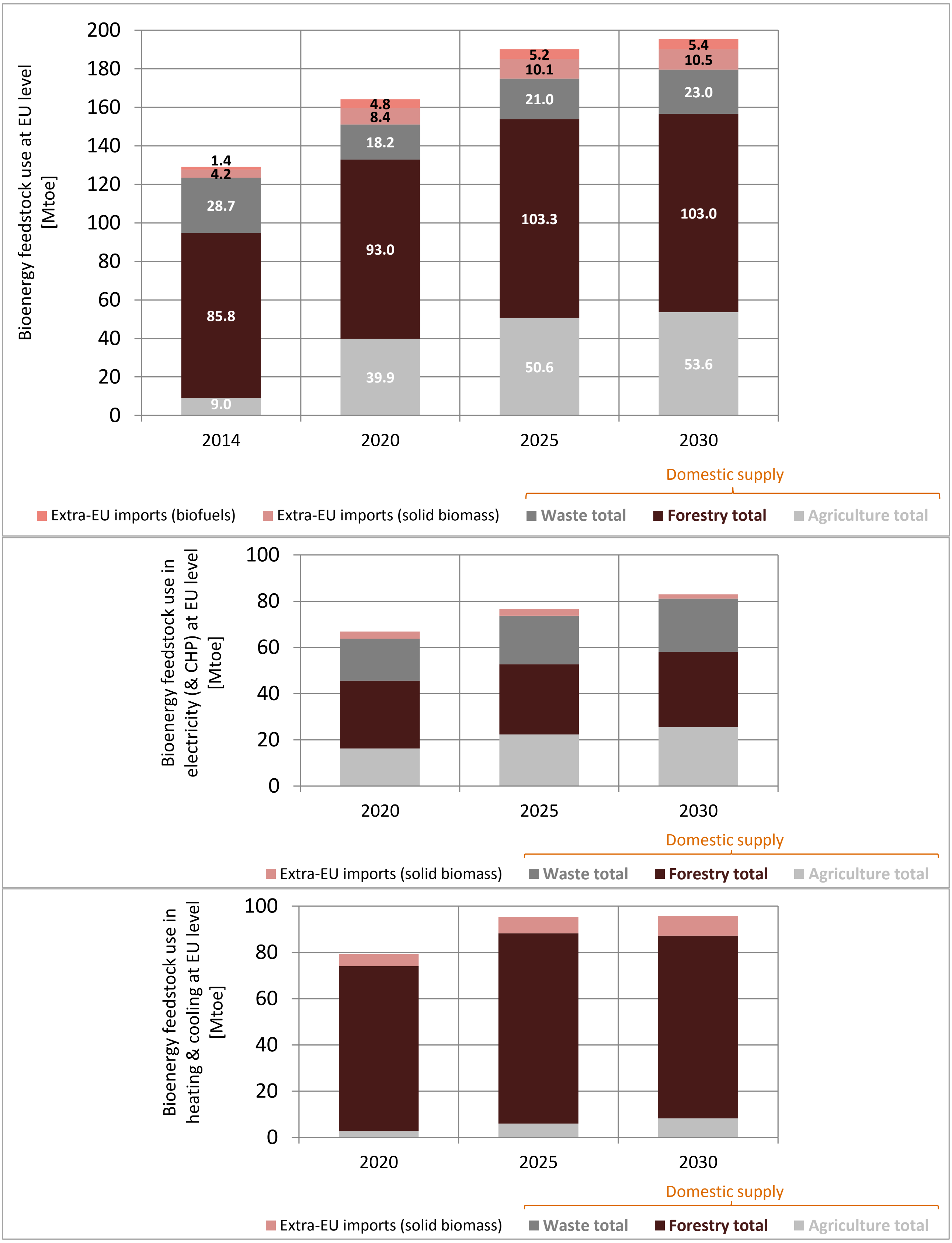
As discussed in section 1.3, the highest supply potentials are in agriculture, followed by forestry and waste. The expected use of these resources follows a different ranking: because of economic viability combined with technical mobilisation, forestry leads. The greatest demand for forestry feedstock is heating & cooling, followed by the electricity sector, which includes CHP.

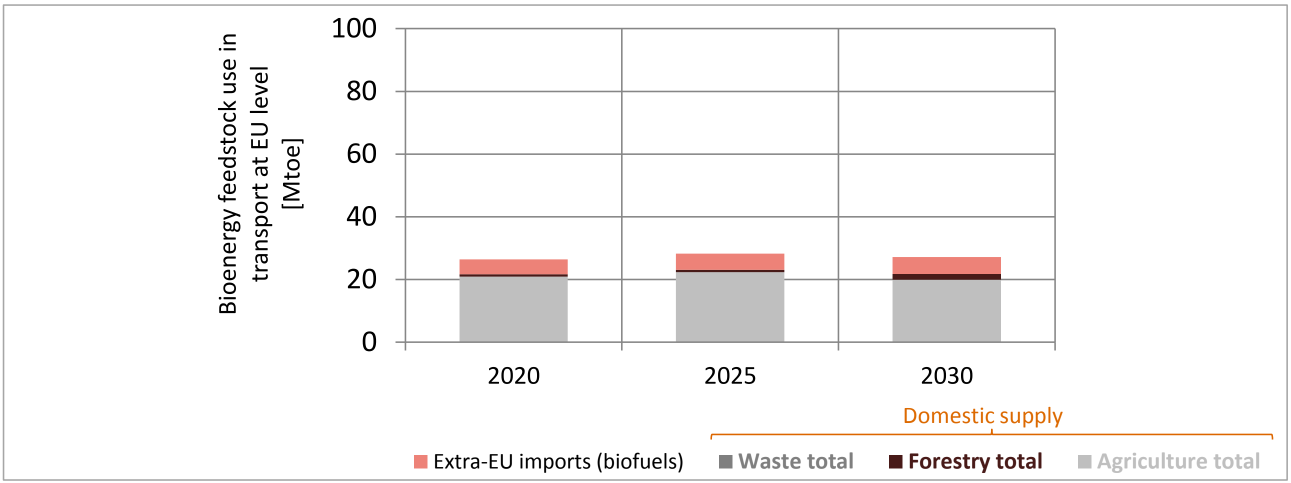
Table 2-2 Bioenergy supply capacities and use under baseline scenario

Bioenergy: supply potentials and projected demand	Case:	**Policy option1, reference scenario, REFERENCE supply potentials**	**Policy option 1, EUCO27 scenario, REFERENCE supply potentials**	**Policy option 1, EUCO30 scenario, REFERENCE supply potentials**	**Policy option 1, EUCO27 scenario, RESTRICTED supply potentials**	**Policy option 1, EUCO27 scenario, RESOURCE supply potentials**
Supply potentials						
Domestic bioenergy:						
Agriculture total	Mtoe	211.0	211.0	211.0	211.0	211.0
Forestry total	Mtoe	111.6	111.6	111.6	78.4	146.1
Waste total	Mtoe	29.5	29.5	29.5	29.5	29.5
Domestic Bioenergy total	Mtoe	352.0	352.0	352.0	318.8	386.6
Extra-EU imports (solid biomass)	Mtoe	11.9	11.9	11.9	4.2	34.4
Extra-EU imports (biofuels)	Mtoe	16.5	16.5	16.5	27.2	27.2
Extra-EU imports total	Mtoe	28.4	28.4	28.4	31.4	61.6
Bioenergy total	**Mtoe**	**380.4**	**380.4**	**380.4**	**350.3**	**448.2**
Demand						
Domestic bioenergy:						
Agriculture total	Mtoe	52.6	53.6	51.0	63.8	45.6
Forestry total	Mtoe	94.0	103.0	101.2	76.2	110.4
Waste total	Mtoe	22.8	23.0	23.0	23.2	22.9
Domestic Bioenergy total	Mtoe	169.4	179.6	175.2	163.3	178.8
Extra-EU imports (solid biomass)	Mtoe	10.6	10.5	10.7	3.6	29.2
Extra-EU imports (biofuels)	Mtoe	2.0	5.4	4.9	5.6	2.8
Extra-EU imports total	Mtoe	12.6	15.9	15.6	9.2	32.0
Bioenergy total	**Mtoe**	**182.0**	**195.5**	**190.7**	**172.5**	**210.8**
Exploitation of supply potentials						
Domestic bioenergy:						
Agriculture total	%	25%	25%	24%	30%	22%
Forestry total	%	84%	92%	91%	97%	76%

Bioenergy: supply potentials and projected demand	Case:	**Policy option1, reference scenario, REFERENCE supply potentials**	**Policy option 1, EUCO27 scenario, REFERENCE supply potentials**	**Policy option 1, EUCO30 scenario, REFERENCE supply potentials**	**Policy option 1, EUCO27 scenario, RESTRICTED supply potentials**	**Policy option 1, EUCO27 scenario, RESOURCE supply potentials**
Waste total	%	77%	78%	78%	79%	78%
Domestic Bioenergy total	%	48%	51%	50%	51%	46%
Extra-EU imports (solid biomass)	%	89%	88%	90%	84%	85%
Extra-EU imports (biofuels)	%	12%	33%	30%	21%	10%
Extra-EU imports total	%	44%	56%	55%	29%	52%
Bioenergy total	**%**	**48%**	**51%**	**50%**	**49%**	**47%**

Figure 2-2 Bioenergy supply in the period 2020-2030 in the Green-X EUCO27 scenario



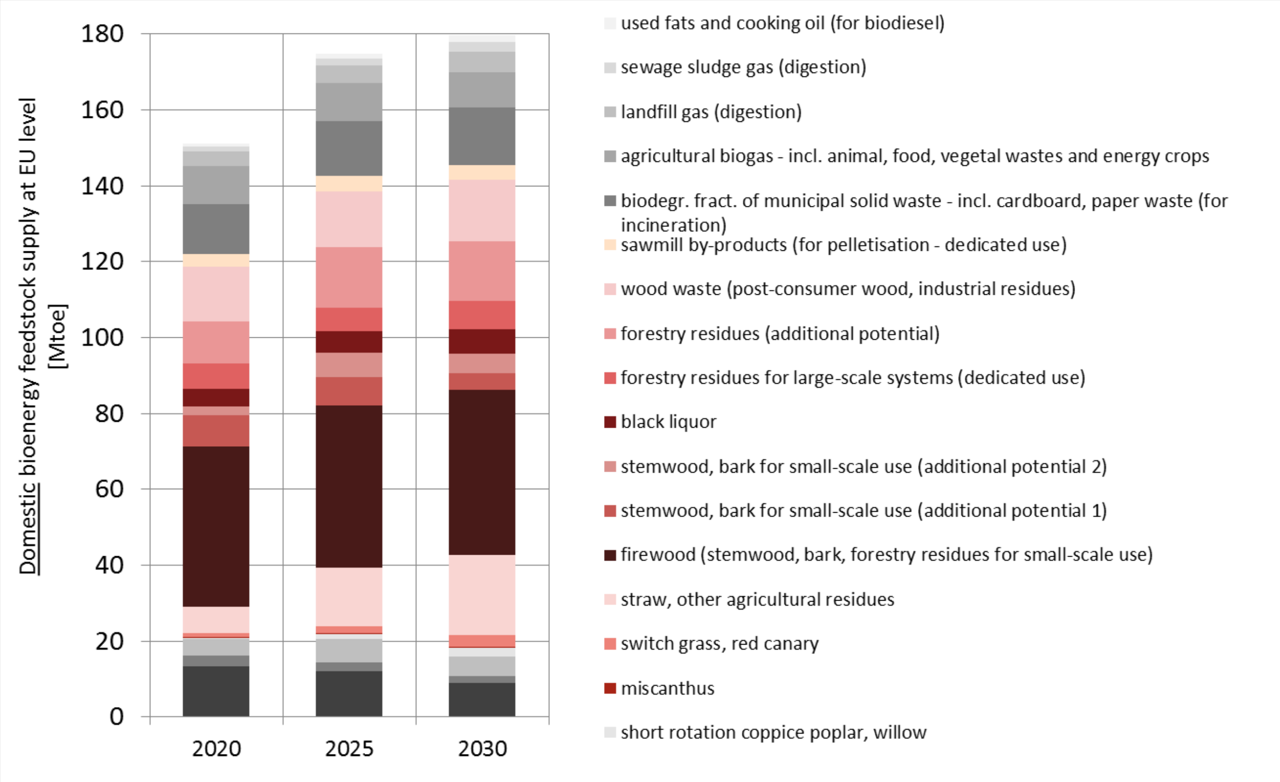


Total (upper) and by sector (electricity: upper-middle; heating & cooling: lower-middle; transport: lower)

In the electricity sector, a wide variety of feedstock is used today, and in our derived scenario, we expect this trend to continue in the coming years. The greatest increase is projected for agricultural biomass where agricultural residues will increase share in the Green-X EUCO27 scenario post-2020. For biomass in heating & cooling, forestry supply is in dominant position today, and we project this to continue also. Total biomass for heating & cooling is projected to decline modestly post-2025 – with assumed increases in energy efficiency. In transport biofuels, agricultural feedstock is dominant today, this trend is projected to continue for the medium term. There is a shift from food and feed crops towards lignocellulosic feedstock to produce advanced biofuels in the period post-2020.

Figure 2-3 shows a breakdown of total domestic bioenergy supply by feedstock for the period 2020-2030. This graph does not include Extra-EU imports of biomass feedstock but does include a detailed breakdown of forestry, agricultural and waste-based biomass supplies, for the Green-X EUCO27 scenario. Firewood makes up the largest part of all feedstock categories, strong increases are projected for agricultural crop residues like straw.

Figure 2-3 Breakdown of domestic bioenergy supply in the period 2020-2030 by feedstock in the Green-X EUCO27 scenario



2.2 Biomass trade flows

This section describes the development of biomass trade and, in more detail, Intra-EU trade and Extra-EU imports of solid biomass.

About 85% of biomass feedstock is consumed close to the production source within that MS in 2030, a small increase in trade compared to 88% in 2014[16]. This share is expected to increase if biomass export facilities are not built and developed, the opposite is true if trade infrastructure is developed.

The role and importance of feedstock trade is however increasing over time, cf. Figure 2-4**Error! Reference source not found.**. Our trade includes both Intra-EU trade and Extra-EU imports that make up the largest part of that trade (about 60% of total bioenergy feedstock trade). Extra-EU imports of biofuels peaked in 2012 at ~3 Mtoe and decreased to ~1 Mtoe in 2014, equivalent to 15% of Extra-EU biomass imports[17]. They are projected to increase modestly again to 5+ Mtoe by 2030. Total demand for biofuels from non-EU countries therefore remains well below their estimated exportable surplus (16 Mtoe in 2030).

[16] Total import of bioenergy including Intra-EU trade in 2014:15.7 Mtoe, gross inland consumption of bioenergy in 2014: 129 Mtoe (Eurostat).

[17] In 2014, net import of bioenergy (solid biomass, biofuels) was 5.4 Mtoe of which 5% ethanol, 9% biodiesel, 48% wood pellets and 37% other wood fuels (AEBIOM 2015, F.O. Licht 2016). EUROSTAT reports 4.9 Mtoe (import – export). Discrepancies are the result of the difficulty of net import and export analysis (EUROSTAT, Statistics explained – energy form renewable sources).

Figure 2-4 Trade of bioenergy feedstock in the period 2020-2030 in the Green-X EUCO27 scenario

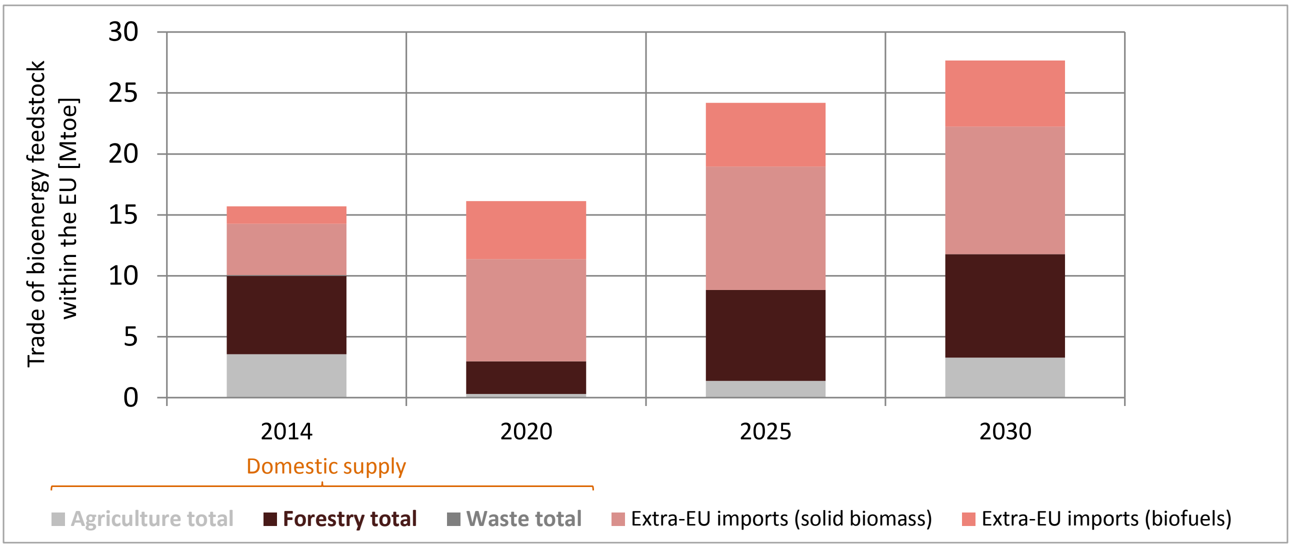


Table 2-3 Trade of bioenergy feedstock under baseline trends

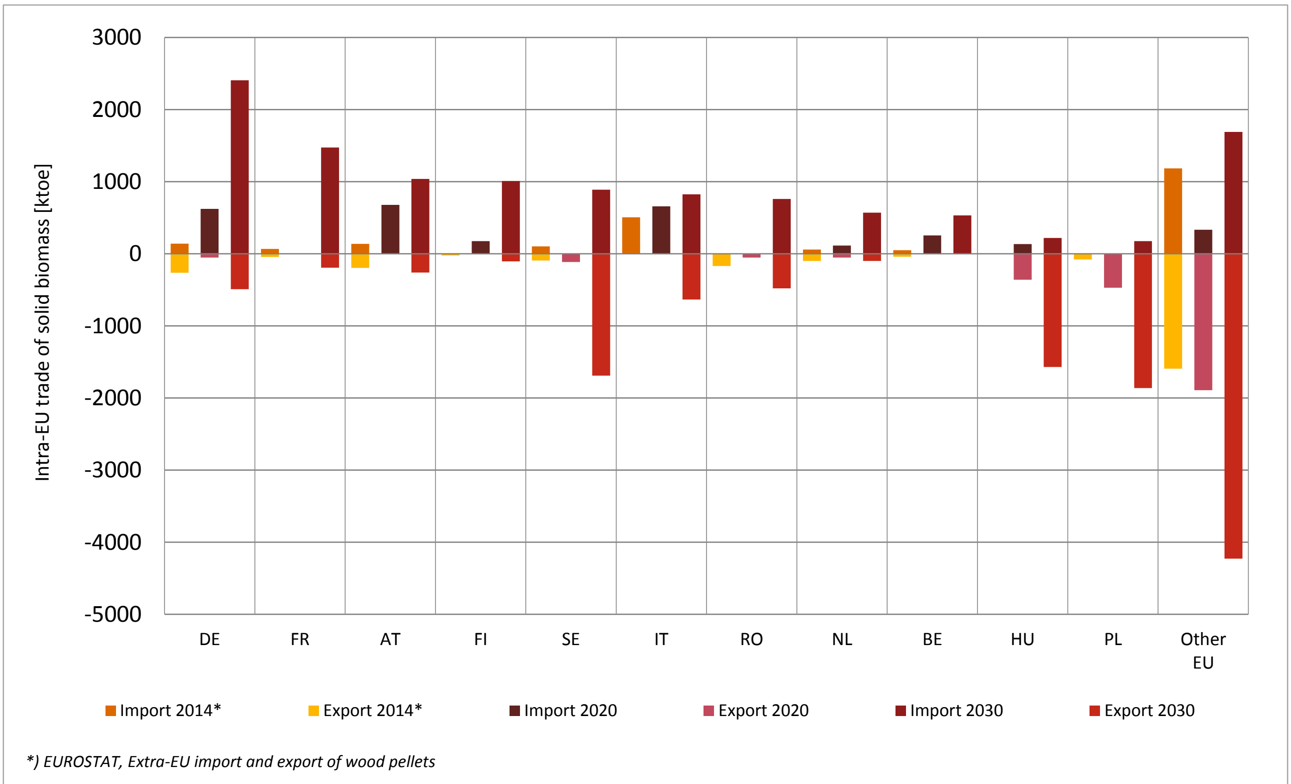
Overview on bioenergy trade: Intra-EU trade and Extra-EU imports	Case:	Policy option1, reference scenario, REFERENCE supply potentials	Policy option 1, EUCO27 scenario, REFERENCE supply potentials	Policy option 1, EUCO30 scenario, REFERENCE supply potentials	Policy option 1, EUCO27 scenario, RESTRICTED supply potentials	Policy option 1, EUCO27 scenario, RESOURCE supply potentials
Bioenergy trade						
Intra-EU trade:						
Agriculture total	Mtoe	1.9	3.3	3.0	6.5	1.5
Forestry total	Mtoe	5.8	8.5	7.7	4.2	3.2
Waste total	Mtoe	0.0	0.0	0.0	0.0	0.0
Intra-EU trade total	Mtoe	7.7	11.8	10.7	10.7	4.7
Extra-EU imports (solid biomass)	Mtoe	10.6	10.5	10.7	3.6	29.2
Extra-EU imports (biofuels)	Mtoe	2.0	5.4	4.9	5.6	2.8
Extra-EU imports total	Mtoe	12.6	15.9	15.6	9.2	32.0
Bioenergy total	**Mtoe**	**20.3**	**27.7**	**26.3**	**19.9**	**36.7**

2.2.1 Trends in biomass Intra-EU trade

Figure 2-5 shows the development of Intra-EU trade of solid biomass and actual import and export of wood pellets in 2014. Trade of solid biomass between EU MS's is projected to become equal to imports from non-EU countries. Intra-EU trade of wood pellets amounted 2.2 Mtoe (5.3 Mt) in 3014. Total Intra-EU trade of solid biomass is projected to increase to 11.6 Mtoe compared to 10.3 Mtoe for Extra-EU import, by 2030. As with many commodities many countries import and export solid biomass due to local economics. For example, Sweden is projected to export 1.7 Mtoe while importing 0.9 Mtoe by 2030. Key trading partners are Germany, France and Finland.

By 2030, Intra-EU trade of solid biomass is mainly comprised of wood chips from forest residues (4.5 Mtoe, 39%) and agropellets from agriculture residues such as straw, sunflower husk, etc. (2.9 Mtoe, 25%). Agricultural residues are processed into agropellets when exported to improve their density and handling properties. Today, agropellets made from agriculture residues (straw, sunflower husk, etc.) make up about 10% of European pellet production (617 ktoe), with production in Poland (198 ktoe), Romania (52 ktoe) and Ukraine (367 ktoe) (AEBIOM 2015). Poland is projected to export 505 Ktoe agropellets and 1355 Ktoe wood chips from stemwood and forest residues to other MSs by 2030. Germany mainly imports wood chips and stemwood from other MS's (mainly Poland and Sweden).

Figure 2-5 Current Intra-EU import (positive) and export (negative) of wood pellets (Eurostat, 2016) and expected Intra-EU import and export of solid biomass in the periode 2020 to 2030 in the Green-X EUCO27 scenario for future key importing MSs



2.2.2 Trends in solid biomass pellets Extra-EU imports

Figure 2-6 shows the development of Extra-EU imports solid biomass (wood pellets, agropellets) between 2010-2030, in the Green-X EUCO27 scenario, and its rising use in the EU28. The total potential supply of solid biomass from non-EU countries increases to 10.7 Mtoe of which 36% (3.9 Mtoe) comes from the US Southeast by 2030. This means a 2.4 fold increase from 2014 export levels of wood pellets from that origin.

The projected import of solid biomass is largely determined by the scenario assumptions of developments at origin, including domestic demand for industrial and energy use as well as the development of infrastructure. The method to calculate export availabilities to the EU developed by BioTrade2020+ was used in BioSustain for Brazil, the US Southeast and Ukraine and explained in Box 1. Key assumptions that determine the export availabilities are summarized in this section, starting with the US Southeast which is projected to remain the largest supplier of solid biomass (wood pellets) to the EU through 2030.

Export availabilities of biomass from the **US Southeast** is based on preliminary results of the "United States Southeast – Case Study of BioTrade2020+" described in detail in the case study report[18]. The BAU scenario[19] is used to determine the Reference export availabilities. As explained in Box 1, these export scenarios take into account domestic supply and demand for industrial and energy uses and prioritise domestic demand for industrial use over demand for energy, i.e. first domestic demand is from the total supply side to determine their export availabilities. Formally Supply (S) = opening stocks+domestic production+imports; Demand (D) = domestic consumption (all uses) +exports+closing stocks, where price makes S=D. Economically biomass is sold to the highest netback bidder. Most industrial markets, including Pulp & Paper represent a higher netback bid than energy markets (Lechner & Carlsson, 2014). Most competition is therefore expected to occur between domestic energy markets and international energy netbacks.

Between 2015 and 2030, domestic demand for panels and other industrial uses is expected to remain relatively constant with pulp markets decreasing slightly. However, domestic demand for bioenergy is projected to grow by over one third by 2030 compared to 2015, leading to a reduced supply of stemwood available for wood pellet production available for export. These are hardwood and softwood pulp logs and other wood sources used for pulp and panel sectors - particleboard and oriented strand board (OSB). Sawlogs and veneer logs are excluded as feedstock for pellets.

Considering the assumptions above, stemwood will be fully utilized domestically in the US Southeast by 2030 leaving only logging residues and other removals[20] available for export by 2030 in the Reference (BAU) scenario. This is in contrast with current developments given that particularly pulpgrade stemwood, mostly from commercial thinnings, is today the largest source of feedstock used to produce wood pellets in the US Southeast (Abt et al. 2014). In addition, the development of bioenergy in the US is going slower than expected because of low natural gas prices and policies focusing on wind, solar and increasing energy efficiency. Also in practice, stemwood is not prioritized for domestic markets but will also be sold to the highest netback. The development described above remains highly uncertain. In contrast to the BAU scenario of BioTrade2020+, but in line with current trends, pulpwood should remain the largest source of wood pellets for export in the US Southeast beyond 2020.

Canada is currently the third largest producer of wood pellets and second largest supplier of wood pellets to the EU. Supply growth from Western Canada in the export scenarios is based on Pöyry. Under Pöyry (Lechner & Carlsson, 2014), wood pellet production will increase moderately from 1.9 Mt pa today to 3.8 Mt pa by 2025. The netback suffers from the large shipping distance between Western Canada and the EU. In the Green-X baseline scenario the supply potential is not fully exploited because of the comparatively high freight costs when delivered to the EU.

[18] http://www.biotrade2020plus.eu/images/IINAS_et_al_2016_WP_3_case_study_report_US_Southeast_FINAL.PDF
[19] The export potential is determined for a Business as Usual (BAU) scenario used in the Reference scenario of this study and High Trade scenario, used in the Resource sensitivity scenario of this study.
[20] Fingerman et al. 2016: "This category includes identified volume as trees removed from the timberland inventory due to land use change to some non-forest use, and any trees felled in timber stand improvement activities, like pre-commercial thinnings, weedings, etc., that are not directly associated with roundwood product harvests."

The supply of solid biomass from agriculture residues, including palm kernel shells from **Southeast Asia**, and wood pellets from Australia and New Zealand in 2020, are based on Lamers et al. (2014c) and on recent trends. The study used similar methods to forecast export availabilities and assumed that these capacities will remain constant between 2020 and2030. If demand in importing regions in Asia continues to grow (e.g. Japan, South Korea), export destinations will be increasingly in Asia.

The export potential of **Sub-Saharan Africa** (SSA) is based on results of the Biomass Policies project. Fritsche et al. (2014) determined the sustainable export availabilities from Mozambique could make it a major SSA exporter. Short rotation plantations (e.g. eucalyptus)[21] would be the main feedstock. However, based on the lack of actual investments in biomass supply as well as infrastructure to mobilize and export biomass, the study considers an early development of this region unlikely. Therefore, the development of supply was delayed with 5 years compared to the Biomass Policies study. Given the negative investment climate and political instability on this continent, the development of export markets for solid biomass remains highly uncertain.

Similar to the US Southeast, supply from **Latin America** is based on the case study of Brazil from BioTrade2020+22. Currently, Brazil is not exporting any solid biomass for energy and developments in dedicated energy crops or forestry plantations for bioenergy purposes are lacking (Lamers et al., 2014c). Nevertheless, Brazil has a large potential for solid biomass export if substantial investments would be made. In this analysis, the residues from crops with the largest technical capacities are included: sugarcane, corn, soybean, cassava, oranges, rice, coffee, eucalyptus and pine. The BAU, used for the Reference supply scenario in this study, assumes that agricultural and forestry production and consumption evolves at the current pace. One crucial factor in both scenarios is the pelletisation and general pretreatment capacity needed to pelletize agricultural residues (a necessity for export). This study assumes 910 kt pa (372 Ktoe) capacity to be available for export in 2020. Ultimately, the total available export potential is not fully exploited because of unfavourable netback economics versus the US Southeast, NW Russia and Ukraine.

As with **Brazil**, the availability of pellet plants is the largest limiting factor to grow exports from **Ukraine**. In 2013, 950 kt pellets were produced in the Ukraine, a mixture of straw and wood pellets (Ukrainian Pellet Union, 2013). However, most of this is produced in small scale pellet producing facilities, targeted at local markets (NL Agency - Ministry of Economic Affairs, 2012). This is the main limitation for the export of pellets in 2015, limiting the potential to 0.5 Mtoe in 2015. Based on the Case study of Ukraine from BioTrade2020+23, the total export potential of straw and wood pellets is estimated to increase to 1.5 Mtoe by 2030.

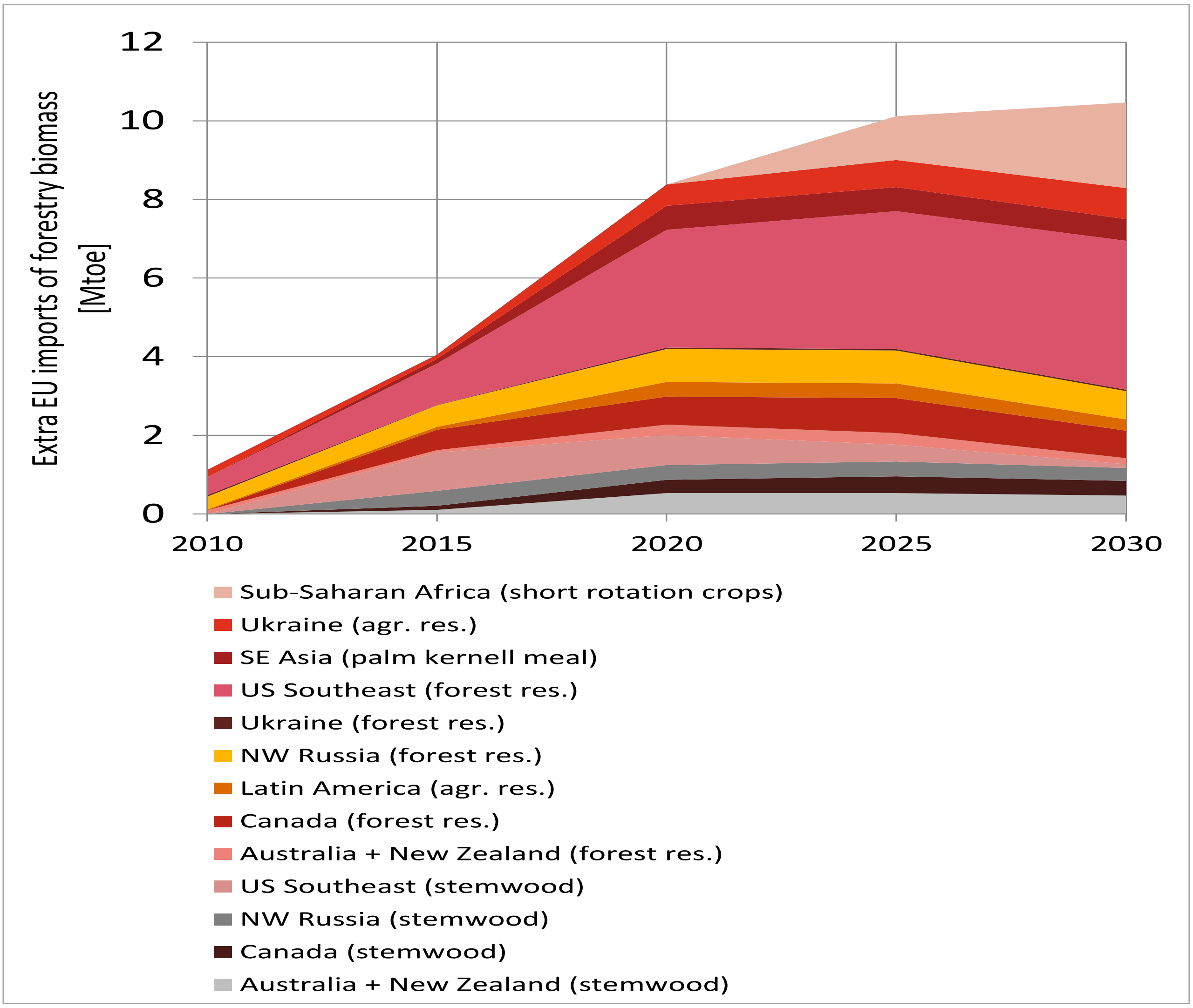
In **Northwest Russia**, large investments are needed to upgrade facilities to increase the export potential. Furthermore, the 6-month winter makes it difficult to mobilize resources and non-economic barriers need to be mitigated including bureaucracy, business culture and language barriers (Proskurina et al., 2015). Under Pöyry, the wood pellet industry will not grow substantially in Northwest Russia with total pellet supply increasing moderately from 0.6 Mtoe (~1.5 Mt) in 2014 to 0.8 Mtoe (~2.0 Mt) in 2025. The study used slightly higher figures based on Lamers et al. (Lamers et al., 2014c) (1.2 Mtoe by 2020) and assumed no further growth beyond 2020.

[21] See: IINAS (International Institute for Sustainability Analysis and Strategy), CENBIO (Centro Nacional de Referência em Biomassa) 2014: Possibilities of sustainable woody energy trade and impacts on developing countries; commissioned by GIZ; Darmstadt, Madrid, Sao Paulo http://www.iinas.org/tl_files/iinas/downloads/IINAS_CENBIO_2014_Sust_Woody_Bioenergy_GIZ_full.pdf

[22] http://www.biotrade2020plus.eu/images/case_studies/D3.2._CS_Brazil_Final_01.06.2016.pdf

[23] http://www.biotrade2020plus.eu/images/case_studies/D3.2._CS_Ukraine_Final_01.06.2016.pdf

Figure 2-6 Extra-EU imports of solid biomass* in the period 2020-2030 (left) and utilisation rate (%) of import potentials (right) in the Green-X EUCO27 scenario.



** Pellets from pulpgrade stemwood, primary and secondary forest residues and agriculture residues (agr. res)*

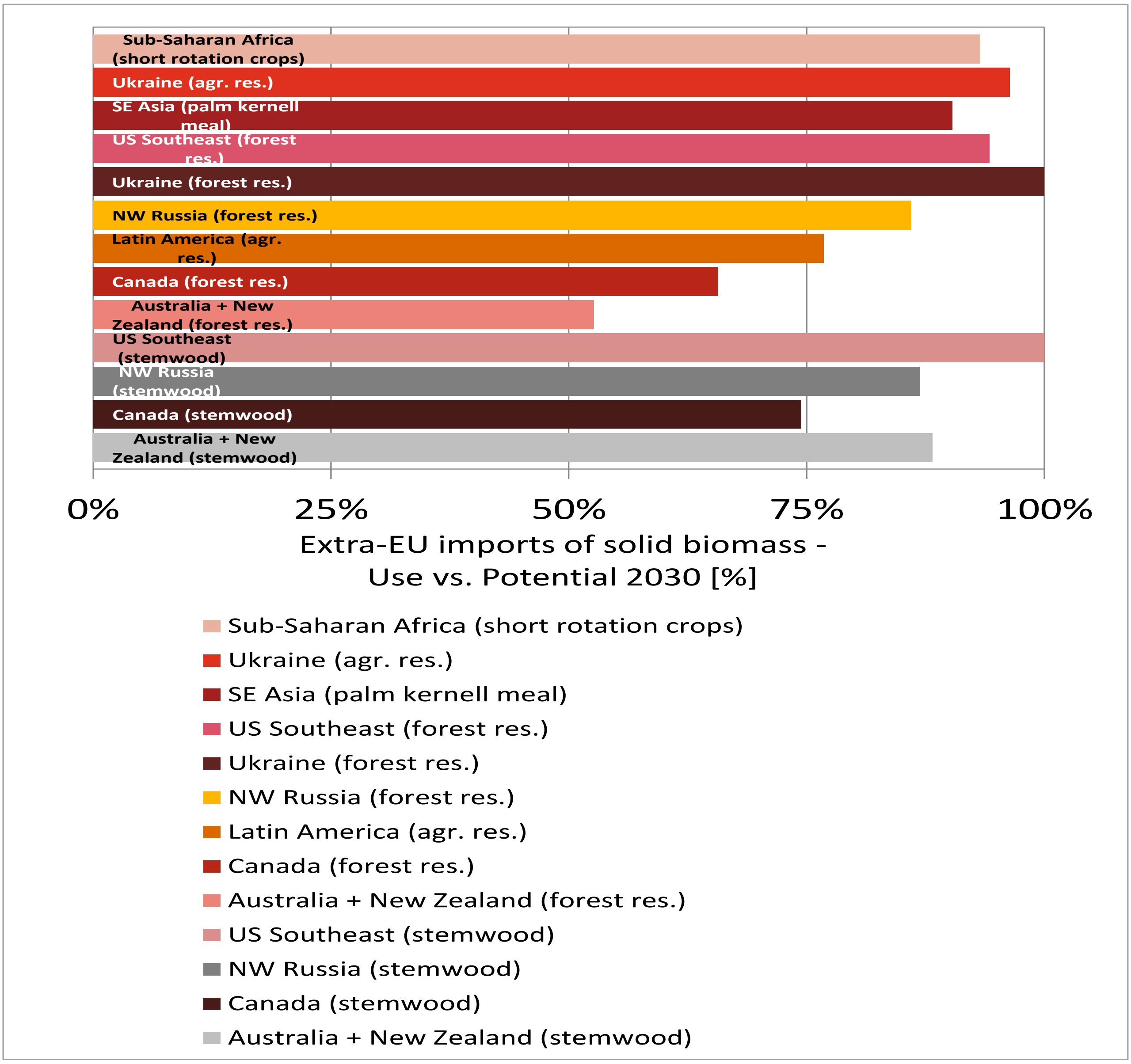
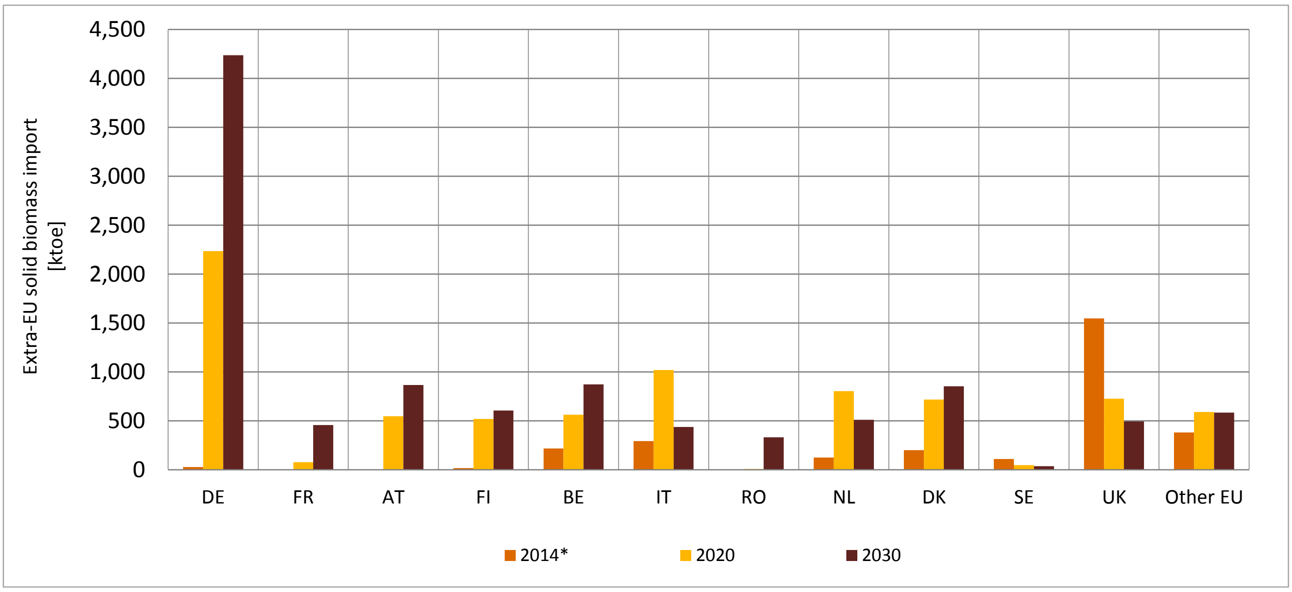


Figure 2-6 shows the development of Extra-EU import of solid biomass for the period 2010 – 2030 in the EUCO27 scenario (left) next to the total exploitation of the export potential per region (right). The differences in exploitation can be partly explained by the differences in shipping distances to the EU, for example pellets from Western Canada or from Australia and New Zealand. Furthermore, unfavourable characteristics can reduce its exploitation model. For example, pellets form agricultural residues in Brazil have a lower energy density compared to wood pellets.

At the MS level, a shift is observed between those that import wood pellets today and those expected to drive future growth (Figure 2-7). The UK is the largest importing MS of wood pellets today (~2 Mtoe in 2014), used mainly in large-scale electricity generation. In the Green-X EUCO27 scenario, imports of wood pellets will decline sharply for the UK. By contrast, Germany, is currently the biggest producer of wood pellets (857 Ktoe, 2.1 Mt), with a total consumption of 750 Ktoe (1.8 Mt), mostly used for heating (small scale & commercial), and a net export of 107 Ktoe in 2014. Nevertheless, Germany is projected to become the largest importing country of wood pellets. By 2020, Germany is projected to import 2.2 Mtoe (5.5 Mt), increasing to 4.2 Mtoe (10.4 Mt) by 2030. Heat remains the largest sector in Germany (83%). A similar development can be observed in Austria that is projected to import 868 Ktoe (2.1 Mt) from third countries by 2030, 89% used in heat sectors. Italy is already heavily dependent on imports of wood pellets for heating markets (Rebiere, 2014). Therefore, it is realistic to assume that demand in heat markets becomes a key driver for the future development of international wood pellet trade.

Figure 2-7 Current Extra-EU import of wood pellets (EUROSTAT, 2016) and expected import in the period 2020-2030 in the Green-X EUCO27 scenario for future key importing MS's.



Fragmentation of the internal market

For the EU single market overall, Intra-EU trade of biomass should be possible without impediment. Today, most barriers to bioenergy trade apply to Extra-EU imports. For example, anti-dumping measures have been taken in the form of import tariffs on Extra-EU imports of ethanol and biodiesel. In addition, the need for sanitary and phytosanitary measures using heat, high pressure or fumigation to avoid pests or pathogens for Extra-EU imports of solid, un-refined biomass prevents Extra-EU imports of wood chips. These measures are not required for imported wood pellets.

The absence of a common international framework on legal and technical standardisation is seen as the biggest barrier to solid biomass becoming a widely-traded commodity. Sustainability criteria for solid biomass vary across the largest importing countries of solid biomass including Belgium, Denmark, the Netherlands and the United Kingdom, which have developed their own legislation and voluntary agreements. Lack of compatibility between country-specific or sector-specific certification systems and criteria reduces the flexibility to trade between countries or sectors. This implies that if biomass could be used in sectors or countries that do not have to comply with, or require less strict, sustainability criteria that there is a large risk for "sustainability arbitrage".

2.3 Differences between Green-X and PRIMES

This section presents a brief discussion of the different projections for bioenergy supply and demand from 2020-2030 between the Green-X EUCO27 scenario, the BioSustain benchmark, and comparable PRIMES work.

It is important to emphasize that the PRIMES EUCO27 scenario served as the key starting point for the Green-X modelling. Thus, energy price trends as well as energy demand trends at sectoral level by MS have been taken from PRIMES modelling, serving as input to the modelling of RES and bioenergy supply and demand for use in the Green-X Model.

A comparison of the results concerning bioenergy supply between the PRIMES and the Green-X EUCO27 scenario is provided in Table 2-4, Table 2-5 analyses differences in underlying biomass demand. Following on from these tables, Figure 2-8 displays the breakdown by supply category for both models.

Figure 2-8 Comparison of bioenergy supply in 2020-2030 between PRIMES and Green-X EUCO27 scenario.

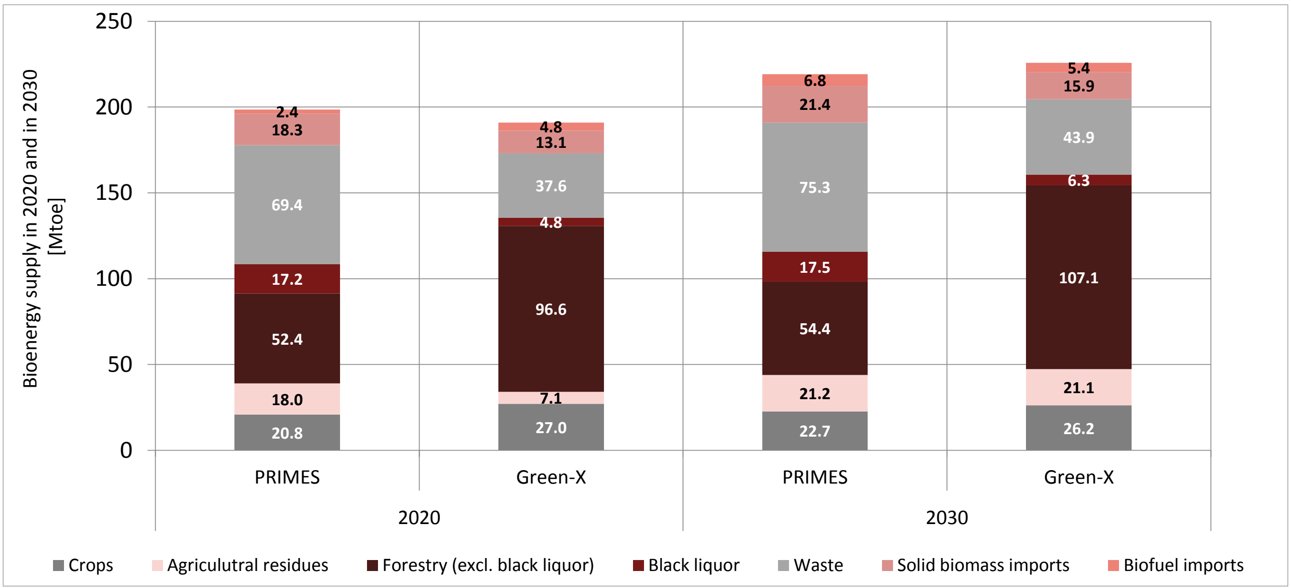


Table 2-4 Comparison of bioenergy supply in 2020-2030 between PRIMES and Green-X EUCO27 scenario

Comparison of PRIMES and Green-X bioenergy supply*		2020		2030	
		PRIMES	Green-X	PRIMES	Green-X
Crops	Mtoe	20.8	27.0	22.7	26.2
Agricultural residues	Mtoe	18.0	7.1	21.2	21.1
Forestry (excl. black liquor)	Mtoe	52.4	96.6	54.4	107.1
Black liquor	Mtoe	17.2	4.8	17.5	6.3
Waste	Mtoe	69.4	37.6	75.3	43.9
Domestic TOTAL	**Mtoe**	**177.9**	**173.1**	**191.0**	**204.6**
Solid biomass imports	Mtoe	18.3	13.1	21.4	15.9
Biofuel imports	Mtoe	2.4	4.8	6.8	5.4
Imports TOTAL	**Mtoe**	**20.7**	**17.9**	**28.1**	**21.3**
Bioenergy TOTAL	**Mtoe**	**198.6**	**191.0**	**219.1**	**225.8**

*Note: * incl. certain waste streams in the case of PRIMES*

Key findings gained from the comparative assessment are:

Bioenergy supply:

- PRIMES indicates around 4% higher supply from biomass origin by 2020 whereas Green-X shows a 3% higher biomass supply compared to PRIMES for 2030. Differences are generally comparatively small – only for certain feedstock categories do they appear significant mainly caused by a different classification (i.e. what should be summarised under waste or under forestry). A significant difference remains however for black liquor where PRIMES uses a three times higher number.

Bioenergy demand:

- For electricity Green-X results match well with PRIMES outcomes. More precisely, differences are applicable for both 2020 and 2030 – i.e. generally, PRIMES data on bioenergy demand for electricity are higher than comparable Green-X results but trends show a similar tendency.
- For the transport sector aggregated figures on bioenergy demand match well - i.e. both models indicate a stagnation in biofuel use post-2020.
- The strongest differences are applicable for biomass heat; Green-X results show a slight increase whereas PRIMES assumes a decline (from a comparatively high figure for 2020). However, it is worth mentioning that related data for PRIMES is only estimated since the respective figures are not applicable in available reporting. Thus, an approximation was undertaken based on reported data for total RES as well as for heat from other renewables (solar thermal, heat pumps) for to estimate results for PRIMES on biomass heat use, specifically for grid-connected heat supply under PRIMES.
- The increased use of grid-connected heat supply in Green-X matches well with the increased use of electricity generation, indicating that CHP is seen as preferred and economically viable option in the post-2020 policy framework compared to "electricity only" plants.
- A difference to PRIMES remains however for the direct use of biomass for heating & cooling. Here PRIMES shows a higher use by 2020 whereas Green-X indicates a higher use by 2030. This increase is caused by the underlying policy framework for the period post-2020 within Green-X, assuming a least cost approach to reflect appropriately a fully competitive market environment post-2020.[24] This facilitates competition between RES technologies as well as between energy sectors. Thus, the direct use of biomass in heating & cooling appears as a viable option under these framework conditions.
- In accordance with that described above, aggregated results (on total bioenergy use) show similar trends (i.e. higher figures for PRIMES by 2020, and higher figures for Green-X by 2030).

Additionally, differences are found also for imports of biomass feedstock to the EU: here PRIMES modelling indicates a significantly stronger growth of imports in forthcoming years than scenarios derived by use of Green-X, specifically in the short term – i.e. the period up to 2020.

[24] Note that this competitive policy framework appears also beneficial for the subsequent assessment of sustainability policy option in order to incorporate well substitution processes arising from the introduction of stricter sustainability regulations for solid and gaseous biomass.

Table 2-5 Comparison of bioenergy demand in 2020-2030 between PRIMES and Green-X EUCO27 scenario

Comparison of PRIMES and Green-X bioenergy* demand		2020		2030	
		PRIMES	Green-X	PRIMES	Green-X
Biomass* electricity	**Mtoe**	**19.6**	**17.7**	**25.5**	**23.9**
Biomass* heating & cooling - direct use	Mtoe	70.0	66.2	62.0	73.5
Biomass* heating & cooling - steam supply (grid-connected heat from CHP and district heat)	Mtoe	*19.1*	21.5	*16.0*	30.4
Biomass* heating & cooling TOTAL	**Mtoe**	***89.1***	**87.7**	***78.0***	**103.8**
Biofuel for transport	**Mtoe**	**21.1**	**18.7**	**20.5**	**18.7**
Bioenergy TOTAL	**Mtoe**	***129.8***	**124.2**	***124.0***	**146.5**

*Note: * incl. certain waste streams in the case of PRIMES*

2.4 Environmental impacts

2.4.1 Supply chain GHG emission savings

Renewable energies are key for mitigating greenhouse gas (GHG) emissions, justifying (among other policy objectives) the adoption of policy targets concerning their uptake in the years to come. This section further details on how renewables contribute in reducing greenhouse gas emissions, shedding light specifically on the role of bioenergy therein. Table 2-6 provides a breakdown of avoided GHG emissions due to RES and bioenergy by 2030, following a supply chain approach for the calculation of net avoidance. An illustration of the dynamic development in the focal period 2020 to 2030 is shown in Figure 2-9 for the default baseline case, i.e. the Green-X EUCO27 scenario.

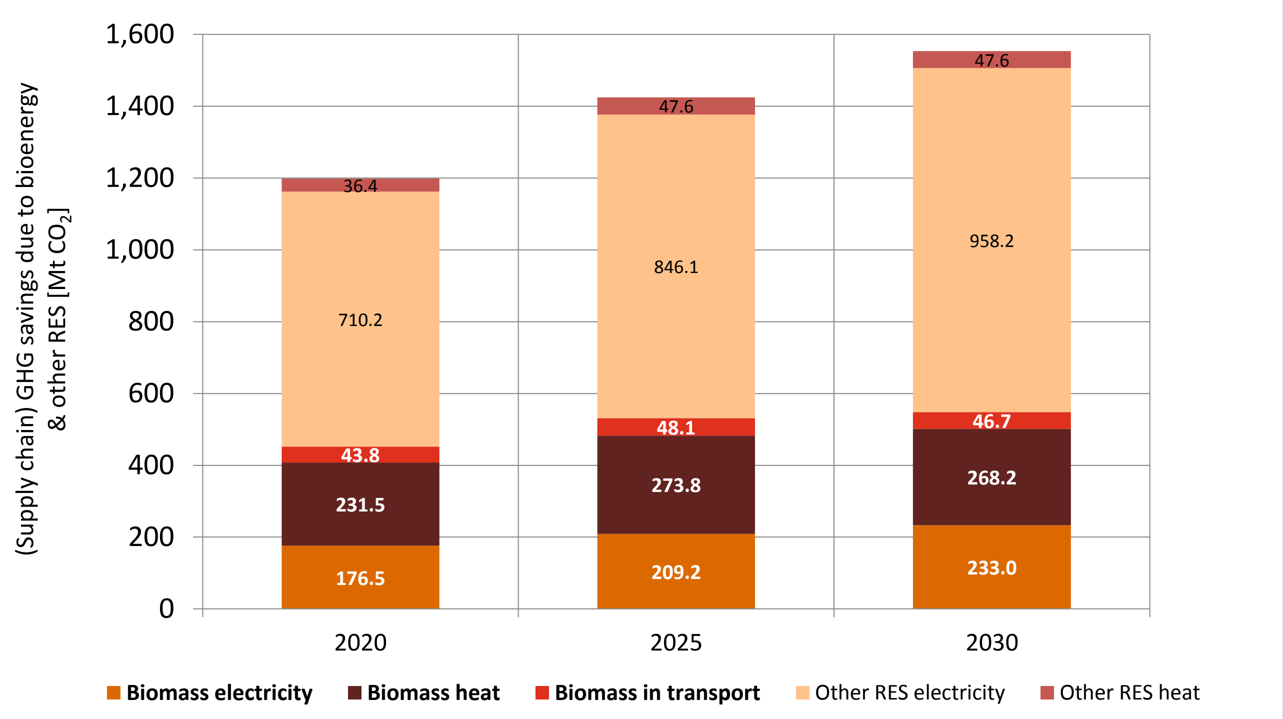
Please note that in the sectoral breakdown of net GHG avoidance, in the case combined heat and power production (CHP) savings are accounted to the electricity sector, meaning that "biomass electricity (including CHP)" accounts the total savings of both the electricity generated and the derived heat produced. This leads to comparatively high GHG savings for bioelectricity (including CHP) in comparison to bioheat that exclude the savings for the derived heat in case of CHP – in order to avoid double counting.

Generally, it can be seen that bioenergy and other RES make significant contributions to GHG emission avoidance. With increasing use of RES, and in particular of bioenergy, as expected under baseline conditions in forthcoming years up to 2030 related savings increase, cf. Figure 2-9. The agreed 2030 RES target would consequently lead to an increase of RES-related GHG savings – this is apparent from a comparison of the baseline scenarios assessed: in particular when comparing GHG savings in Table 2-6 for the scenario where a reference policy approach is presumed - leading to a comparatively weak increase in RES use post-2020 (and a RES share of ca. 23% by 2030), with all other policy variants building on the "EUCO27" RES policy concept, i.e. where the agreed RES target of (at least) 27% RES by 2030 is taken into consideration.

Table 2-6 GHG savings due to bioenergy and other RES by 2030 under baseline trends

GHG avoidance due to RES by 2030	Case:	Policy option 1, reference scenario, REFERENCE supply potentials	Policy option 1, EUCO27 scenario, REFERENCE supply potentials	Policy option 1, EUCO30 scenario, REFERENCE supply potentials	Policy option 1, EUCO27 scenario, RESTRICTED supply potentials	Policy option 1, EUCO27 scenario, RESOURCE supply potentials
Electricity sector						
Bioenergy electricity (incl. CHP)	**Mt CO2**	**221.7**	**233.0**	**233.0**	**225.4**	**243.1**
Other RES electricity	Mt CO2	874.8	958.2	936.9	1,094.5	911.2
RES-E total	**Mt CO2**	**1,096.5**	**1,191.2**	**1,169.9**	**1,319.9**	**1,154.3**
Heat sector						
Bioenergy heat	**Mt CO2**	**241.9**	**268.2**	**259.4**	**195.0**	**306.0**
Other RES heat	Mt CO2	42.0	47.6	46.4	62.5	44.2
RES-H total	**Mt CO2**	**283.9**	**315.8**	**305.8**	**257.5**	**350.2**
Transport sector						
Bioenergy in transport	**Mt CO2**	**42.2**	**46.7**	**43.0**	**51.4**	**41.2**
RES-T total (excl. electricity)	**Mt CO2**	**42.2**	**46.7**	**43.0**	**51.4**	**41.2**
Summary: RES vs bioenergy						
Bioenergy total	**Mt CO2**	**505.8**	**547.9**	**535.3**	**471.8**	**590.3**
RES total	**Mt CO2**	**1,422.6**	**1,553.7**	**1,518.7**	**1,628.9**	**1,545.7**

Figure 2-9 Direct GHG savings due to bioenergy and other RES in the period 2020-2030 in the Green-X EUCO27 scenario



2.4.2 Impacts on land use

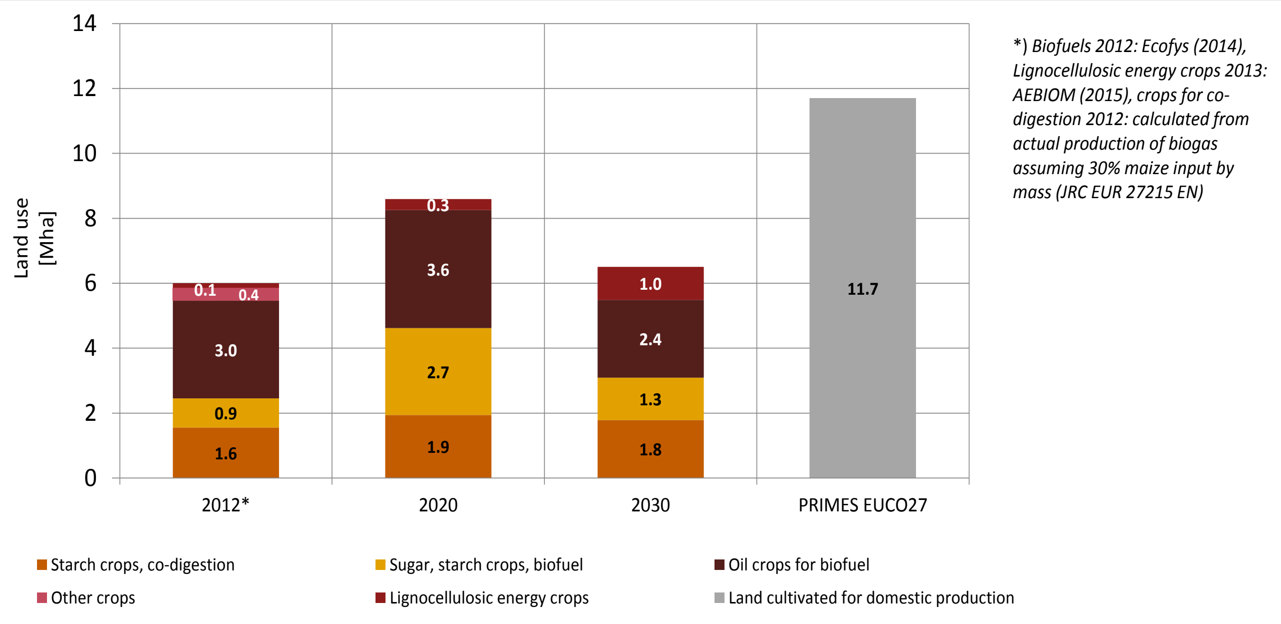
Figure 2-10 presents the development in land use for energy crops by 2030, in the Green-X EUCO27 scenario, and compared to land use for domestic production of biomass as projected by PRIMES for the EUCO27 scenario by 2030. Under the Green-X, land use for energy crops is projected to increase to 8.0 Mha in 2020 compared to 6.0 Mha in 2012, mainly driven by the increased demand for food-based energy crops (oil crops, starch crops, sugar crops) used in the production of biofuels. Between 2020-2030, land required for the cultivation of food- and feed- based energy crops for liquid biofuels and anaerobic co-digestion[25] declines whilst land cultivated with lignocellulosic energy crops is projected to increase 7-fold from 0.14 Mha in 2013 to 1.0 Mha in 2030. Key drivers for the declining trend in land use for domestic energy crop cultivation are the reduced demand for biomass in transport (Section 2.1.1) and shift from food-based energy crops to lignocellulosic energy crops with higher yields. Over 70% of lignocellulosic energy crops are used for biofuel production by 2030 and have to comply with RED sustainability criteria. Energy crops cultivated for co-digestion do not have to meet sustainability criteria, but have to demonstrate compliance with the Common Agricultural Policy (CAP) with good environmental practices with respect to land use. Furthermore, no substantial growth is projected compared to current land use for co-digestion (1.6 Mha in

[25] Most biogas plants use more than one type of feedstock because of supply limitations and to improve the overall efficiency of biogas production from anaerobic digestion. As a result of the rapid growth of biogas production, total land use for energy crops used as substrate for co-digestion has grown to 962 thousand ha in Germany in 2012 (AEBIOM 2014). Biogas should be mainly produced from by-products and organic waste and the use of energy crops for (co-)digestion should be limited to avoid potential negative environmental impacts, mainly with respect to biodiversity, soil, water (SWD(2014)259). The updated German RESs Act (EEG 2014) has withdrawn a premium on energy crops and added criteria to plant sizes and annual capacity growth. Also in Italy and France, recent changes to policies should reduce further expansion of biogas from dedicated energy crops (EurObserv'ER, biogas barometer 2014). Land use for biogas, results have been calculated based on JRC's proposed method in SWD(2014) 259 for co-digestion and reported in Report EUR 27215 EN for a mixture of 70% manure and 30% fodder maize (wet mass). The combination of manure with maize can achieve GHG savings above 70% when the correct systems are used. Specific land use (toe/ha) is in similar range to land use estimates in Germany (900,000 ha in 2011, 4414 ktoe primary biogas production).

2012). In the Green-X EUCO27 scenario, it increases to 1.9 Mha in 2020 and decreases slightly to 1.8 Mha by 2030.

Under PRIMES EUCO27, development of cultivated land for bioenergy follows a strong increasing trend between 2010 and 2020 (66%) followed by a moderate decline of 15% between 2020 and 2030. Although the trend is roughly similar to Green-X, the difference in total land use for energy crops between Green-X and PRIMES is large in absolute terms. This can most likely be explained by definitions and data used for current land use. Under PRIMES, already in 2015, almost 11 Mha of land is cultivated for domestic production of bioenergy.

Figure 2-10 Developments in land use for domestic energy crop cultivation in the EU28 - Green-X EUCO27 scenario compared to current land use and land cultivated for domestic production under PRIMES EUCO27 2030.



The amount of land area required for the cultivation of energy crops is restricted by the model to so-called 'surplus' land, i.e. land not needed for other purposes including food production to ensure food security and to avoid indirect land use change. Land available for food-based energy crops is assumed similar to projections of food-based energy crops under CAPRI baseline projections (CAPRI, 2013). Land available for lignocellulosic energy crops (woody and grassy crops) is based on estimated surplus agricultural land released between 2008, 2020 or 2030, fallow land, areas of degraded land and long term abandoned lands outside utilised agricultural areas (UAA) as determined in Biomass Policies (Elbersen et al. 2015). Furthermore, two types of areas are excluded for bioenergy feedstocks to meet RED criteria for biofuels: high biodiversity areas (i.e. primary forest and other wooded land, legally protected areas, natural and non-natural highly biodiverse grassland) and high carbon stock areas (i.e. wetland including peatland and continuously forested areas). Total land available for energy crop cultivation on 'surplus' land in the EU28 is estimated to increase to 22.5 Mha by 2020 and 24.0 Mha by 2030. This restriction is however artificial, as it does not reflect actual market forces or regulations.

Despite the artificial restriction, no significant impacts to land use in the EU are expected because land required for domestic energy crop cultivation in the Green-X EUCO27 scenario remains well below the total estimated 'surplus' land available for energy crop cultivation in the EU, taking the RED sustainability criteria into account. Furthermore, the reduced land use for annual crops (oil, starch, sugar crops) and increased cultivation of lignocellulosic, perennial crops between 2020 and 2030 could lead to positive impacts. These impacts are highly variable to local environmental, biophysical and climatic conditions and the type cultivated and management practices applied. When lignocellulosic perennial crops are introduced in areas that are dominated by annual crops, perennial crops could improve landscape heterogeneity and structured diversity (Immerzeel et al. 2014, Vis e al. 2010). Secondly, perennial crops have in general a positive impact on soil conditions compared to annual crops, especially on sites susceptible to soil erosion, since annual crops may require regular tillage operations, while perennial crops do not. For example, cultivation of miscanthus or fast growing poplar on degraded land improves soil quality, increase soil organic levels and improve vegetation and habitat quality (EEA 2013[26]).

Although no significant negative impacts are expected under baseline conditions, it cannot be guaranteed that cultivation takes place on ‘surplus’ land. Habitat losses resulting from land use change (mostly related to urbanisation) have been the key driver for global biodiversity decline and are expected to remain so in the next 50 years (Chum et al. 2011, Immerzeel et al. 2014). Related to bioenergy, these losses could occur when semi-natural ecosystems land and high nature value (HNV) farmland is converted for cultivation of energy crops or when changes in forest management are made to mobilize forest biomass. Existing land use criteria of the RED do not apply to crops cultivated for heat and electricity, including crops cultivated for co-digestion (e.g. fodder maize). Because no large increases in land use in the EU are projected for these sectors and because feedstock cultivated in the EU need to comply with Common Agricultural Policy, no significant impact is expected. However, because land use and biodiversity criteria do not apply to food, feed and biofuels consumed outside the EU, indirect effects to land use and biodiversity could still be large. Because these markets are connected via shared national markets or international trade, losses in land use, habitat and biodiversity could occur indirectly. To assess indirect land use change and impacts to biodiversity a global land use modelling framework is required such as GLOBIOM (Frank et al. 2012). Although the quantification of indirect land use change is very difficult and highly uncertain (Wicke et al. 2012), these studies show that indirect effects to land use and biodiversity as a result of EU biomass demand could be significant whereas direct effects in the EU are projected to remain small (Hellman & Verburg 2010, Frank et al. 2012).

2.5 Socio-economic impacts

2.5.1 Investment needs

Table 2-7 provides an overview of investments in bioenergy and other RES and Table 2-8 shows the related operation expenditures (bottom) for all assessed cases under baseline conditions. Adding to this, a detailed view on the dynamic development of investments in RES in the focal period 2020 to 2030 is provided in Figure 2-11 for the default baseline case, i.e. the Green-X EUCO27 scenario.

It is apparent that under default baseline conditions (Green-X EUCO27 scenario) investments in RES are expected to decline in the next decade, compared to current levels. This is a consequence of the targeted 2030 RES deployment, aiming for a RES share of at least 27% of gross final energy demand by 2030. In combination with a reduction of overall energy demand, as prescribed by the energy efficiency target for 2030, the required RES uptake can be classified as moderate. The decline in investments is however also partly driven by progress made in reducing costs of RES – as achieved in past years in an impressive manner for technologies like photovoltaics or wind energy. This trend is expected to continue in the coming years, in accordance with technological learning and global trends in RES use. Another influence is the underlying policy concept in the years post-2020 – i.e. here a least-cost approach is presumed, incentivising further RES uptake in a cost-effective manner.

[26] EEA - EU bioenergy potential from a resource-efficiency perspective - Copenhagen, Denmark (2013) - Available at www.eea.europa.eu/publications/eu-bioenergy-potential

Bioenergy accounts for a large part of the investments but its role is even more pronounced if operation expenditures are considered. RES such as wind and solar have no variable cost of energy fuel so only O&M expenditures are relevant for these technologies. For bioenergy, the fuel cost is significant.

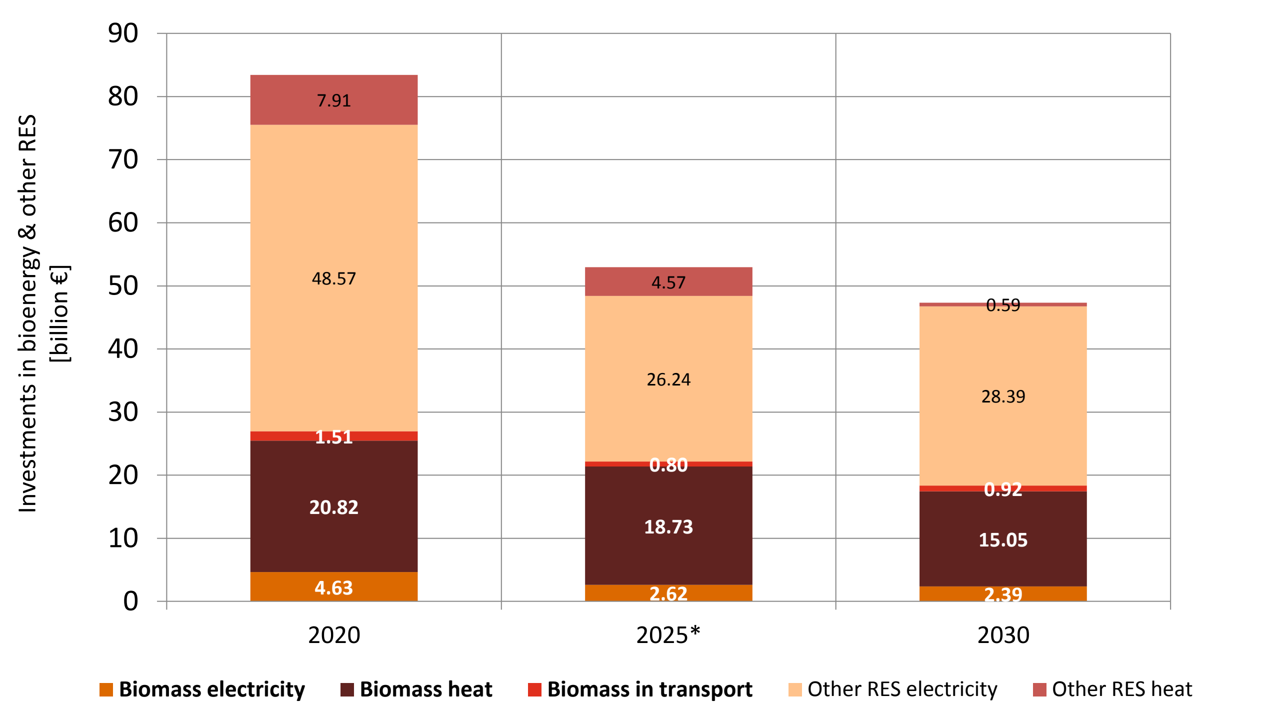
Table 2-7 Capital expenditures for bioenergy and other RES under baseline trends

Capital expenditures for RES in the period 2021-2030 (yearly average)	Case:	**Policy option1, reference scenario, REFERENCE supply potentials**	**Policy option 1, EUCO27 scenario, REFERENCE supply potentials**	**Policy option 1, EUCO30 scenario, REFERENCE supply potentials**	**Policy option 1, EUCO27 scenario, RESTRICTED supply potentials**	**Policy option 1, EUCO27 scenario, RESOURCE supply potentials**
Electricity sector						
Bioenergy electricity	**€bln**	**2.2**	**2.6**	**2.6**	**2.8**	**3.1**
Other RES electricity	€bln	18.8	26.2	24.4	40.1	22.0
RES-E total	**€bln**	**21.0**	**28.9**	**27.0**	**42.9**	**25.2**
Heat sector						
Bioenergy heat	**€bln**	**14.5**	**18.7**	**17.2**	**12.2**	**22.6**
Other RES heat	€bln	2.8	4.6	4.3	10.1	3.5
RES-H total	**€bln**	**17.3**	**23.3**	**21.5**	**22.3**	**26.1**
Transport sector						
Bioenergy in transport	**€bln**	**0.6**	**0.8**	**0.8**	**0.9**	**0.9**
RES-T total (excl. electricity)	**€bln**	**0.6**	**0.8**	**0.8**	**0.9**	**0.9**
Summary: RES vs bioenergy						
Bioenergy total	**€bln**	**17.3**	**22.2**	**20.6**	**15.9**	**26.6**
RES total	**€bln**	**38.9**	**53.0**	**49.3**	**66.1**	**52.1**

Table 2-8 Operational expenditures for bioenergy and other RES under baseline trends

Operational expenditures for RES in the period 2021-2030 (yearly average)	Case:	Policy option1, reference scenario, REFERENCE supply potentials	Policy option 1, EUCO27 scenario, REFERENCE supply potentials	Policy option 1, EUCO30 scenario, REFERENCE supply potentials	Policy option 1, EUCO27 scenario, RESTRICTED supply potentials	Policy option 1, EUCO27 scenario, RESOURCE supply potentials
Electricity sector						
Bioenergy electricity	**€bln**	**13.5**	**14.3**	**14.3**	**13.8**	**14.6**
Other RES electricity	€bln	17.3	18.4	18.2	19.8	17.8
RES-E total	**€bln**	**30.8**	**32.7**	**32.5**	**33.6**	**32.4**
Heat sector						
Bioenergy heat	**€bln**	**34.5**	**37.9**	**37.2**	**29.2**	**38.7**
Other RES heat	€bln	3.4	3.7	3.6	4.2	3.5
RES-H total	**€bln**	**37.9**	**41.5**	**40.8**	**33.4**	**42.2**
Transport sector						
Bioenergy in transport	**€bln**	**14.5**	**16.4**	**15.7**	**17.7**	**14.6**
RES-T total (excl. electricity)	**€bln**	**14.5**	**16.4**	**15.7**	**17.7**	**14.6**
Summary: RES vs bioenergy						
Bioenergy total	**€bln**	**62.5**	**68.5**	**67.1**	**60.7**	**67.9**
RES total	**€bln**	**83.2**	**90.6**	**89.0**	**84.7**	**89.3**

Figure 2-11 CAPEX for bioenergy and other RES in the period 2020 to 2030 in the Green-X EUCO27 scenario



2.5.2 Employment impact

This section deals with the socio-economic relevance of bioenergy use in the baseline scenario. Since the policy options also concern other RES technologies, these are also included. Socio-economic relevance is measured as the gross value added generated and the number of jobs supported by RES use. Apart from total employment, employment in SME is also reported. It was distinguished between the direct economic relevance of enterprises active in RES deployment and the indirect economic impact triggered by these enterprises in their respective supply chains. The socio-economic relevance was estimated by combining outputs from the Green-X model with data on RES cost structures and calculations with the MULTIREG model. The results refer to the annual average for the period 2021 – 2030.

In this period, RES deployment is estimated to generate a total value added of almost €122 bln pa (cf. Table 2-9). Direct value added of RES facilities and their direct suppliers (e.g. technology suppliers, fuels supply, maintenance services, etc.) amounts to approximately €76 bln. The remaining €46 bln are generated by supply chain industries. Bioenergy deployment accounts for almost half of total value added (48%), with the other half related to other RES technologies.

RES deployment is estimated to support 1.4 million jobs in the reference period, 750,000 directly and 670,000 indirectly in supply chains. Bioenergy deployment accounts for 60% of the jobs. Labour productivity, i.e. value added per unit of employment, is thus lower for bioenergy than for the other RES technologies. Small and medium enterprises provide almost 1 million jobs.
In its annual overview[27], EurObserv'ER published figures for 2014-2015 on the socio economic impact of the renewable sectors across the European Union. Employment data cover both direct and indirect jobs and relate to gross employment, meaning job losses in other industrial sectors or losses due to expenditure and investment in other sectors are not taken into

[27] http://www.eurobserv-er.org/15th-annual-overview-barometer/

account. Biogas is quantified as one of the smaller renewable market segments with a stable work force of nearly 66,000 persons in installation of plants, component manufacturing, operation and maintenance and fuel supply.
Employment in the sector of biogas stayed unchanged compared to previous years, whereas economic crises and adverse policy conditions led to reduced investments in other renewable energy sectors. For biofuels, a workforce of around 110,000 jobs is estimated for 2014. These are assumed as a conservative estimation by EurObserv'ER, taking into account the supply side activities of the agricultural sector. For renewable urban waste (i.e. the incineration of the renewable biomass share contained in urban waste), Eurobserv'ER arrives at a revised total of around 8,410 direct jobs for the entire European Union. Despite some lower figures for 2014, the European solid biomass sector (for electricity and heat generation) remains the socioeconomic "elephant in the room", taking second position in terms of employment. With 306,800 jobs across the European Union, the sector is only beaten by the wind energy sector.

Table 2-9 Relevance of bioenergy and other RES deployment for value added and employment, annual average 2021 - 2030

Indicator	Unit	Direct relevance	Indirect relevance	Total relevance
Gross value added				
Bioenergy deployment	€mln	31,600	27,100	58,700
Other RES deployment	€mln	44,200	18,800	63,000
Total RES deployment	**€mln**	**75,800**	**45,900**	**121,700**
- as % of total GDP (EU28)		0.6%	0.4%	1.0%
Employment				
Bioenergy deployment	1,000 EP	470	400	870
Other RES deployment	1,000 EP	280	270	550
Total RES deployment	**1,000 EP**	**750**	**670**	**1,420**
- as % of total employment (EU28)		0.3%	0.3%	0.6%
Employment in SME				
Bioenergy deployment	1,000 EP			610
Other RES deployment	1,000 EP			360
Total RES deployment	**1,000 EP**			**970**

EP: employed persons

Source: calculation by Rütter Soceco

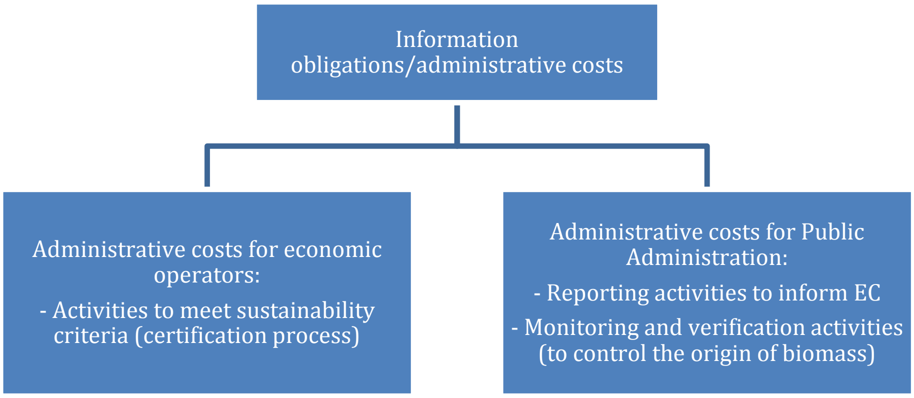
2.5.3 Administrative costs

Administrative costs are defined as the costs incurred by enterprises and Public Administration in meeting the information obligations imposed by EU legislation on their action or production.
The RES Directive imposes administrative costs on economic operators and Public Administration who need to conduct administrative activities in meeting the legal obligation to comply with sustainability requirements of biomass feedstock in all the supply chain. In particular:

- Economic operators need to conduct activities to apply for a certification scheme in order to certify biofuels to show compliance with sustainability requirements specified in the RED.

- On the other hand, Public Administration conduct reporting activities to inform EC and monitoring/verification activities to control the origin of biomass and end users.

Figure 2-12 Distribution of information obligations/adminstrative costs



The baseline scenario includes the provisions of the RED. The EU RED introduced sustainability criteria for biofuels and bioliquids as a condition for their inclusion in national targets and for eligibility to financial support. Under the RED, voluntary certification schemes can be used to prove that the RED regulation is met.

In order to present a high level of detail of the assessment, the analysis follows the "step-by-step" method for the application of the Standard Cost Model. Some steps are generic and affect all policy options in the same manner. Other steps will be adapted to the context of each policy option. For clarity, the main differences of each policy option analysis are highlighted.

Steps 1 & 4: Identification and classification of information obligations and identification of target groups

In policy option 1 (baseline), the target groups are agriculture biomass producers, economic operators involved in the supply chain and biofuel plants operators. Agriculture biomass producers and biofuel plants operators need to show compliance with current land criteria[28].
Main legal obligations imposed by the RED to economic operators and Public Administration in policy option 1 are:

- Economic operators: the obligation to get the required certification to show compliance with the sustainability criteria
- Public Administration of MSs: reporting obligation to EC and verification and monitoring activities within the respective MS to check compliance with sustainability requirements (verification of the origin of biomass, the supply chain method and measurements of the GHG performance)

Steps 2, 5, & 6: Identification of required actions, the frequency of required actions and relevant cost parameters

For the economic operators identified, there are a number of required actions to receive and maintain the certification. It is worth mentioning in this section that there are two kinds of costs incurred by economic operators: one-off costs related with activities to get the certification (incurred the first year) and recurring costs related with activities to maintain the certification (yearly cost in the subsequent years after obtaining the certification).
Actions of economic operators:

- Actions to get the required certification the first year (one-off costs)
    - Process application

[28] Traders and conversion units in the downstream supply chain do not have to show compliance

  - Gathering information to prepare the office & on-site audit
  - Supervising external personnel
  - Discussing the results
  - Providing additional information
  - Compiling the report
  - Submitting and filing the report
  - Training personnel
- Activities to maintain the certification the subsequent years (recurring costs, once a year)
  - Gathering information
  - Processing information
  - Compiling the report
  - Submitting and filing the report
  - Discussing the report
  - Training personnel
- Communication activities to MS (recurring costs, once a year)
  - Gathering the evidences of certification
  - Compiling the form
  - Submitting the report to the competent authority

Public Administration need to conduct actions to report to EC and other entities related with verification activities of biomass products. Both are recurring costs, incurring once a year.
Actions of Public Administration:

- Monitoring and verification activities (recurring costs, once a year):
  - Preparing the investigation
  - Carrying out measurements
  - Processing the results
  - Compiling an investigation report
- Reporting activities to EC (recurring costs, once a year):
  - Gathering information
  - Processing the information
  - Compiling a report
  - Submitting and filing the report
  - Discussing and presenting the report

Step 3: Classification by regulatory origin

The regulatory origin is the European Union that sets rules to meet sustainability requirements on biomass production, supply chain methods and other requirements as GHG savings or efficiency measures of bioenergy plants. This classification is valid for all policy options.

Steps 7 & 8: Choice of data sources to calculate the number of entities concerned in Policy Option 1 and assessment of the number of entities concerned

Different data sources have been used to estimate the number of entities concerned in Policy Option 1. For simplicity, agricultural biomass producers of biofuels are the market participants selected for the estimation. Because of insufficient data available, market participants involved in the supply chain are not considered in the estimation for each policy option.

- Estimation of the number of agriculture biomass producers (farm operators)

Statistics of the EC were used to calculate the number of economic operators for the Baseline Scenario. In particular, official statistics about area used for energy crop production and quantity of biofuel produced were used to undertake the estimation[29].
Considering that the area used for energy crop production in EU28 in 2005 was 2,800,000 hectares and approximately 3,914,000 tonnes of biofuel were produced it is estimated that approximately 1,120 farm groups were producing agriculture biomass to produce biofuels.

Three main assumptions were set up:

- A group certification for a voluntary scheme covers on average 2,500 hectares of arable land
- 1 tonne of biofuel is equal to 1,250 litres
- Conversion factor considered: 1 litre of biofuel has on average 28MJ of calorific value

Using these assumptions, the productivity of the feedstock produced by each farm operator is equal to 2,921 toe per farm group.

Using the production of biofuel projected for 2030, estimated by Green-X model (23.9 Mtoe) and assuming that the productivity of each farm operator will remain the same in 2030 (2,921 toe), it is estimated that for Option 1 there will be approximately 8,181 farm groups in 2030[30].

Step 9: Assessment of the performance of a "normally efficient entity" in each target group

The cost parameters are composed by time spent on activities to respond to the requested actions and wage tariffs.

To get the certification two kinds of costs are considered for economic operators:

- Internal costs: time spent by the certified entity to undertake the certification process (gather relevant information, support the process and elaboration of all the necessary information). Internal costs also includes consulting services which serve to support the preparation and the auditing process
- External costs: services of the certifying body to plan and execute the certification process (auditing activities: planning the audit and on-site audit, discussing the results, preparation of the report/issuing the certificate). Those costs are the certification costs charged by certifying bodies for providing services of certification

Tariffs vary depending of the cost category explained above. Firstly, for internal costs incurred by certified entities, two different tariffs are set[31]:

- For the time spent on activities to undertake the certification, a tariff of 15€/hour was set for professionals and technicians of the entities concerned[32]
- For consulting services, a tariff of 18€/hour was set[33]

Secondly, for external costs (services of the certifying body) related with auditing activities, a tariff of 125€/hour was set. This tariff represents the average of the man-day tariff range for auditing activities as presented in the report of NL Agency, *Selecting a biomass certification system – a benchmark on level of assurance, costs and benefits*[34] (man-day tariff ranges from 500-1500€).

[29] Biofuels in the European Union: An Agricultural Perspective (EC factsheet)
[30] This figure changes depending on the projections of Green-X model for each policy option
[31] Similar tariffs were used in the report for the EC *Technical assistance for an evaluation of international schemes to promote biomass sustainability* prepared by the COWI Consortium
[32] These costs are within the range of EU hourly wage, available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52016SC0164&qid=1466591434844&from=EN
[33] See footnote number 33
[34] The man-day tariff for auditing varies per country and per certification body. This tariff currently ranges from 500-1500 €

For Public Administration, a tariff of 18€/hour which is in line with referred literature used to set the tariffs for internal costs[35].

An additional analysis of the most relevant certification schemes has been conducted for agriculture feedstock for biofuel (for more details refer to Technical Annex F: Administrative costs) in order to verify and improve the quality of the assumptions considered in the present analysis which applied the Standard Cost Model. It results that external costs from the present study are in line with the certification costs estimation from the analysis carried out to estimate certification costs referred in Technical Annex F: Administrative cost analysis (this estimation considered fees applied by various biofuel certification schemes used in Europe).

In particular external costs in €/ton for the certification of biofuel result to be around 0.27 - 0.36€/ton as the additional study has confirmed (Technical Annex F: Administrative cost analysis).

[35] See footnote number 33

Table 2-10 Time spent (hours) on activities –Economic operators

Obligation to get and maintain the certification	Type of cost by frequency	Time spent (number of hours by entity concerned)	
Producers of agriculture biomass for biofuel		**Internal**	**External**
	One-off	70	26
	Recurring	38	12

Table 2-11 Time spent (hours) on activities – Public Administration

Obligations for Public Administration	Type of cost by frequency	Time spent (number of hours by MS)
Reporting to the EC	Recurring	92
Monitoring and verification	Recurring	320

Steps 10 & 11: Extrapolation of validated data to EU level and final reporting and transfer to the database

The results of the assessment of the administrative costs are shown in the tables below. The costs resulting from the obligations considered are presented separately for each kind of actor involved. In order to show the differences in a clear way, one-off and recurring costs are presented separately. Administrative costs of Public Administration are presented in one-off and recurring costs.

Table 2-12 Results of administrative costs – Economic operators

Market participants	Number of market participants	One-off costs (€mln)	Recurring costs (€mln)
Producers of agriculture for biofuels	8,181	25 - 46	12 – 22
TOTAL	8,181	36 (average)	17 (average)

Table 2-13 Results of administrative costs – Public Administration

Public Administration	One-off costs (€mln)	Recurring costs (€mln)
TOTAL	0.00	0.15 - 0.27

One-off costs carried by economic operators are, in average, 36 million € while recurring costs are between €12-22mln. For Public Administration there is no need of transposition of laws activities because it is assumed that the MSs already implemented the provisions of the RED, therefore one-off costs are inexistent. Recurring costs are between €0.15-0.27mln. The results are also presented in Figure 2-13 and Figure 2-14.

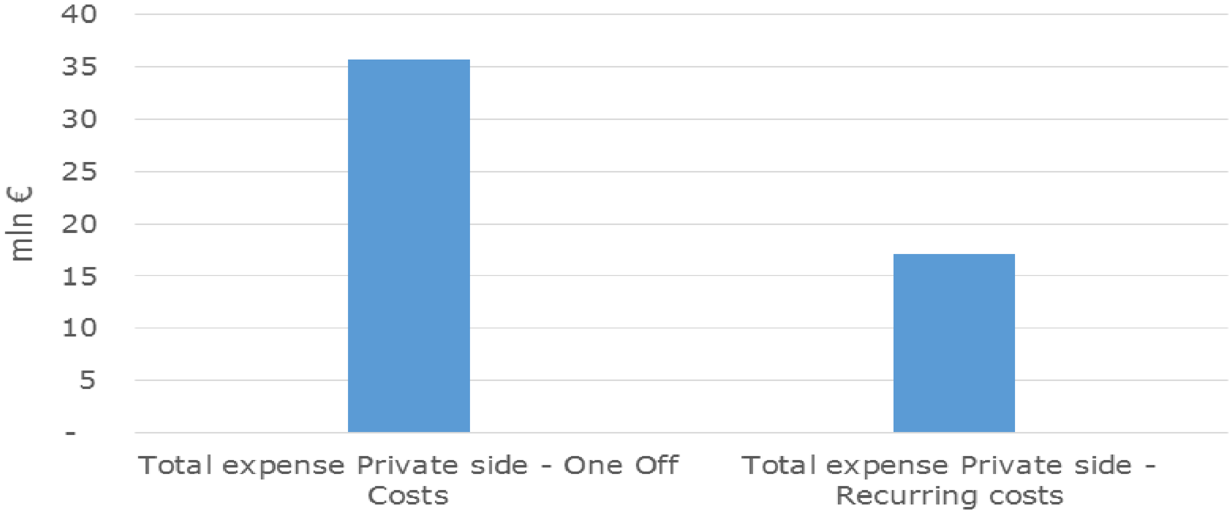


Figure 2-14

Figure 2-13 Total administrative costs for private operators (one-off and recurring, in average) – baseline

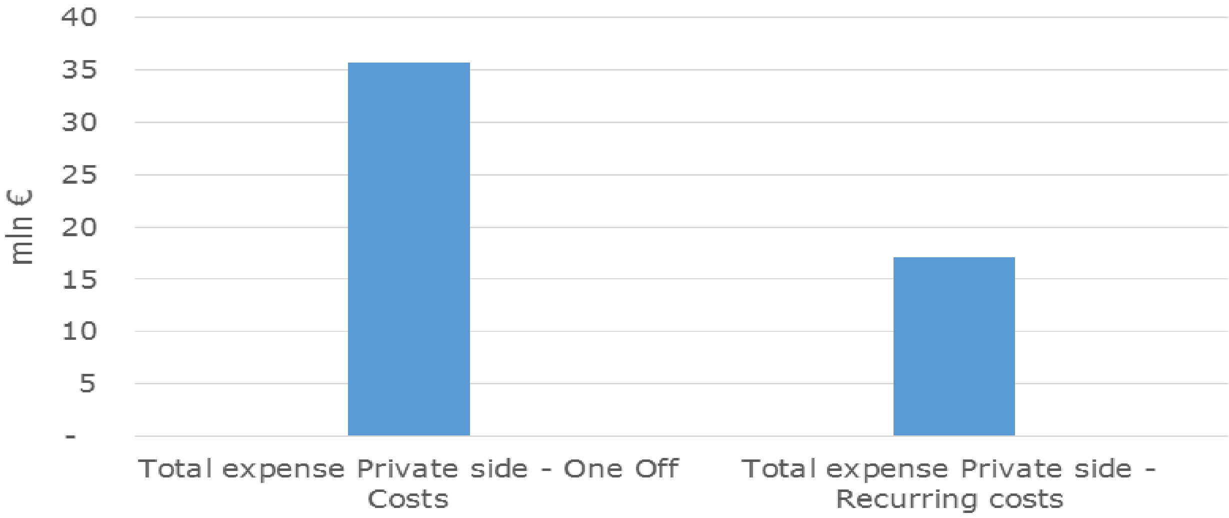
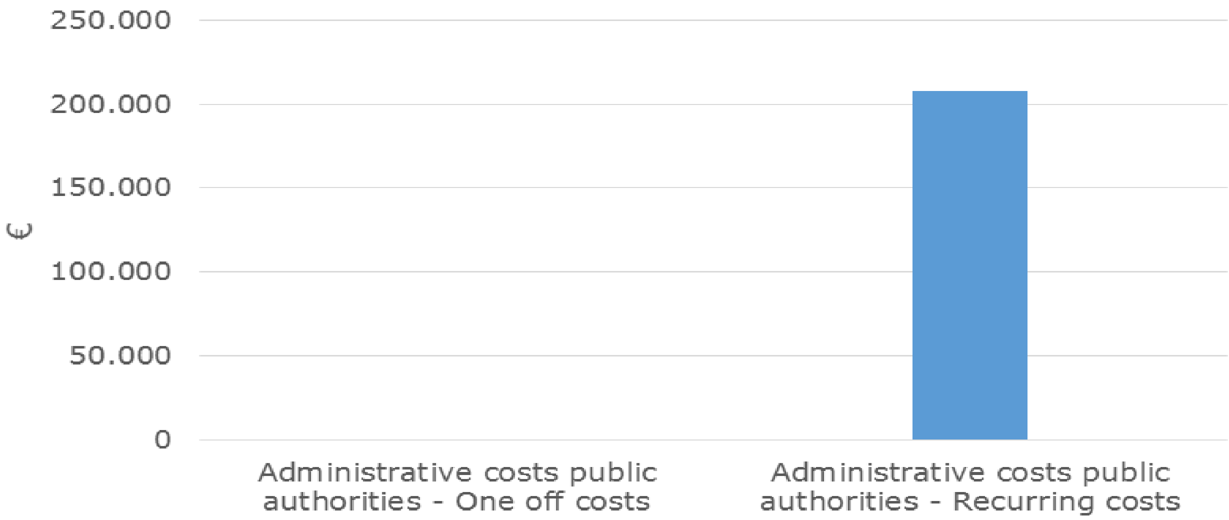


Figure 2-14 Total administrative costs for Public Administration (one-off and recurring, in average) – baseline



3 Policy context and problem definition

3.1 Policy context

The **Renewable Energy Directive (2009/28/EC)**, published in April 2009, was one of the legislative actions following the 2020 Climate and Action Package adopted in 2007. It established a common framework of measures for the promotion of renewable energy within the EU in order to ensure the achievement of the 20 % renewable target by 2020. All EU countries must also ensure that at least 10% of their transport fuels come from renewable sources by 2020. The Directive includes a set of **sustainability criteria** for the use of biofuels (used in transport) and bioliquids (used for electricity and heating). Only biofuels and bioliquids that comply with the criteria can receive government support and count towards national renewable energy targets. The requirements include minimum greenhouse gas savings compared to fossil fuel, exclusion of raw material from converted high carbon stock land, or from land with high biodiversity value, and raw material coming from European agriculture needs to be produced following 'good agricultural practises' as described in the Common Agricultural Policy (CAP). The **Fuel Quality Directive** revision of 2009 (**2009/30/EC**) amended a number of elements of the petrol and diesel specifications, and introduced a requirement on fuel suppliers to reduce the greenhouse gas intensity of energy supplied for road transport by 6% by 2020. Biofuels can play an important role for this target, and this directive included the same sustainability criteria for biofuels as in the Renewable Energy Directive.

In terms of solid and gaseous biomass sources in electricity, heating and cooling, the European Commission presented a report in 2010 (**COM(2010)11**)[36], issuing non-binding recommendations for Member States on sustainability criteria for biomass. These recommendations are meant to apply to energy installations of at least 1MW thermal heat or electrical power. In 2014, the Commission published a **Staff Working Document** (SWD(2014)259) on the state of play of sustainability of solid and gaseous biomass for electricity, heating and cooling in the EU[37]. It concluded that EU demand for solid and gaseous biomass for bioenergy production is likely to continue to be met largely through domestic raw material up to 2020, the majority providing significant GHG savings compared to fossil fuels. So no binding EU-wide sustainability requirements were proposed at that time. It was announced that these would be revisited in the post 2020 policy framework.

In its Communication on the 2030 policy framework for climate and energy (**COM(2014)15**)[38] early 2014, the European Commission set out its views on a new policy framework on climate and energy for 2030. In October 2014 the European Council agreed on the **2030 Climate and Energy Policy Framework**[39], including the following targets for 2030: a binding target for GHG reduction of at least 40% compared to 1990, a share of renewable energy in final energy demand in the EU of at least 27%, and an indicative target for energy efficiency improvement of 27% - the energy efficiency target may be adjusted to 30% after a review in 2020.

In February 2015, the Juncker Commission presented the **Energy Union Framework Strategy** (*A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy*)[40] as one of the ten priorities of the European Commission, which confirmed the political commitment of the European Union to become world leader in renewable energy. In this Strategy, the Commission announced that it would propose a **new Renewable Energy Package** in 2016-2017, which **includes a new policy for sustainable biomass and biofuels** as well as legislation to ensure that the 2030 EU target is met cost-effectively. The

[36] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52010DC0011&from=EN
[37] https://ec.europa.eu/energy/sites/ener/files/2014_biomass_state_of_play_.pdf
[38] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014DC0015&from=EN
[39] http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/145397.pdf
[40] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52015DC0080

Commission also stated in its 2015 Communication on the **Circular Economy** (COM(2015)614)[41] that it will 'ensure coherence and synergies with the circular economy when examining the sustainability of bioenergy under the Energy Union'.

In September 2015, the Renewable Energy Directive (as well as the Fuel Quality Directive) has been amended by **Directive (EU)2015/1513**[42] to reduce the risk of indirect land use change and to prepare the transition towards advanced biofuels. The amendments include a limit of 7% of the share of biofuels from crops grown on agricultural land that can be counted towards the 2020 renewable energy targets, an indicative 0.5% target for advanced biofuels as a reference for national targets, a requirement that biofuels produced in new installations achieve a minimum GHG saving of 60% compared to fossil fuels, and stronger incentives for the use of renewable electricity in transport.

On 20 July 2016 the European Commission presented a legislative proposal (COM/2016/479)[43] to integrate greenhouse gas emissions and removals from **land use, land use-change and forestry (LULUCF)** into the 2030 climate and energy framework. The proposal follows the agreement with EU leaders in October 2014 that all sectors should contribute to the EU's 2030 emission reduction target, including the land use sector. It is also in line with the Paris Agreement, which points to the critical role of the land use sector in reaching long-term climate mitigation objectives. LULUCF also makes a link with the use of land (forest or agriculture) to produce feedstocks for bioenergy.

3.2 Nature and extent of the problem

Biomass represents the dominant renewable energy source today with a overall demand of 105 Mtoe in 2013, meaning that more than 60% of current renewable energy production in the EU-28 is produced from biomass, the majority from solid biomass. Biomass is expected to continue to make up a significant part of the overall energy mix in the future. According to the Green-X model calculations for the EUCO27 scenario (see Figure 2.1), bioenergy demand in the EU in 2020 would be 124 Mtoe, which is 53.7% of renewable energy. While the relative share of bioenergy is expected to decrease to 50.4% towards 2030, the total amount of bioenergy is expected to increase to 146 Mtoe in 2030, given the growth of the RE target from 20% in 2020 to 27% in 2030. Highest absolute growth in this scenario is expected in biomass heat (+16 Mtoe), then in biomass electricity (+6 Mtoe), while biomass in transport is expected to stabilize in this scenario. When considering feedstock use (see Figure 2.2), primary energy supply of domestic agricultural biomass is expected to grow from 40 Mtoe in 2020 to 53 Mtoe in 2030, domestic forestry biomass from 93 to 103 Mtoe, waste biomass from 18 to 23 Mtoe, and imported biomass from outside the EU from 13 to 16 Mtoe, of which around one third for transport biofuels.

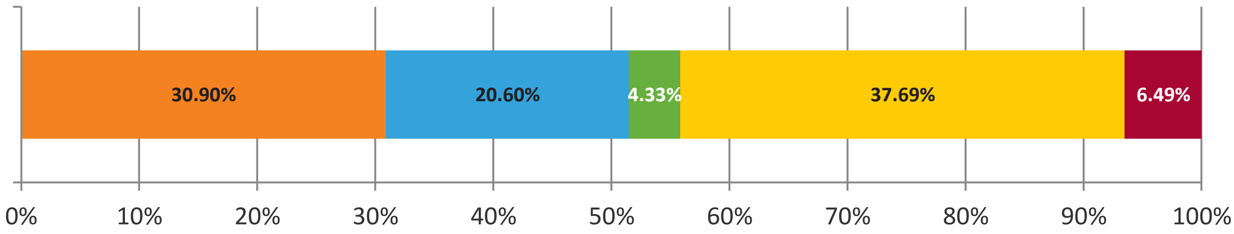
While bioenergy plays a key role towards EU climate and energy objectives, a number of sustainability risks are linked to its increasing use, and various stakeholders in society have raised concerns about sustainability impacts and competition for resources stemming from the increasing reliance on bioenergy production and use. The European Commission therefore organised a public consultation in the first months of 2016 in view of the development of a sustainable bioenergy policy for the period after 2020. Detailed results are described in Annex D (Results of Public Consultation).

A key result from the responses of the public consultation is that 63% of the in total 971 respondents see a clear need for additional legislative action on bioenergy sustainability, e.g. by extending the sustainability schemes towards solid and gaseous biomass for heat and power and to improve the issues tackled by the sustainability schemes. This is reflected in the

[41] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52015DC0614
[42] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32015L1513
[43] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52016PC0479

following diagram representing the scores on a question related to the bioenergy sustainability framework.

Figure 3-1 Overall response to the question on the bioenergy sustainability policy framework (all respondents) in the 2016 EC public consultation on a sustainable bioenergy policy



These results reconfirm stakeholders' concerns on the optimal and sustainable use of biomass. Therefore, during the project an analysis was carried out on the potential risks associated with the use of biomass for energy. Next to identifying risks and drivers for these risks, it was assessed whether potential gaps would exist in the existing set of legislative measures in place today. From this gap analysis, new options for EU action have been proposed and used for the assessment of impacts.

Generally expressed risks are:

- Insufficient or even negative **greenhouse gas savings** of certain bioenergy pathways. This encompasses supply chain GHG emissions, but also impacts on biogenic carbon storage, as well as indirect land use change.
- Adverse impacts on **biodiversity, soil and water,** particularly related to biomass production;
- Adverse impacts on **air quality,** particularly related to biomass combustion;
- Low **conversion efficiency** of some biomass to energy installations;
- **Competition** with non-energy end-use markets;
- **Distortion of biomass markets and trade** among Member States.

In the following sections these risks will be further discussed, as well as the drivers behind the risks, and how or if these are mitigated through policy, thereby identifying policy gaps. Focus in this study is on European policy. Several references will be made to European Directives and regulations, but also national sustainability schemes for solid biomass in the UK, Belgium, the Netherlands and Denmark. Summary sheets of these policies are provided in Annex E.

3.2.1 Risks associated with greenhouse gas (GHG) emissions

Climate change mitigation is one of the main drivers of renewable energy support, so it is important to demonstrate that actually greenhouse gas emissions are saved compared to fossil pathways. Greenhouse gas emissions of bioenergy value chains contain different components:

- Supply chain greenhouse gas emissions, including emissions related to direct land use change, biomass cultivation, transport and processing;
- Biogenic emissions related to changes in carbon stock, particularly in forest and soils;
- Indirect emissions related to displacement effects. The most commonly debated issue is land displacement and corresponding indirect land use change emissions.

In the following paragraphs these three components will be discussed.

Supply chain related greenhouse gas emissions

Risk: some bioenergy pathways provide insufficient greenhouse gas savings compared to fossil pathways

Supply chain emissions of **transport biofuels and bioliquids** (for electricity and/or heat production) are regulated through the Renewable Energy Directive (2009/EC/28). Directive (EU)2015/1513 increased the threshold for new installations (i.e. starting in operation after 1 October 2015) to 60%. Existing installations need to achieve at least 35% GHG savings until end 2017 and 50% afterwards. Overall, conventional liquid biofuels (crop based ethanol or biodiesel) typically achieve supply chain GHG reductions between 30 and 60% compared to fossil fuels (Edwards et al., 2014[44]). With increasing GHG reduction thresholds, there is an upward tendency of GHG savings for conventional biofuels in European facilities, with several reaching 60% savings or higher[45]. Particularly diverting process energy from fossil (typically natural gas) to renewable resources (typically biomass residues) or switch to CHP is applied to achieve improved GHG performances. Changes of carbon stock related to (direct) land use change can be high in case forest land or peatland is converted to agricultural land. The Renewable Energy Directive includes criteria to avoid the conversion of high carbon stock areas for biofuels cultivation.

GHG savings for **solid biomass** pathways are generally above 60% both for power and heat produced. Pathways achieving relatively low GHG savings (30% or less) are e.g. pellets or chips from SRC (Short Rotation Coppice), transported over long distance and applied in low efficiency electricity-only mode; also pellets produced from stemwood with natural gas as process fuel in the pellet production process have limited GHG savings. Transport distances, cultivation inputs and process utilities supply are the parameters which have the strongest influence on the final result. Furthermore, the GHG savings are subject to the final energy conversion efficiency. A higher conversion efficiency, which for example can be achieved in co-firing application in existing power plants or in combined heat and power installations, would allow the majority of pathways to exceed 70% GHG savings (Giuntoli et al., 2015[46]). There are no binding regulations at EU level regarding the GHG performances of solid biomass pathways to heat and power, but instead the 2010 Communication (COM(2010)11) provided recommendations for Member States, also in terms of avoiding the conversion of high carbon stock areas. A few Member States (UK, Belgium and the Netherlands) have implemented national regulations on GHG emissions of solid biomass installations. Mind that GHG emissions of advanced liquid biofuels based on solid biomass are regulated through the Renewable Energy Directive.

Concerning **biogas**, distinction can be made between feedstocks, typically maize silage, manure or biowaste, and the way the digestate is stored (in open or closed systems). Open digestate systems of manure, biowaste or maize silage have high methane emissions, which may negate the GHG advantage of biogas systems, particularly in the case of maize silage. The

[44] http://iet.jrc.ec.europa.eu/about-jec/sites/iet.jrc.ec.europa.eu.about-jec/files/documents/report_2014/wtt_appendix_2_v4a.pdf
[45] http://epure.org/media/1466/epure-key-figures-2015.pdf
[46] https://ec.europa.eu/energy/sites/ener/files/documents/Solid%20and%20gaseous%20bioenergy%20pathways.pdf

reference systems also need to be taken into account, particularly in case of manure the reference has very high methane emissions. Manure digestion and biowaste digestion with closed digestate storage can reach GHG savings of 80% and even up to 200% in case of manure compared to fossil systems. For maize silage based systems, GHG savings are generally much lower, i.e. up to 50% for closed digestate storage, which is related to the maize cultivation process. The conversion efficiency to electricity, heat or biomethane is also a decisive factor in the overall GHG balance. Overall, the GHG savings of biogas systems can range from negative to very high. When biogas is converted to methane and used as transport fuel, the GHG thresholds of the Renewable Energy Directive are applied; for electricity or heat applications there are no GHG thresholds, which can be an issue in some cases.

Drivers

For *liquid biofuels from agricultural crops*, the main factors influencing GHG emissions from the supply chain are potential land conversions, particularly if forests or peatlands are converted to agricultural land, emissions related to the production of fertilisers and N2O emissions from fertilised soils, fossil energy use in the processing of biofuels, fossil transport energy, particularly in case of long distance transport, as well as the use of co-products as part of the supply chain GHG emissions can be allocated to these.
For *solid biomass to heat and/or power*, the main factors are also related to the (fossil) energy to dry and process pellets/chips, fossil transport energy, particularly in case of long distance transport, and, in case of energy crops potential land conversion and fertilisation are also to be considered. Conversion efficiencies in the value chain, and particularly the final conversion efficiency - e.g. electricity-only installations compared to CHP installations - may lead to a relatively higher importance of the greenhouse gas emissions in the value chain, in relation to the energy produced from the biomass.

For *biogas*, the main factors influencing GHG emissions are potential methane slip, in particular related to the way the digestate is stored (open or closed storage), and the final conversion process. The feedstock choice of energy crops, biowaste or wet manure is also decisive as in case of energy crops the agricultural cultivation process needs to be included, as for conventional liquid biofuels.

Potential policy gaps

Currently the (Amended) Renewable Energy Directive and Fuel Quality Directive include provisions that biofuels for transport and bioliquids have to fulfil GHG thresholds. For solid or gaseous biomass used for the generation of electricity and/or heating/cooling such requirements do not exist, except for those governed by national sustainability schemes. The logic behind that is that for agricultural based feedstocks, often used for biofuels, the energy input and non-CO2 emissions (CH4, N2O) in the cultivation phase can be significant, as compared to forestry products and residues. The Commission Staff Working Document (SWD(2014)259) concluded that where forest biomass or agriculture residues are used, the GHG emission savings are generally above 70% compared to fossil fuel alternatives. However, lower savings can occur for short-rotation coppices - e.g. eucalyptus in tropical countries - in cases of high fertiliser use in agriculture, when natural gas is used for drying pellets, and when there are no provisions against conversion of high carbon stock land. Only the few countries that have implemented specific national sustainability schemes for solid biomass, which are countries with high shares of biomass imports for energy, cover this risk. This can be considered a policy gap for all other Member States.

The Commission Staff Working Document (SWD(2014)259) also concluded that GHG emission performance of biogas and biomethane can vary significantly depending on the feedstock and the conversion technology used at plant level. In particular, GHG performance is sensitive to the amount of energy crops used and to the leakage of methane emissions, particularly in case of open storage of digestate. In this respect, the revised Common Agricultural Policy requires

Member States to establish maximum thresholds for the use of cereals and other starch rich crops, sugars and oil crops (including silage maize), in order for biogas plants to receive financial support from the Rural Development programmes. The lack of GHG thresholds for biogas for electricity or heating, as compared to transport applications of biogas, where GHG thresholds are defined in the Renewable Energy Directive, can be considered a policy gap.

Greenhouse gas emissions related to changes in biogenic carbon stocks

Risk: increased extraction of biomass may lead to a loss of biogenic carbon stocks

CO2 emissions of biomass combustion are considered carbon neutral as these are linked to previous CO2 absorption of the plant, or can be considered part of a system of continuous balance of CO2 uptake in biomass growth and CO2 release through extraction or decay in the (forest) landscape. Nevertheless an increased extraction of biomass may lead to changes in carbon stock, e.g. in forest landscapes or soils, which need to be accounted for. Mind that carbon stock changes related to direct land use change are in principle included in supply chains emission calculations (see before). Risks in terms of biogenic carbon depend on the type of feedstock, in particular primary forest biomass – i.e. stemwood and forest residues - and agricultural biomass – i.e. crops and crop residues - should be considered.

In terms of **forest biomass**, there is a risk that intensification of forest harvesting may lead to a loss of carbon stored in the forest, both below and above ground, or a loss of long-term carbon sequestration capacity. Mind that extraction as part of sustainable forest management can also lead to increased growth of forests, e.g. through reduced fire risks, or stimulating growth of remaining trees. So far, the European growing stock in forests continues to grow, as harvesting from forests, including for non-energy purposes, amounts to 60-70% of forest increment. The EC Staff Working Document SWD(2014)259 indicates that there is no evidence of a systematic imbalance between forest functions at the European level. However, in order to meet growing forest biomass demand for energy and other uses, forest production will need to be intensified across the EU. This needs to be done sustainably to prevent negative impacts on biodiversity and ecosystem services, including the carbon pool. Enhancements of sustainable forest management practices throughout the EU are required to preserve the forest health and vitality. In the European Union, forest management is mostly regulated through national forest laws; large part of European forests are also managed and certified through FSC or PEFC systems. While these systems as such do not (yet) prevent carbon loss in forests, they do provide assurance for soil quality and biodiversity and can avoid excessive wood removals which would result in a decrease in carbon sinks. Imported biomass from regions outside Europe may provide less assurance, and should be assessed more specifically. So far, forest areas in the US Southeast or in Canada, which are important sourcing areas for European biomass imports, also show a proper balance between increment and extractions.

In relation to harvesting of **agricultural biomass**, i.e. harvesting of energy crops and agricultural residues, provisions need to be taken that soil carbon is not depleted, which is also part of good agricultural practice to keep agricultural soils in good condition. In the European Union, the Common Agricultural Policy (CAP) includes a link through the cross-compliance (CC) system between receipt of CAP support by farmers and respect of a set of basic rules related to the main public expectations on environment, public and animal health, as well as, animal welfare. The CAP applies to all farms in the EU and aims to ensure "good agricultural and environmental conditions" including the protection of climate, which includes carbon stock changes, soil, water and biodiversity. The condition of CAP compliance is specifically mentioned in the Renewable Energy Directive for biofuels from European agricultural feedstocks. Also in this case, imported biomass from regions outside Europe may provide less assurance, and should be assessed more specifically.

The reason for not accounting biogenic CO2 emissions in the energy sector is that emissions from land use, land use change and forestry are accounted for in the **LULUCF** sector. Emissions and removals of greenhouse gases in LULUCF are currently covered by the Kyoto

Protocol. These international obligations run up to 2020. The European LULUCF Decision of 2013 (Decision 529/2013/EU) provides improved accounting systems for emissions and removals at EU Member States territory on afforestation, reforestation, deforestation and forest management, and from 2021 also on cropland management and grazing land management. In July 2016, the EC published a proposal for a LULUCF Regulation (COM(2016)479) to secure an optimal functioning of the single market post 2020. It is proposed to include LULUCF into the 2030 EU climate and energy policy framework, among others to avoid double counting of emissions. The commitment for each Member State is to ensure that the LULUCF sector should have no net emissions on their territory. So after 2020, emissions related to biogenic carbon stock changes should be accounted by Member States in their LULUCF accounting. The same would be the case for non-EU countries that have included the LULUCF sector in their overall GHG reduction objectives and account for these emissions towards their international commitments. Importing biomass from countries that have not committed to LULUCF accounting may need dedicated assessment on the local impact on carbon stocks. Mind also that LULUCF reporting is on national level, so this does not necessarily prevent carbon stock changes at regional level.

Drivers

Increased demand for bioenergy is the main driver for a higher harvesting of resources from forestry and agriculture. Systems to secure sustainable management of forests and agricultural lands are crucial to mitigate the impact of intensified harvesting. Increased demand may also lead to higher biomass imports; concerns have been raised concerning the production of forest biomass in third countries, where little environmental safeguards may exist or where forest law enforcement is weak. Unsustainable agricultural practices with excessive harvesting of agricultural residues, potentially caused by the increased demand from bioenergy side, may also lead to a net loss of carbon stored in the soil.

Potential policy gaps

From the policy gap analysis in Section I.2.3 it is concluded that risks of carbon stock loss in forests or agricultural soils are expected to be mitigated for the most European Member States, due to well-established sustainable forest management, expressed in national forest laws and sustainable forest management certification, and clear regulatory framework affecting the agricultural practices (CAP). Such regulatory frameworks might not be in place in third countries outside the European Union, which may be considered as a policy gap.

Greenhouse gas emissions related to indirect land use changes

Risk: increased use of land (at global level) due to European demand for biofuels/bioenergy may lead to indirect land use changes, creating additional GHG emissions

Land use change can occur in a direct and indirect way. The conversion of forest for the purpose of establishing a plantation for a variety of products, including agricultural crops or wood products for bioenergy, is an example of direct land use change. In principle, these emissions are covered in the supply chain GHG emissions (see before). Indirect land use change has been on the agenda in the last decade in relation to crop-based biofuels. The argument is that the production of feedstocks for biofuels for transport on agricultural land that formerly was producing crops for food or feed ‘pushes’ the production of those food or feed crops to elsewhere, potentially in other regions of the world, and may lead to expansion into non-agricultural land with indirect land use change (iLUC) and corresponding greenhouse gas emissions as a result.

Several studies have been conducted to estimate GHG impacts related to indirect land use change, as a result of European biofuel expansion, also in relation to the type of crop. Estimates range from 4-17 gCO2eq/MJ for starch and sugar crops and 33-66gCO2/MJ for oil crops, as indicated in Annex I of Directive (EU)2015/1513. The higher figure for oil crops is related to the connection made with peatland conversion in Southeast Asia for palm plantations, mostly for food purposes. The amendments in the Renewable Energy Directive and the Fuel Quality Directive introduced a 7% cap on the contribution from crop-based biofuels to reduce the risk of indirect land use change and prepare the transition towards advanced biofuels.

So far, iLUC effects of solid or gaseous biomass for electricity and/or heat production have not been considered. Overall, there needs to be a link with land use, so extracting biomass from forest, or increasing the use of agricultural residues is less relevant in this respect, except when there is a link to deforestation. Using land for energy crops, like lignocellulosic crops, or also maize for biogas could in principle have an iLUC impact. The estimated iLUC range for starch crops may be indicative for maize. When biogas from maize is used for the production of methane as transport fuel, it will be part of the 7% cap in the Amended Renewable Energy Directive. For other purposes (electricity and/or heat), there is currently no limitation.

The iLUC impact of other lignocellulose crops is expected to be lower, as such crops can have higher energy yield per hectare. Moreover, these crops have the potential to be grown on degraded or currently unused lands. So far, knowledge on iLUC impacts of such crops is limited.

Drivers

Increased demand for biofuels and bioenergy is the main driver for the higher stress and competition for land use. The importance of the risk is related to land use management practices for forests, nature and agriculture, as well as market resilience in agriculture and food production. The way co-products are used also impacts the final iLUC effect, for instance, current biodiesel and bio-ethanol facilities produce animal feed as co-product, which may substitute imported animal feed.

Potential policy gaps

iLUC impacts are currently only accounted for transport biofuels through the amendments to the Renewable Energy Directive (in Directive (EU)2015/1513). When similar fuels like bioliquids, or biogas from maize are used for electricity or heating, no limitations are applied. This creates an unbalance between these different applications.

On the other hand, in a number of cases, starch, sugar or oil crops can demonstrate low displacement effects, e.g. through the use of marginal or abandoned lands. Even then, these biofuels will still be limited by the 7% cap in the Amended Renewable Energy Directive, which creates an unbalance with other energy crops.

3.2.2 Risks associated with other environmental impacts

Impacts on biodiversity, soil and water

Risk: increased extraction of biomass may lead to adverse impacts on biodiversity, soil and water

Potential negative impacts on biodiversity, soil and water strongly relate to the issue of carbon stock change and land use change and may become manifest in the case that forestry operations or agricultural practices change because of an increased extraction of biomass. Increasing mono-cultivation of biomass feedstocks might put biodiversity and quality of soil and water under pressure.

Risks depend on the type of feedstock. In terms of **forest biomass**, there is a risk that intensification of forest harvesting and residue extraction may lead to a loss of biodiversity and soil quality. Harvesting intensification needs to be done sustainably to prevent negative impacts on biodiversity and ecosystem services. Enhancements of sustainable forest management practices throughout the EU are required to preserve the forest health and vitality and its overall biodiversity status. In Europe, forest management is mostly regulated through national forest laws and the EU Forest Strategy (COM(2013)659) actively promotes sustainable forest management; large part of European forests are also managed and certified through FSC or PEFC systems. Imported biomass from regions outside Europe may provide less assurance, and should be assessed more specifically.

While the Renewable Energy Directive provides provisions that transport biofuels and bioliquids shall not be made from raw material obtained from land with high biodiversity value, including primary forest, nature protection areas or highly biodiverse grassland, such provisions are not valid for biomass for electricity or heat production. The 2010 Communication (COM(2010)11) provided recommendations for Member States, also in terms of avoiding biomass from highly biodiverse areas. Only a few Member States (UK, Netherlands) have implemented national regulations covering this.

The EU Timber Regulation (Regulation (EU) 995/2010) and the FLEGT Action Plan aim to reduce risks of deforestation in third countries and have the potential to contribute to biodiversity protection, conservation and sustainable management of forests in countries trading woody biomass with the EU.

Unsustainable agricultural practices with excessive harvesting of **agricultural crops and residues** (potentially caused by the increased demand from the bioenergy side), high fertilisation or soil compaction may also lead to a loss in biodiversity, soil fertility and water quality. It should be noted, however, that plantations of short rotation forestry on degraded land or poor arable land could result into environmental improvements, although the location may affect their productivity. EU cross compliance rules in the Common Agricultural Policy aim to ensure “good agricultural and environmental conditions” including the protection of climate (carbon stock changes), soil, water and biodiversity in European agriculture. In relation to water quality in the EU, the Water Framework Directive (Directive 2000/60/EC, amended by Council Directive 2013/64/EU) provides a general framework, and the Nitrates Directive (91/676/EEC) specifically targets the protection against pollution caused by nitrates from agricultural sources, particularly through manure and fertilisers. Nature and biodiversity are protected by several laws: the Habitat Directive (Directive 92/43/EEC) forms the cornerstone of Europe's nature conservation policy with the Birds Directive (Directive 2009/147/EC) and established the EU wide Natura 2000 ecological network of protected areas. Most concerns have been raised concerning the production of agricultural biomass in third countries, where little environmental safeguards may exist or where law enforcement is weak. This would require specific assessment.

Drivers

Increased demand for bioenergy may result in higher harvesting of resources from forestry and agriculture, which can put stress on biodiversity, soil quality and water. The importance of the risk is related to land use management practices for forests, nature and agriculture.

Potential policy gaps

While risks in the EU may be covered by environmental regulations, for non-EU biomass resources, these risks may not be covered with similar adequate regulations and enforcement. The Renewable Energy Directive includes provisions for biofuels and bioliquids to exclude biomass from highly biodiverse land. In relation to solid biomass for energy, only few Member States include such provisions in a national sustainability scheme, which can be considered a policy gap.

Impact on air quality

Risk: increased biomass combustion can add to air quality problems

Biomass combustion is often connected with air pollution problems. This is mostly related to open fires, ‘traditional’ use of biomass, the use of older biomass combustion installations with insufficient combustion and pollution control, or the uncontrolled combustion of contaminated biomass. SWD(2014)259 already stated that wood burning, especially in case of incomplete combustion, can be an important source of air pollutants, harmful to human health and the environment.

Air emissions are addressed in different EU Directives, including the National Emissions Ceiling (NEC) Directive (Directive 2001/81/EC), Industrial Emission Directive (Directive 2010/75/EU) and Medium Combustion plants Directive (Directive (EU)2015/2193). Ecodesign requirements are introduced for (new) solid fuel boilers (up to 500 kW) and local space heaters including energy efficiency and emissions[47]. These requirements will enter into force from 2020. Some Member States have already implemented national requirements on efficiency and emission levels of (new) small scale heating installations. While new installations will be regulated in terms of their emission performance, the combustion in older (uncontrolled) stoves and firing places may still be an issue in relation to air quality, as lifetime of stoves may be long.

Drivers

The main driver is the increased use of biomass, particularly for heating in urban areas. The existing stock of older installations with insufficient combustion and pollution control is the main reason for increased pollution levels linked to biomass combustion.

Potential policy gaps

Policies have been installed, particularly for medium to large installations, and new small scale stoves and boilers; the issue of high air pollution is mainly linked to open fires and small scale combustion in older installations, or also through the use of contaminated biomass in such installations. As such stoves or boilers may have long lifetime, specific actions may be required to prevent excessive air pollution. In principle, Member States can take action in the frame of the NEC Directive, e.g. restricting open fires, putting restrictions on small scale biomass combustion in sensitive periods, or accelerate the replacement of older installations.

3.2.3 Risks associated with efficiency levels of biomass conversion and market impacts

Efficiency of biomass conversion

Risk: inefficient use of biomass

The supply of biomass feedstock is constrained by the finite availability of land and residues and should be in balance with provision of food and biobased materials. In the context of the transition to a low-carbon and bio-based economy in Europe, biomass feedstocks can be used in an increasing number of sectors beyond the energy sector, e.g. the chemical sector. Inefficiencies in value chain processes, as well as a limited end use conversion efficiency - e.g. for electricity-only installations compared to CHP installations - may lead to a higher demand of biomass resources for the same amount of energy and create extra pressure on feedstock supply. Inefficient stoves (see discussion on air pollution) or electricity-only installations, in comparison to CHP installations, are examples where higher efficiency can be pursued.

According to Eurostat, in 2014, 44.3Mtoe of biomass (including renewable waste) was consumed in thermal power stations; 40% of that was in electricity-only facilities and 60% in CHP facilities. The possibilities to install CHP are related to opportunities to use the heat locally, e.g. infrastructure for district heating may be lacking or seasonal demand for heat may be low, as may be the case in some Mediterranean regions. Mind that co-firing in coal power installations or conversion of such installations to biomass is a relatively quick and easy option to replace fossil fuels in several Member States, and such coal power facilities are not always connected to a district heating system.

The Energy Efficiency Directive (2012/27/EC) aims to increase energy efficiency. It brings forward legally binding measures to step up Member States' efforts to use energy more efficiently at all stages of the energy chain – from the transformation of energy, to its

[47] Commission Regulations (EU) 2015/1189 and 2015/1185

distribution and to its final consumption. These will drive energy efficiency improvements in households, industries and transport sectors. With respect to electricity generation the Directive emphasises to tap the potential of high-efficient cogeneration and district heating and cooling. Special attention is given to small and medium installations to encourage distributed energy generation.

With respect to efficient end use conversion, the EcoDesign Directive allows the Commission to regulate the minimum performance of products and thereby push inefficient products out of the market in favour of better performing products. Such requirements have been installed for new solid fuel boilers and space heating installations.

Within the EU Emission Trading System (ETS) biomass is viewed as carbon neutral or zero emission. As such, this system might not promote the energy efficient conversion of biomass to electricity and/or heat. As mentioned before, the end use conversion efficiency can play an important role in the GHG performance of several biomass value chains. As mentioned before, there are no binding regulations at EU level regarding the GHG performances of solid and gaseous biomass pathways to heat and power. Also for bioliquids, which are covered in the Renewable Energy Directive, the GHG emissions are only counted in relation to the energy content of the fuel; the final energy conversion is not included.

The fact that biomass generally is more expensive than its current fossil alternatives will set direction to the purchase by end-users of more efficient biomass systems to achieve overall lower operation costs, so less biomass feedstock will be needed per unit of energy produced.

Drivers

The main drivers for inefficiencies in the conversion of biomass, are the existing stock of inefficient biomass heating systems, as well as existing (coal based) power plants which are not always aimed at valorising residual heat. Nevertheless, co-firing in coal power installations or conversion of such installations to biomass is a relatively quick and easy option to replace fossil fuels in several countries/regions. Another driver is the lack of opportunities to use the heat locally, e.g. because of lacking district heating systems, or low seasonal heat demand, like in South Europe.

Potential policy gaps

As mentioned before, there are no binding GHG thresholds for solid and gaseous biomass at EU level, apart from a few countries. The end use conversion efficiency can play an important role in the GHG performance of several biomass value chains, so next to economic reasons, a GHG threshold would provide an argument to reach higher efficiency levels. In the frame of the Energy Efficiency Directive, recognition of installations reaching minimum efficiency requirements can be considered.

Competition with other sectors

Risk: the bioenergy sector may drive up prices and limit availability of biomass for other sectors

Increased demand for biomass for energy has an impact on the available resources and may interfere with other (current) applications of the same types of biomass. The risk is linked to specific types of feedstocks and the market resilience, i.e. the extent that these markets can deal with external changes. Incentives for bioenergy may increase the purchasing power of the bioenergy sector and cause market distortion with other (biobased) applications. Wood processing and pulp and paper industries have expressed their concerns on the development of bioenergy plants. Mind that wood processing and pulp and paper industries generally also are major bioenergy producers, based on their residues.

Avoiding competition with food production is one of the arguments in Directive (EU)2015/1513 to cap the use of food crops for biofuels. Moreover it is stated that Member States should have due regard to the waste hierarchy - with reference to the Waste Framework Directive (Directive 2008/98/EC) - when setting policies to promote biofuels from waste and residues. The waste hierarchy principle in the Waste Framework Directive lays down a priority order of what constitutes the best overall environmental option in waste legislation and policy, with re-use and recycling having a higher priority than energy recovery. This only applies to waste and residues, not to fresh material like stemwood or agricultural crops which may be a gap. Some Member States list types of biomass that under certain conditions are (not) entitled to receive support for energy production, e.g. support is excluded when there are recycling options. Nevertheless, this approach is not consistently applied between Member States. The market stress on specific feedstock types can also be very region dependent.

The localisation of biomass processing plants is also highly relevant. For example, pulpwood is an important feedstock for pellet plants in the US. When the sourcing area of pellet plants overlaps with sourcing areas of the pulp and paper industry this may create direct competition. On the other hand, in some regions feedstock demand from the pulp and paper industry has declined due to structural problems of the sector which led to the closing of certain facilities. The pellet industry may provide opportunities for forest managers to divert part of their products (next to high value timber), which may also be an incentive to manage their forest, or for afforestation.

Drivers

The main driver for the risk of competition is the increased demand from the bioenergy sector. This is related to renewable energy support and incentives provided to bioenergy. The type of feedstock is decisive, and the localisation of biomass/pellet processing plants and the regional situation in terms of stress on certain feedstocks are very important. Market resilience is a key parameter to indicate if a certain market segment can cope with external changes in the market. Mind that bioenergy and biobased products are also complementary, as in many cases energy is a co-product of wood based products through the use of residues.

Potential policy gaps

A potential policy gap is that the approach of Member States differs in terms of the biomass types that are entitled to receive support for bioenergy. This may induce trade of such feedstocks to neighbour countries where different regulations apply.

Distortion of the single market

Risk: different national regulations in terms of solid biomass may distort the single market

As mentioned in Table 2-3, by 2030 trade of solid biomass for energy between EU countries is expected to be in the same range (~11.8 Mtoe) as extra EU imports (~10.5Mtoe), according to the Green-X calculations of the EUCO27 baseline scenario. Overall, intra-EU trade and extra-EU imports together represent around 11% of biomass use for energy.

In some EU Member States (particularly in the UK, Netherlands, Belgium and Denmark), national regulations for the sustainability of biomass resources for electricity and heat generation are in place or being implemented. These countries are currently heavily relying on biomass imports for their renewable energy targets. Sustainability requirements have mostly been developed in relation to concerns over imported biomass of which the production is outside the jurisdiction of the Member State, and the lack of uniform EU-wide sustainability requirements for solid biomass. To some extent these regulations are inspired by the EC’s non-binding recommendations on sustainability criteria for biomass (COM(2010)11). There are however considerable differences in national approaches and requirements; biomass fulfilling the requirements in one Member State may not match the requirements of other. This leads to potential distortion of biomass trade among EU Member States and to suboptimal performance of the single market. Furthermore, this may lead to unnecessary high administrative costs due to these different national regulations.

In the past, European utilities have faced such differences in requirements when shipping individual consignments to Europe. To solve these issues a number of large European energy utilities have set up an international working group and developed a voluntary, industry-led sustainability certification scheme for woody biomass, called SBP (Sustainable Biomass Program)[48]. The aim of the scheme is to provide assurance that woody biomass is sourced from legal and sustainable sources, allowing companies in the biomass sector to demonstrate compliance with regulatory requirements in the different EU Member States.

The University of Utrecht has assessed the most relevant differences in the operation of the national schemes in the UK, Belgium, Denmark and the Netherlands. More details can be found in Annex E. It was concluded that the legislation and support schemes in these countries have, to certain degree, different goals and targets whilst there are also differences among various sustainability criteria and reporting requirements. A number of sustainability criteria for solid biomass may be harmonised in the four countries (biodiversity protection, ecosystems conservation, forest productivity and well-functioning forests); other sustainability requirements differ, e.g. the GHG emission thresholds are not (yet) aligned in the four countries investigated. Criteria to limit carbon stock and indirect land use change are introduced and tested only in the Netherlands.

With regard to lessons learned, the Belgian system(s), which have already been in place for over a decade, seem to function relatively well – the utilities in Belgium have been able to source sufficient biomass that meets the Belgian requirements and demonstrate energy balances in the value chain and still allowed for profitable business with the green certificate system. The same seems to apply to the sustainability criteria linked to the UK renewables obligation. Import volumes, especially from the US, are increasing and while mandatory compliance with sustainability criteria is only required since 1 December 2015, it appears that this has not been a limiting factor since. With regard to the administrative burden, the monthly reporting requirement is obviously a laborious task. However, as the UK has recognized the SBP certification to meet the requirements of the Renewables Obligation and this system is supported by the main UK utility provider Drax, the administrative burden seems to be manageable, at least for this large player. However, for the Netherlands, the impact of the new legislation remains largely to be seen. Wood pellet producers in the US have voiced strong concerns with regard to the dutch requirements that increase over time, especially the requirement to fully certify also small forest owners/plots from 2020 onwards. As utilities in the Netherlands have not used any significant volumes of wood pellets in 2014 and 2015 (due to lack of subsidies), and the new legislation will only enter into force in the near future, the impact of the new sustainability criteria cannot be evaluated yet. On the other hand, industrial stakeholders in Denmark seem to be fairly confident that they can source sufficient volumes of biomass that meet the requirements set under the Danish Industry agreement.

Full harmonisation of these national schemes is unlikely to happen in the near future, unless an EU-wide scheme is imposed. As a result of different approaches there are market limitations in the sense that supply chains have to be developed for each particular end-market. The lack of harmonisation prevents the efficient operation of the market as a commodity market, which results in higher administrative costs and probable higher operational costs.

Drivers

The main drivers for potential trade distortions are the differences in Member States support systems and sustainability requirements.

[48] http://www.sustainablebiomasspartnership.org/

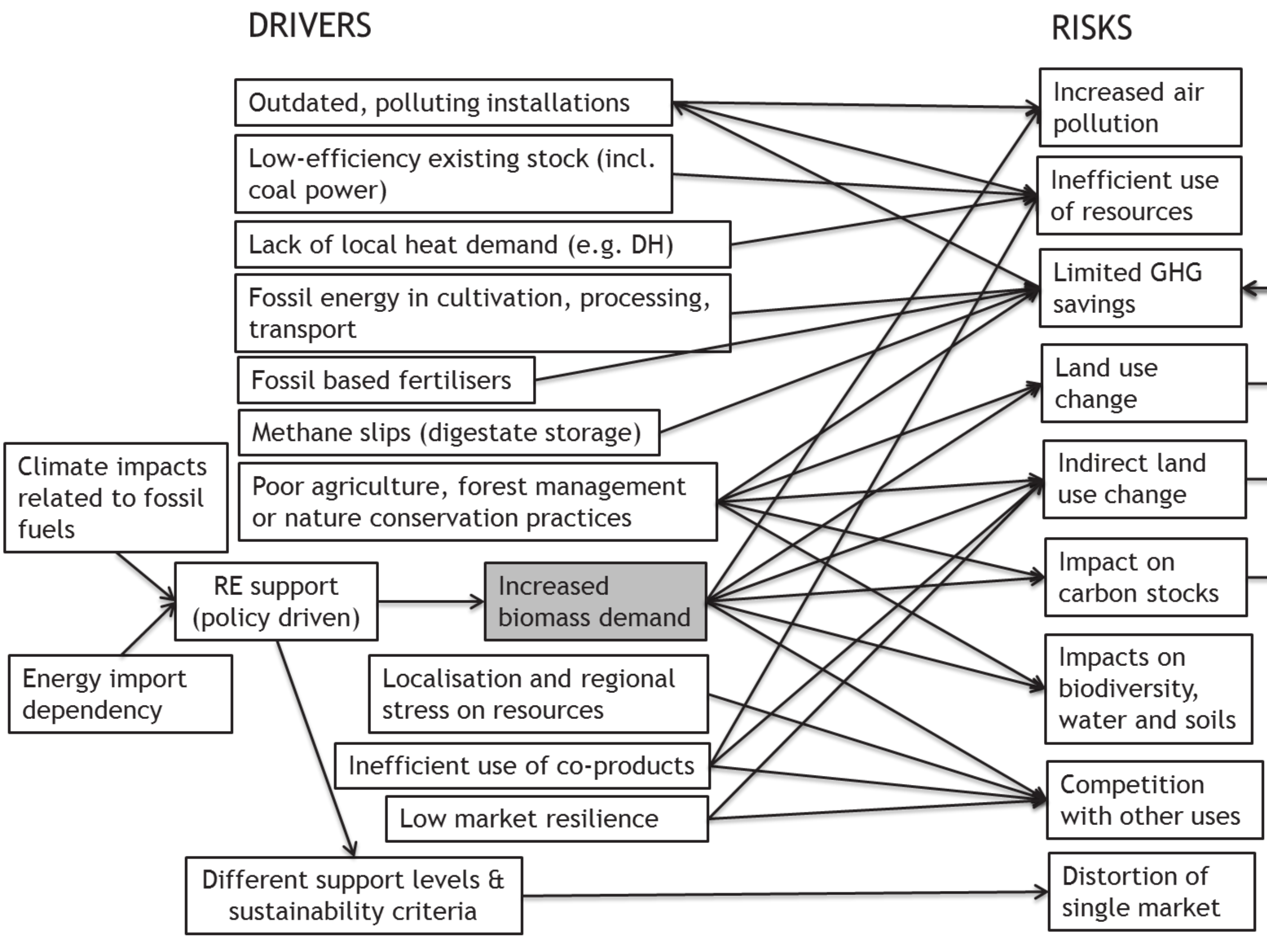
Potential policy gaps

Member States have developed their own approaches regarding sustainability requirements for solid biomass, particularly with imports from outside the EU in mind, as EU biomass is largely governed by EU and Member States regulations. Even though they were inspired by the recommendations of the EC in COM(2010)11, the lack of EU-wide harmonized sustainability criteria for solid biomass - in contrast to biofuels and bioliquids - has led to different Member States approaches. This can be considered a policy gap.

3.2.4 Problem tree

The following problem tree shows the connections between risks and drivers, identified in the previous chapters.

Figure 3-2 Problem tree for sustainability risks related to solid biomass and biogas use for heat and power



4 Policy objectives and options for EU action

4.1 Policy objectives

The 2020 CEP adopted in 2007 defined specific objectives towards 2020 to **reduce greenhouse gas emissions** to combat climate change, move to a more secure and sustainable energy system through an **increased share of renewable energy** and a **reduced energy intensity** of the economy. These objectives still stand.

In the RED (2009/28/EC) it was acknowledged that biofuels should be subject to sustainability criteria to make sure that they actually contribute to greenhouse gas savings (including GHG emissions related to land use change), that they don't contribute to the destruction of biodiverse lands and the production of agricultural biomass for biofuels in the EU should comply with the environmental requirements for agriculture as defined in the Common Agricultural Policy.

In 2015 new rules came into force with the iLUC Directive ((EU)2015/1513) amending the current legislation on biofuels (the RED and the FQD) to **reduce the risk of indirect land use change** and to prepare the transition towards advanced biofuels that reach high greenhouse gas savings and have low risks for indirect land use change.

In its Communication on the 2030 policy framework for climate and energy (COM(2014)15), the EC indicated that "an improved biomass policy will be necessary to maximise the resource efficient use of biomass in order to deliver **robust and verifiable greenhouse gas savings** and to allow for **fair competition** between the various uses of biomass resources in the construction sector, paper and pulp industries and biochemical and energy production. This should also encompass the **sustainable use of land**, the **sustainable management of forests** in line with the EU's forest strategy and **address indirect land use effects** as with biofuels. **Improved energy efficiency** makes an essential contribution to all of the major objectives of EU climate and energy policies."

The Single Market Strategy is one of the fundamental principles of the European Union. The Single Market refers to the EU as one territory without any internal borders or other regulatory obstacles to the free movement of goods and services. In that sense, also **barriers to biomass trade should be prevented**.

These general strategic objectives can be translated into the following specific operational objectives:

- Ensure that bioenergy use in the EU contributes to climate change mitigation;
- Avoid direct and indirect land use change;
- Minimize biodiversity impacts;
- Prevent distortion of the biomass market
- Ensure efficient uses of biomass for energy;
- Prevent barriers to trade of biomass for energy.

4.2 Options for EU action

Six central issues were defined in relation to the gap analysis described in the previous chapter:

1. Some bioenergy options may have limited **life cycle GHG emission reductions** compared to the fossil reference. In particular, there are currently no binding GHG saving requirements for solid and gaseous biomass for electricity and heat.
2. **Carbon stocks** (particularly in forests) can be reduced when certain feedstocks are used for bioenergy.
3. Harvesting biomass for bioenergy may have an impact on **biodiversity** (through land use change, or changes in management of forests or agricultural land).
4. Bioenergy applications can have non-optimal **energy conversion efficiency** in heat and power plants.
5. Bioenergy may **compete** with other applications of biomass (e.g. food, roundwood). For waste material, waste hierarchy principles can be applied, however, these principles do not apply to fresh material like roundwood (the use of food crops is limited by the iLUC directive).
6. Different requirements/approaches of MS's may lead to **Intra-EU market distortions**.

The options for EU action presented in this section have been developed in collaboration with the EC and address one or more of the above key problems and objectives.

Table 4-1 below shows an overview of the considered options, and the correspondence between the options and the problems, sub-problems and objectives. The policy options will be described further on.

Table 4-1 Correspondence between issues, drivers, objectives and options for EU action

Row no.	Issues	Drivers	Specific objectives	Policy options
1	Some bioenergy options may lead to non-optimal **life cycle GHG emission** reductions compared to the fossil reference	The GHG balance of given biomass energy applications differs depending on the value chain (biomass growth and harvesting, transport, processing and conversion into energy)	Ensure that bioenergy use in the EU contributes to climate change mitigation	**OPTION 2: EU biomass criteria for heat and power** Introduce a 70% GHG saving requirement for biomass **heat and power** plants (for solid biomass, bioliquids and biogas). This includes the final conversion step to energy.
2	**Carbon stocks** (particularly in forests) can be reduced when certain feedstocks are used for bioenergy	Increased demand for biomass may lead to unsustainable forest management practices	Avoid direct and indirect land use change	**OPTION 2: EU biomass criteria for heat and power** For agriculture and forest biomass: Extend criteria of high carbon stock land of the Renewable Energy Directive (for biofuels/bioliquids) to heat and power applications (for solid biomass, bioliquids and biogas)

			Minimize biodiversity impacts	**OPTION 3a: SFM certification** SFM certification requirements on all forest biomass (instead of RED land criteria) **OPTION 3b: Risk-based approach for forest biomass** Application of risk-based approach on forest biomass (instead of RED land criteria)
3	Harvesting biomass for bioenergy may have an impact on **biodiversity**	Increased biomass demand can impact biodiversity (through land use change or through the use of residues)	Minimize biodiversity impacts	**OPTION 2: EU biomass criteria for heat and power** For agriculture and forest biomass: Extend criteria of land with high biodiversity value of the Renewable Energy Directive (for biofuels/bioliquids) to heat and power applications (for solid biomass, bioliquids and biogas)
4	Bioenergy applications can have a non-optimal **energy conversion efficiency** in heat and power plants	Biomass conversion technologies with low energy efficiency require more biomass feedstocks than necessary. This requires more biomass feedstock supply, which is constrained by the finite availability of land	Ensure efficient uses of biomass for energy	**OPTION 2: EU biomass criteria for heat and power** Introduce GHG saving requirements for biomass **heat and power** plants, which includes the final conversion step to energy (for solid biomass, bioliquids and biogas). As a result, the GHG emissions in agricultural operations have to be taken into account for al biomass to energy applications
				OPTION 4: Energy efficiency requirement Introduce a **minimum efficiency requirement** of 65% for biomass heat and power plants.
5	Bioenergy may **compete** with other applications of biomass (e.g. food, roundwood)	When bioenergy applications are promoted (through subsidies or other incentives) this may impact other markets (availability, prices) which rely on the same types of biomass, or on the use of land	Prevent distortion of the biomass market	**OPTION 5: Stemwood cap** Forest biomass: disincentive to use roundwood for energy. This option favours use of biomass for resources for options where biogenic carbon is stored for longer periods, i.e. in materials and other products.
6	Different requirements/approaches of MSs may lead to **Intra-EU market distortions**.	Depending on the specific country situation, more attention may be placed on the issue of biomass imports and securing its sustainability	Prevent barriers to trade of biomass for energy	**OPTION 2: EU biomass criteria for heat and power (also in options 3, 4 and 5)** EU wide implementation of uniform sustainability criteria Similar requirements for heat and power applications of biomass as for biofuels

Option 1: Baseline scenario

Option 1 is the baseline scenario where current provisions on bioenergy sustainability will be continued to 2030. This includes the current provisions in the Renewable Energy Directive and the recent amendments in the iLUC Directive. No additional EU actions on bioenergy sustainability will be taken. The baseline is explained in Chapter 2.

Sustainability criteria are limited to biofuels for transport and bioliquids (for heat and power):

- At least 60% GHG savings for biofuels produced in installations starting operation after 5 October 2015; at least 50% GHG savings for biofuels produced in older installations.
- Land criteria where raw material can be sourced:
    - Raw material should not come from high carbon stock land that was converted after January 2008, or drained peatland.
    - Raw material should not come from land with high biodiversity value.
- Agricultural raw materials cultivated in the EU should fulfil cross-compliance rules of the Common Agricultural Policy.

As decided by the iLUC Directive, the contribution of food crop based biofuels to the renewable energy target in transport is limited to 7%. In this option, we assume that this cap will remain constant between 2020 and 2030.

From the results of the public consultation, it became clear that a significant share of the Public Administration (especially from MSs with high domestic forest resources) and public enterprises as well as biofuel and bioliquids producers prefer this option. The latter are in favour of simplifying the existing criteria to minimize the administrative burden. Private enterprises in the forestry sector, as well, are in favour of simplification. A common ground among these forestry companies is that they view the current framework of sustainable forest management as sufficient and do not want to impose an additional administrative system to the sector.

Option 2: EU biomass criteria for heat and power

Option 2 implies that sustainability criteria for biofuels will be continued (as in Option 1), but that these will be extended to solid biomass and biogas for heat and power production.

More specifically the land criteria and cross-compliance rules for agricultural biomass (for heat and/or power) will be identical to the criteria for biofuels and bioliquids.

For GHG savings, there will be a specific threshold for heat and power applications. In this case, the final conversion step will be included, so the fossil comparator will be expressed per GJ electricity or per GJ heat. GHG saving requirements for heat and power will be set at 70%, and levels of 60% and 75% will be used for a sensitivity analysis.

The requirements will only be applied to large-scale units above 4-5MW (this level is chosen for modelling reasons) and for the sensitivity analysis to plants above 1 MW (thermal biomass input), alternatively (as a sensitivity analysis) to all heat and power plants, or only large-scale units above 4-5MW.

The extension of sustainability criteria for biofuels to solid and gaseous biomass is welcomed by various stakeholders, under the latest public consultation. In their response to the question on the bioenergy sustainability policy framework (Question 8.1 of the public consultation) civil society organizations and the academic/research institutions are unanimous in the sense that they want both extension of the sustainability criteria to solid and gaseous biomass and at the same time they want an improvement of the sustainability scheme for biofuels and liquids[49]. Within the group of private enterprises, half of the respondents support this option; most of them operate in the energy sector, but some are also active in the forestry and agricultural sector (this information is based on detailed background information of the public consultation responses). Small forest owners oppose additional EU requirements on forest biomass, raising concerns regarding EU competence and subsidiarity. Among the Public Administration more than one third want an extension to solid and gaseous biomass, but together with improved criteria for biofuels and liquids. They mainly stress the need for resource efficiency, local energy chains and preferred utilization of waste and residues. As mentioned before, a significant share of the Public Administration (especially from MSs with high domestic forest resources) and private enterprises in the forestry sector oppose the extension of EU wide sustainability criteria beyond biofuels. A common ground among these forestry companies is that they view the current framework of sustainable forest management as sufficient and do not want to impose an additional administrative system to the sector.

Option 3a: SFM certification

This option is similar as option 2 in terms of GHG savings and conditions for agricultural biomass. For forest biomass, the land criteria are replaced by SFM criteria in order to ensure that biomass feedstocks are sourced through sustainable forest management practices and that emissions from the LULUCF sector are accounted for. This means that all forest biomass consignments should comply with the EU minimum sustainability criteria for forest biomass, and this should be demonstrated by means of certification or other equivalent evidence at the forest holding level.

In modelling the assumption is taken that the imposed requirement of SFM leads to a reduction of forestry supply potentials – i.e. assuming a shift from the "reference" to the "restricted" scenario.[50] This affects both domestic EU bionenergy supply potentials and the capabilities for Extra-EU imports of solid biomass, leading to a reduction of total bioenergy supply potentials.

The use of SFM criteria is preferred by civil society organizations and academic institutions as it sets the most strict sustainability rules for the use of forest feedstocks with respect to sustainability risks associated with biodiversity, carbon stock change and indirect land use change. Most of the forestry industries and public administrations are not in favour of this option as they argue that within Europe the sustainable management of forests is already well governed by a sufficient set of regulations and policies. Under them, adding a sustainability scheme will not improve the sustainable management within European forests, while it does add to the administrative burden for operators.

Option 3b: Risk-based approach for forest biomass

This option is similar as option 2 in terms of GHG savings and conditions for agricultural biomass.

A risk-based approach replaces land-based criteria for forest biomass, and compliance relies on existing legislation on national or sub-national level. If there is no legislation meeting the EU requirements, economic operators need to demonstrate compliance at forest holding level, through SFM certification or other equivalent evidence.

[49] In accordance with the discussion on improvements concerning the sustainability scheme for biofuels and liquids we have taken the assumption in modelling that a prioritisation of advanced biofuels is prolonged post-2020. Besides that, no further changes to the existing scheme were presumed, nor incorporated in modelling.

[50] The "restricted" scenario indicates EU wood availability under the condition of stronger utilisation restrictions and larger set aside areas. For Extra-EU solid biomass higher global competition is assumed and a lack of investments in infrastructure to mobilize alternative woody biomass.
In contrast to the "restricted" scenario the "reference" scenario assumes that EU wood availability is given under today's circumstances, and that Extra-EU solid biomass development follows a BAU trend.

To minimise the risk of use of unsustainable forest biomass for producing bioenergy, the risk-based approach shall be carried out by the operator. The risk-based approach has two levels: "national or regional level" and "forest holding level". Evidence should be gathered firstly at the national level and only if additional evidence is required than on forest holding level or certification or other third party verified schemes should be used.

Table 4-2 Sustainability criteria and their requirements and way to apply them on "low-risk" level and "other" level.

Sustainability criteria	National/regional level	Forest holding level	
		Certification	Gathering evidence
Regeneration	Legislation and assurance of compliance	Certification or other third party verified schemes	Regeneration is ensured
Protection			BMP are used
Harvesting			Permit is obtained
Following international agreements	Evidence of signatory to processes and reporting	Certification or other third party verified schemes as proxy	
Land-use, land-use change and forestry	Accounting under agreed IPCC Guidelines	Not counting towards the target or use REDD+	

MSs in favour of extending the sustainability schemes to the solid and gaseous biomass for the heat and power sector prefer this approach over SFM criteria (option 3a), mainly because of the pragmatic and cost-effective approach and the fact that it builds on existing forest management practices. Forest owners have the same position. Pulp & Paper and wood panel industries also support the option with a risk-based approach.

Option 4: Energy efficiency requirement

This option takes over the provisions of option 2 in terms of GHG and land use criteria. Moreover, a minimum efficiency standard (of 65%) for the conversion of biomass is introduced as an obligatory requirement for new (large-scale) bio-based facilities in electricity and heat supply. In practical terms, this implies a redirection of biomass use in the electricity sector towards efficient CHP production, affecting investment decisions in the years post-2020.

The non-energy forest products industry welcomes this criterion as it minimizes the amount of biomass resources needed to produce energy – it allows for a better balance with other uses for bioenergy. For this reason, also civil society organizations are in favour. It is not clear whether Public Administration have a strong preference for this option. It is the assumption from the project consortium experts, based on the responses to the public consultation, that private and public enterprises will probably not be strong supporters of this option as it limits the flexibility of using biomass for energy conversion to specific facilities. Due to high costs for biomass feedstocks and the competitive market, conversion facilities are already optimized based on conversion efficiencies.

Option 5: Stemwood cap

This option takes over the provisions of option 2 in terms of GHG and land use criteria. Moreover, restrictions are imposed on the use of stemwood for bioenergy. Wood currently used for residential heating (fuel wood) is assumed not to be affected.

This disincentive is modelled through a sharp increase of related stemwood feedstock prices of both domestic and imported supply in the years post-2020.

The non-energy forest product industry (like the pulp and wood panel industries) might be expected to support this option, as it prevents using roundwood for energy purposes and keeps this biomass resource available for their markets. Based on the responses to the public consultation it is concluded that NGOs and academic institutions also have a preference from a competition point of view but it is not clear to what extent they prefer this option to option 4 or 2. In many of the additional comments from NGOs and academic institutions it was highlighted that the cascading principle should be guiding in the use of biomass for various energy and non-energy end applications. Under information received from EC representatives, NGOs have indicated to the EC that they are in favour of restricting the use of stemwood for bioenergy.

5 Analysis of the impacts of the options for EU action

This section presents the assessment of the environmental, economic and social impacts of the different options for EU action defined in the previous chapter, under the following main effects (when relevant for the concerned policy option):

- Economic impacts: impacts on overall investment and operational costs of achieving the at least 27% target, impacts on non-energy sectors, impact on support expenditures/ households energy costs, impact on gross value added, impact on third countries and impact on administrative costs for economic operators and public administrations;
- Environmental impacts: greenhouse gas savings, impacts on land use change and biodiversity;
- Social impacts: impact on total employment and employment in SMEs.

Box 5 The implications of modelling installations with a capacity above 5 MW only

One constraint in the quantitative assessment of the Green-X model is that only two categories could be applied for distinguishing bioenergy plants according to size. As default, Green-X uses a threshold of 5 MW thermal capacity to distinguish between large (i.e. above 5 MW) and small-scale biomass plants (i.e. below or equal to 5 MW). A further sub classification, e.g. a separate category for plants above 20 MW, was not feasible to add due to time constraints.

In the assessment of policy options the assumption is taken that, as default, only large-scale plants are affected by certain sustainability requirements whereas small actors are excluded. However, the Green-X distinction is different from the preferred policy design in the current debate at European level where only plants above 20 MW (and not 5 MW as used in Green-X) would be affected. As a consequence, Green-X modelling overestimates the impacts of applying sustainability regulations since in modelling a larger proportion of the market is affected by the regulation.

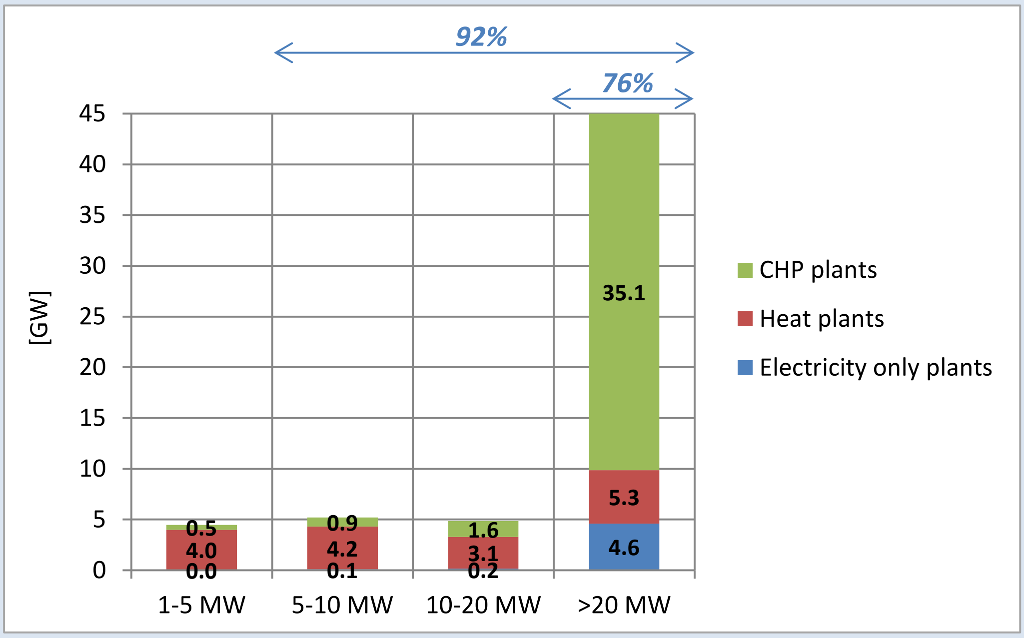
To clarify on the implications arising from that it is important to take a closer look at the current stock of bioenergy facilities in Europe, and on how this might evolve in future. Here a recent assessment of bioenergy plants consuming wood chips provides further insights. In the IEE project Basis Bioenergy[51] 4079 bioenergy plants have been recently (as of 2016) identified in the EU28. The survey was limited to plants consuming wood chips that have total capacity equal or above 1 MW. Figure 5-1 illustrates the outcomes of that assessment, showing a breakdown of the total installed capacity by size category and type of plant. As indicated in that graph, 92% of the total installed capacity falls under the Green-X category "plants larger than 5 MW" whereas 76% of total installed capacity can be detached to large-scale bioenergy plants with a capacity above 20 MW. 16% of installed capacity is in the range between 5 and 20 MW. However, one needs to take into consideration that, firstly, the conducted market survey was limited to wood chip consumers and, secondly, it considered only plants larger than 1 MW. Today a large amount of wood chips is also consumed in small-scale bioenergy plants with a capacity below 1 MW. These types of plants are not included in that survey.

Power and CHP plants relying to a large extent on imported pellets, are mostly affected by sustainability regulations. These include mainly full conversion of fossil power plants to biomass and biomass co-firing in northwest Europe (Belgium, Denmark, the Netherlands, UK). These are dominated by plants with an installed capacity well above 20MW with an estimated total biomass input capacity of 6.5 GW in 2015 increasing to 17 GW by 2020, and only a marginal share in the category between 5 and 20MW. However, the future of these biomass projects is highly uncertain, especially beyond 2020. These projects are highly dependent on support schemes and most granted support ends well before 2030. Furthermore, these power

[51] www.basisbioenergy.eu

plants already need to comply with sustainability criteria, either mandatory (Belgium, Netherlands, UK) or voluntary via an industry agreement (Denmark).

Figure 5-1 Breakdown of total installed capacity of bioenergy plants in the EU28 consuming wood chips by size categories and type of plant (Source: AEBIOM – Basis Bioenergy project)



Taking a look at expected market developments post 2020 Green-X modelling points out that under a "least cost" resource allocation the market share of plants above 20 MW would further increase due to their stronger viability compared to smaller scale bioenergy plants. In contrast to above, only a small portion of the market would then be in the category between 5 and 20 MW.

Summing up, in the assessment of policy options the assumption is taken that, as default, only large-scale plants are affected by certain sustainability requirements whereas small actors are excluded. A different threshold is however used in Green-X modelling than compared to the preferred policy design to distinguish between small- and large-scale bioenergy plants: Green-X classifies all plants above 5 MW as large-scale whereas the preferred policy design uses a 20 MW threshold. As a consequence, Green-X modelling overestimates the impacts of applying sustainability regulations since in modelling a larger proportion of the market is affected by the regulation. The assessment of the current stock of bioenergy facilities indicates that this difference is in range of 16%. With increasing competition between the various bioenergy and renewable energy technologies it can however be expected that bioenergy plants above 20 MW would benefit and consequently increase market penetration.

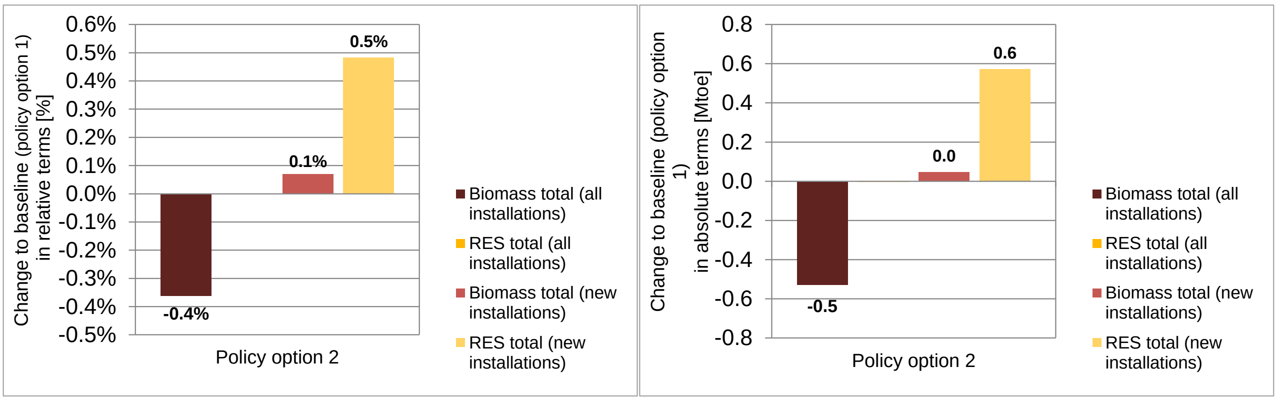
One can conclude that the difference in terms of market coverage between modelled and currently preferred diminishes further, and that, consequently, the overestimation of impacts done in Green-X modelling is small.

5.1 Policy option 2 - EU biomass criteria for heat and power

5.1.1 Bioenergy supply and demand

Policy option 2 – more precisely, considering the default design of sustainability measures (i.e. applied to all large-scale installations, and prescribing a GHG threshold of 70% net reduction) – has only minor impacts on biomass demand and supply. This is shown in Table 5-1, offering a breakdown of the demand for bioenergy and other RES by 2030 at sectoral level, as well as in Figure 5-2, showing the change of bioenergy demand and of overall RES demand compared to policy option 1. The corresponding overview on the supply of bioenergy is provided by Table 5-2 whereas trade aspects are discussed in a subsequent section.

Figure 5-2 Change in demand for bioenergy and RES total by 2030 compared to baseline (policy option 1) under policy option 2 (EU biomass criteria for heat and power – default design), in relative (left) and in absolute terms (right)



Remark: "New installations" means all plants installed post-2020

Total biomass demand in terms of final energy decreases by 0.4% compared to default (policy option 1), and corresponding (feedstock) supply declines by 0.5%. This indicates generally that solid and gaseous biomass used for energy purposes can cope well with a GHG threshold of (at least) 70% net avoidance. A close consideration at demand and supply by sector shows however, some rededication of biomass supply and use. Whereas in the electricity sector biogas, specifically anaerobic digestion, is reduced by about 5% compared to default (policy option 1), advanced waste-based biofuels experience an uptake by more than 2%. Thus, here the phase-out of non-compatible technology-feedstock combinations (like certain anaerobic digestion plants) increases the viability of other biomass technology-feedstock combinations as well as of other RES under the underlying "least-cost" approach used in modelling, leading for example to an increase use of advanced lignocellulosic options in the transport sector. Impacts on all other biomass technologies are comparatively small (i.e. a change in use is below 1%).

Table 5-1 Breakdown of demand for bioenergy and other RES by 2030 under policy option 2 (EU biomass criteria for heat and power – default design)

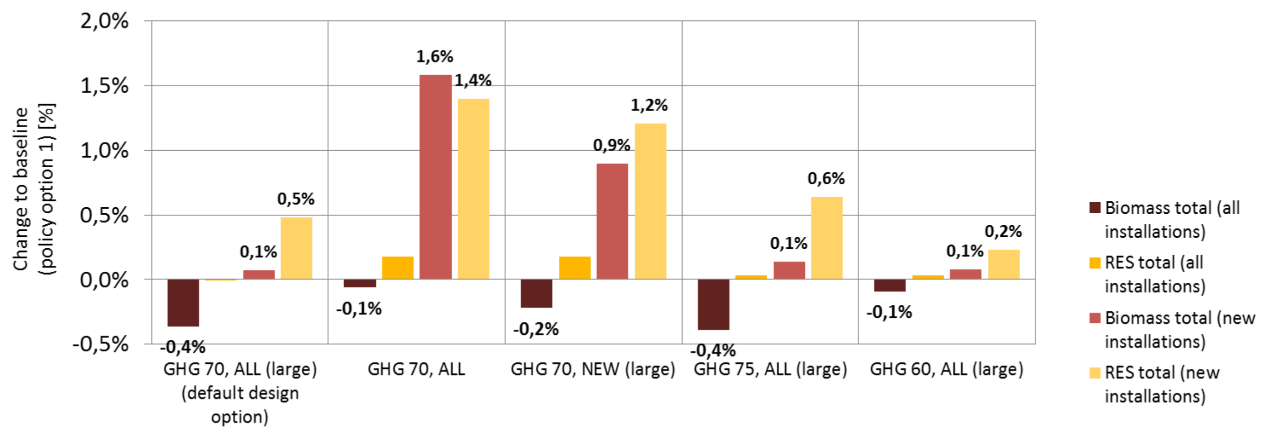
Demand for bioenergy and other RES in terms of final energy (electricity and heat generation, transport fuels) **by 2030**	**Policy option 2**	*Change to baseline (policy option 1)*	
	[Mtoe]	*[Mtoe]*	*[%]*
Electricity sector			
Biogas	5.2	*-0.3*	*-5.2%*
Solid biomass (incl. bioliquids)	15.7	*0.0*	*0.3%*
Biowaste	2.8	*0.0*	*0.0%*
Total bio-electricity	**23.7**	***-0.2***	***-1.0%***
Other RES-electricity	121.9	*0.5*	*0.4%*
Total RES-electricity	**145.6**	***0.2***	***0.2%***
Heat sector			
Derived heat from biomass (CHP, district heat)	30.3	*0.0*	*-0.1%*
Direct use of biomass	73.3	*-0.2*	*-0.2%*
Total bio-heat	**103.6**	***-0.2***	***-0.2%***
Other RES-heat	23.0	*0.0*	*0.2%*
Total RES-heat	**126.7**	***-0.2***	***-0.1%***
Transport sector			
Food-based biofuels (1G)	12.4	*-0.2*	*-1.8%*
Waste-based biofuels (advanced biofuels)	6.3	*0.1*	*2.3%*
Total biofuels	**18.7**	***-0.1***	***-0.4%***
Summary			
Total biomass	**146.0**	***-0.5***	***-0.4%***
Other RES	145.0	*0.5*	*0.4%*
Total RES	**290.9**	***0.0***	***0.0%***

Table 5-2 Biomass supply by 2030 under policy option 2 (EU biomass criteria for heat and power – default design)

Bioenergy supply by 2030	**Policy option 2**	*Change to baseline (policy option 1)*	
	[Mtoe]	*[Mtoe]*	*[%-change]*
Domestic supply			
Agriculture	53.9	*0.2*	*0.4%*
Forestry	102.7	*-0.2*	*-0.2%*
Waste	22.0	*-1.0*	*-4.5%*
Total domestic biomass	**178.6**	***-1.0***	***-0.6%***
Extra-EU imports			
Solid biomass	10.7	*0.2*	*2.1%*
Biofuels	5.2	*-0.2*	*-3.8%*
Total Extra-EU biomass imports	**15.9**	***0.0***	***0.1%***
Summary			
Total biomass	**194.5**	***-1.0***	***-0.5%***

Considering biomass supply, a negligible decline of forestry biomass (by 0.2%) can be observed, a small increased use of agricultural biomass, increasing by 0.4% compared to default (policy option 1), and, most significant in terms of effects, a decline of waste supply by 4.5%. This goes hand in hand with the reduction of biogas from anaerobic co-digestion used for CHP due to the stricter environmental regulation, where manure and use of crops (i.e. maize) are also serving as feedstock.

Figure 5-3 Sensitivity assessment of alternative design options: Change in demand for bioenergy and RES total by 2030 compared to baseline (policy option 1) under all assessed design variants of policy option 2 (EU biomass criteria for heat and power – default design), expressed in relative terms



Remark: "New installations" means all plants installed post-2020

Figure 5-3 (above) illustrates the detailed design of EU-wide harmonised sustainability measures and related impacts. More precisely, this graph indicates the change in bioenergy and total RES demand for all analysed design options concerning policy option 2. The following observations appear of relevance:

- In particular, a smaller impact on bioenergy demand (and supply) can be expected if all market participants (except direct use in households) are included in the regulation, i.e. not only large-scale facilities (above 4-5 MW fuel capacity) in electricity, heat and CHP supply as presumed under default design. Here a smaller decline by 0.1% (compared to option 1) instead of 0.4% under default design can be seen, thanks to an increased penetration of new bioenergy installations concerning the direct use in households and tertiary because of improved viability compared to (grid-connected) derived heat supply.
- An increase of the GHG threshold to 75% (required net saving) would hardly lead to stronger effects and changes in biomass and RES allocation whereas a decline of the threshold to 60% would diminish impacts, causing very negligible changes (i.e. below 0.1%) in biomass demand and supply.
- The limitation of a new sustainability regulation for bioenergy to only new plants that will be installed in the years to come (post-2020) cuts the change in EU-wide bioenergy demand to half. On the contrary, such a design variant does more proactively affect future investment decisions in biomass and other RES.

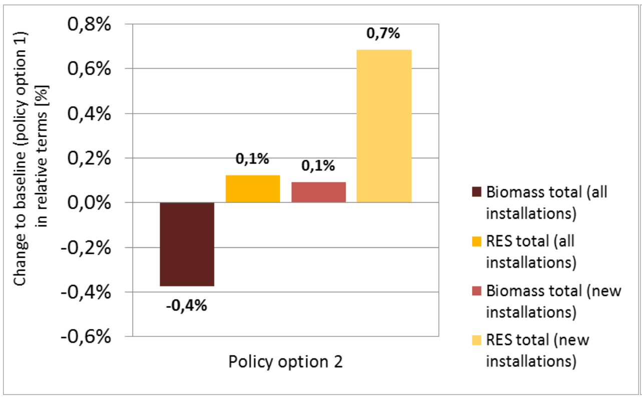
5.1.2 Environmental impacts

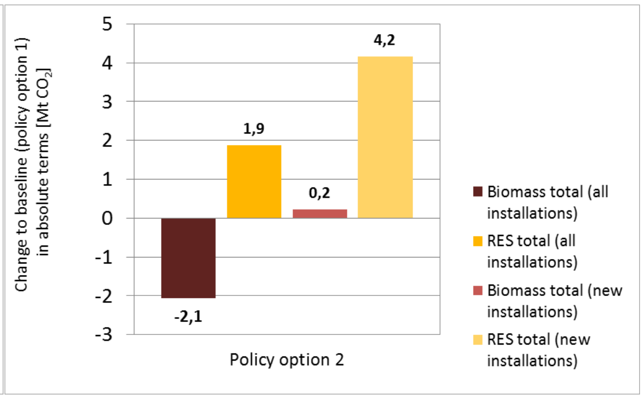
The assessment of environmental impacts is limited to implications on GHG emission savings, biodiversity impacts and land use change. With respect to GHG savings, the assessment covers the direct impact on biomass-related GHG emission avoidance as well as the overall impact for RES.

Supply chain GHG emission savings

Figure 5-4 summarises the outcomes of the assessment related to the GHG performance of biomass and other RES under policy option 2, indicating the change of net supply chain GHG emission savings for biomass and RES total compared to policy option 1. This overview includes a balance of GHG performance for new installations (post-2020) and for all installations, including also the bulk of biomass, hydro and wind plants that have been installed in the years before a new EU-wide sustainability regulation is presumed entering into force. Whereas biomass-related GHG savings generally coincide with bioenergy deployment, the most decisive figure is the balance made for RES total considering all RES installations. This figure shows the overall impacts, and, in contrast to the balance made for new RES installations, it incorporates also the phase-out of existing installations and the corresponding decline of GHG emission avoidance that come along with the GHG performance requirement.

Figure 5-4 Change in net (supply chain) GHG emission savings due to bioenergy and RES by 2030 compared to baseline (policy option 1) under policy option 2 (EU biomass criteria for heat and power – default design), in relative (left) and in absolute terms (right)

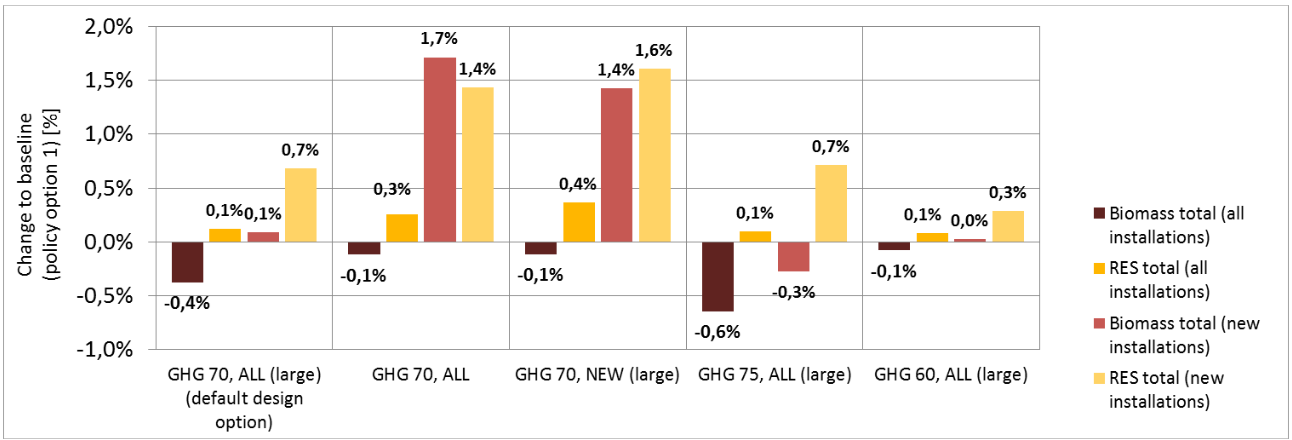




Remark: "New installations" means all plants installed post-2020

Results show that policy option 2 (considering the default design of the sustainability regulation) hardly deviates from policy option 1 in terms of overall impacts on GHG performance. Only a small increase in GHG emission savings is apparent (+1.9 Mt CO2 by 2030), caused by the reduction of biomass demand, and, in turn, the increased use of other RES, specifically in the electricity sector where specific gross GHG avoidance (i.e. per unit of fossil electricity substituted) is highest among all sectors.

Figure 5-5 Change in net (supply chain) GHG emission savings due to bioenergy and RES by 2030 compared to baseline (policy option 1) under all assessed design variants of policy option 2 (EU biomass criteria for heat and power – default design), expressed in relative terms



Remark: "New installations" means all plants installed post-2020

Regarding the impacts on GHG performance arising from alternative designs of the EU-wide harmonised sustainability measures, Figure 5-5 (above) shows the change in GHG emissions savings due to bioenergy and total RES by 2030 considering all analysed design options of policy option 2. Key results are:

- A stronger positive impact on the GHG performance can be expected if all market participants are covered by the sustainability scheme, i.e. not only large-scale facilities (above 4-5 MW fuel capacity) in electricity and CHP production as assumed under default design. Thus, higher GHG savings can be achieved by 2030 – i.e. +0.3% instead of +0.1%

for RES total considering all installations. This is a consequence of the stronger deployment of new environmentally well performing bioenergy facilities with improved GHG performance of these systems.

- An increase of the GHG threshold to 75% (required net saving) would not lead to stronger GHG savings than under default design, since also bioenergy demand and supply remains hardly more affected. Contrarily, a reduction of the threshold to 60% would further diminish impacts, and hardly cause changes in GHG performance compared to baseline (policy option 1).
- The inclusion of only new facilities (installed post-2020) in a sustainability regulation for bioenergy indicates a positive impact on the GHG performance. The stronger deployment of new environmentally well performing bioenergy facilities improves the GHG performance of these systems, which, in turn, positively affects the overall GHG performance, increasing by +0.4% for RES total instead of +0.1% under default design.

Impacts on land use and biodiversity

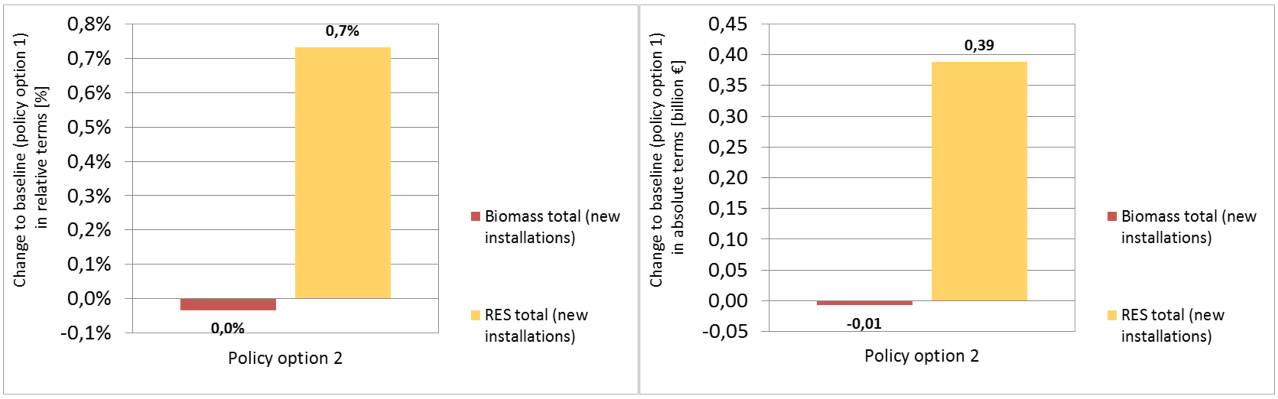
Under policy option 2, land use criteria are extended to sectors that already make use of energy crops, but to which these criteria do not apply in policy option 1. Most importantly, this includes dedicated crop cultivation for anaerobic co-digestion. Although land use for energy crop cultivation in policy option 2 is similar to policy option 1, the applied criteria could lead to net positive impacts on land use and biodiversity that cannot be observed from the model results because land supply is predefined in this study.

5.1.3 Economic impacts

Impact on capital (CAPEX) and operating expenditures (OPEX) for RES technology sectors

Generally, capital expenditures (CAPEX) characterise the amount of required investments in RES technologies. Apparently, as shown in Figure 5-6, there is hardly any impact on CAPEX for bioenergy in the years post-2020, and only a comparatively small impact on investments in RES total – i.e. an increase by 0.7%, corresponding to 0.39 billion €/year on average in the period 2021-2030 – can be expected. This small increase for RES total is because of the stronger penetration of wind and solar in the electricity sector to compensate the reduced contribution of existing biomass installations (as a consequence of the newly introduced GHG regulation).

Figure 5-6 Change in average (2021-2030) annual capital expenditures for new biomass and RES installations compared to baseline (policy option 1) under <u>policy option 2</u> (EU biomass criteria for heat and power – default design), in relative and in absolute terms



Remark: "New installations" means all plants installed post-2020

When comparing operating expenditures (OPEX) only for new (post-2020) RES installations, a similar tendency as for CAPEX can be identified. Relative changes of OPEX in comparison to option 1 are nevertheless smaller on average. If in addition to new (post-2020) also existing RES installations are taken into consideration, a change of sign is becoming apparent: A 0.08% decline in OPEX can be seen concerning total RES when looking at average impacts in the forthcoming decade (2021-2030), whereas biomass total exhibits a decrease of nearly 0.15%.

Under a combined consideration of both CAPEX and OPEX the increase in CAPEX clearly outweighs the decline of OPEX for RES total – i.e. an increase by 0.31 billion € on average per year throughout the period 2021-2030 can be identified. Contrarily, in the case of bioenergy OPEX are of dominance, and the combined consideration of CAPEX+OPEX indicates a decline by -0.12 billion € on average (2021-2030) per year.

Figure 5-7 Change in average (2021-2030) annual operating expenditures for all biomass and RES installations compared to baseline (policy option 1) under policy option 2 (EU biomass criteria for heat and power – default design)

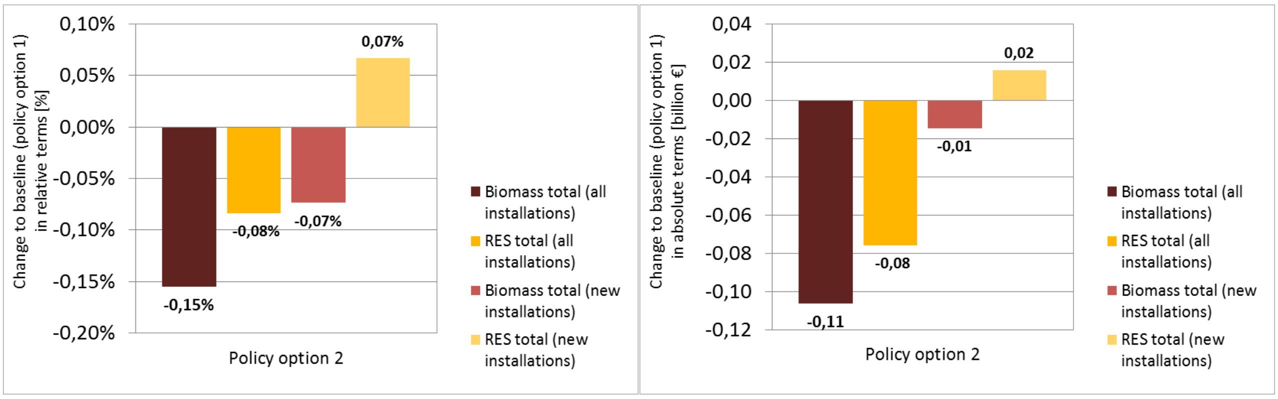
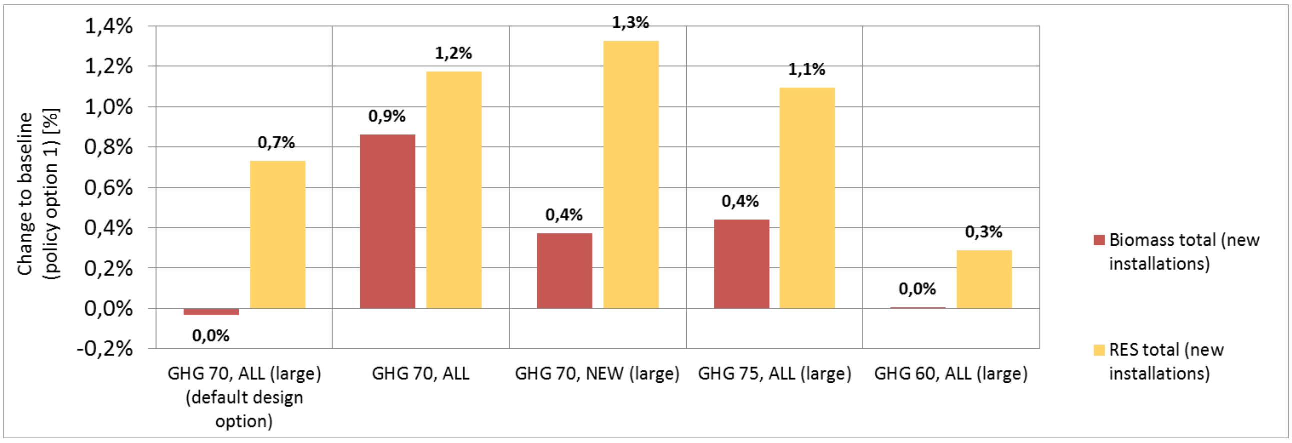


Figure 5-8 Change in average (2021-2030) annual capital expenditures for new biomass and RES installations compared to baseline (policy option 1) under all assessed design variants of policy option 2 (EU biomass criteria for heat and power – default design), expressed in relative terms



Remark: "New installations" means all plants installed post-2020

Alternative designs of the EU-wide harmonised sustainability measures are taken into consideration in a sensitivity analysis. Figure 5-8 shows exemplarily the change in CAPEX for bioenergy and total RES on average in the period 2021-2030 considering all analysed design options of policy option 2. A list of key findings includes:

- In accordance with the changes concerning new installations, strong impacts on CAPEX can be expected if all market participants are covered by the sustainability scheme. Thus, CAPEX for total RES increase by 1.2% instead of 0.7% whereas investments in bioenergy increase by 0.9% compared to no change under default design. As discussed above, this is caused by the shift in biomass supply and demand towards direct use in households and tertiary.

- The coverage of only new facilities (installed post-2020) in a sustainability regulation for bioenergy leads to a stronger demand for new RES installations, and, consequently, to an increase of related CAPEX (i.e. by 1.3% compared to 0.7% under default design).
- A higher GHG threshold (i.e. 75% required net saving) leads also to stronger impacts compared to default. Investments in new RES increase here by 1.1% on average in the forthcoming decade. Contrarily, a reduced GHG threshold of 60% would further diminish impacts, and hardly cause changes in investments compared to baseline (policy option 1).

Impact on non-energy sectors

In the case of forestry, the Reference scenario is assumed for the utilisation of forest resources.

From an economic point, further restrictions will mainly affect the use of forest residues in CHP. About 14% of the biomass used for energy in CHP (2010) comes from forest residues (Vis, Mantau, Allen 2016). Even if only for a few countries the distribution of raw material mixes is known and data are subject to uncertain assumptions, it can be assumed that the availability of woody biomass for energy use will be significantly affected. The largest proportions of unused woody biomass potential are forest residues. As a result, demand will focus more on post-consumer wood. However, that is already largely used. Even if waste policy becomes very successful in mobilising post-consumer wood, the potential to fill the gap will still be limited. Landscape care wood and short rotation plantations are as well resources, which have to be mobilised.

The social (employment) impacts are limited as long as the restrictions apply only to CHP, because forest residues are only part of the CHP resource mix and households are larger consumers (60%) of total biomass used for energy (Vis, Mantau, Allen 2016). The far larger impact would come from a ban on residues for the firewood use in private households. However, if stemwood would be used to a larger extend for material uses the overall employment effect will be positive.

In case the use of forest residues is restricted, the relative competitiveness of waste (post-consumer wood) will possibly increase, but the possibilities in volume and quality cannot compensate a relevant decline of primary wood. The EU28 uses approximately 450 Mm^3 of forest biomass. Around 36 Mm^3 post-consumer wood is recovered, of which 16 Mm^3 is recycled. The actual potential is estimated at 52 Mm^3. If the EU is able to organise the recovery perfectly it may increase to 80 Mm^3, but this would require substantial policy action (Vis, Mantau, Allen 2016). Post-consumer wood is part of the overall supply of biomass but the market is small and the possibilities to improve are limited.

Some countries are developing their own national systems on sustainability of solid and gaseous biomass. These requirements may differ by country and create trade barriers. In principle, export countries could redirect their export to countries with low restrictions for biomass. However, it is mostly the countries largely relying on imports that impose sustainability requirements. It results to be a barrier for economic operators if these requirements differ by country, mainly to demonstrate compliance (with various auditing and verification procedures).

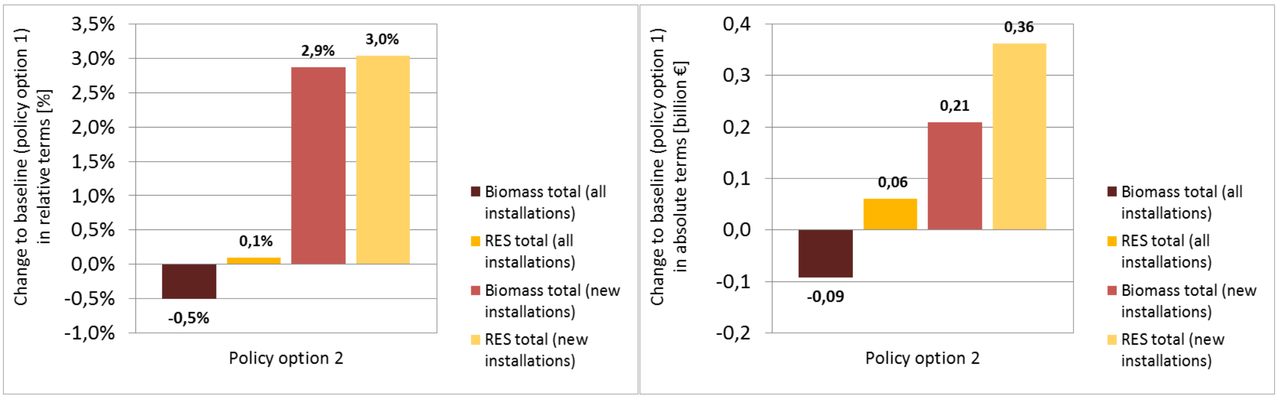
Different requirements also hinder trade between MSs; a uniform system at EU level would remove such trade distortions.

Regarding impact on waste, a reduced access to primary forest material may direct more focus to waste as input for bioenergy. This may induce some pressure on waste markets, with its own recycling targets (e.g. for wood waste), but it may also trigger a more effective waste management, e.g. in terms of stimulating separate collection of specific waste fractions, or a faster diversion from landfill.

Impact on support expenditures

Another indicator for the impacts of the different policy options is the support expenditure[52] for biomass and for RES in total. RES-related support expenditures describing the direct financial impact of RES support, while indirect costs or benefits are ignored (such as environmental benefits, change of employment), appear generally sensitive to changes in regulation. Looking into the comparison for RES total, it is possible to observe slight increases by around 3% on average for the assessed period between 2021 and 2030 (policy option 2) when new RES installations are taken into consideration. Dedicated financial support for biomass exhibits also substantial changes: for new installations they are in same order as for total RES – i.e. a consequence of the underlying least-cost policy approach as presumed for all RES post-2020 and the corresponding uniform incentives. When looking at all installations (i.e. existing and newly installed post-2020) changes in biomass-related support go hand in hand with changes in biomass use, meaning a decline of support by 0.5% or o.09 billion € on average per year. Surprisingly, for RES total considering all installations hardly any change is applicable: support expenditures increase by 0.1% or 0.06 billion € on average per year, a negligible number that is the combined result of the increase of support for new RES and the decline of support for existing bioenergy installations (due to their phase-out).

Figure 5-9 Change in average (2021-2030) annual support expenditures for biomass and RES compared to baseline (policy option 1) under <u>policy option 2</u> (EU biomass criteria for heat and power – default design)



Remark: "New installations" means all plants installed post-2020

The outcomes of the sensitivity analysis on alternative designs of the EU-wide harmonised sustainability measures are discussed. Figure 5-10 presents the change in support expenditures for bioenergy and total RES on average in the period 2021-2030 considering all analysed design options of policy option 2. Key results gained from this graph include:

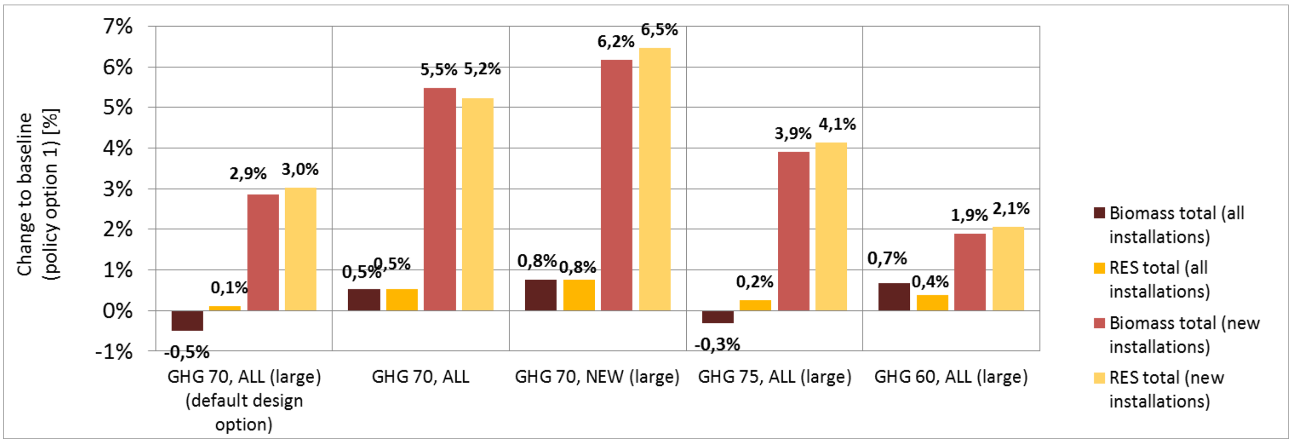
- Similar to above, strong impacts on support costs can be seen if all market participants (except households) are covered by the sustainability scheme. Support expenditures for all new RES installations post-2020 would then increase by 5.2% compared to 3.0% under default design. The decline in bioenergy demand for grid-connected supply comes along with increases in cost – since new bioenergy installations for direct use as well as

[52] Support expenditures, that is the transfer costs for consumers (society) due to RES support, are defined as the financial transfer payments from the consumer to the RES producer, compared to the (reference) case of consumers purchasing conventional energy. Thus, support expenditures describe the direct financial impact of RES support, while indirect costs or benefits are ignored (such as environmental benefits, change of employment).

alternative other RES options come at higher cost and, consequently, require higher support.

- The coverage of only new facilities (installed post-2020) in a sustainability regulation for bioenergy leads to impacts of similar magnitude compared to above: support expenditures increase by 6.5% on average.
- The impact on support expenditures of introducing a higher GHG threshold (i.e. 75% required net saving) is comparatively small: expenditures for new RES increase by 4.1% compared to 3.0% under default design (70% GHG threshold). In turn, a lower GHG threshold causes lower changes but also comes along with almost no environmental benefits as discussed in the previous section.

Figure 5-10 Change in average (2021-2030) annual support expenditures for biomass and RES compared to baseline (policy option 1) under all assessed design variants of policy option 2 (EU biomass criteria for heat and power – default design), expressed in relative terms



Remark: "New installations" means all plants installed post-2020

It is assumed that support expenditures are entirely passed on to households, thus leading to a decrease of real purchasing power of households.

Impact on gross value added

The following results for option 2 refer to the main variant of the above mentioned variants, namely the option with a 70% threshold on GHG emissions used for all large bioenergy installations (above 4–5 MW). The economic impacts are triggered by the changes in RES deployment expenditures and in support expenditures, as compared to policy option 1. Under policy option 2 these only change marginally. Consequently, value added increases by €330mln (cf. Table 5-3). This equals 0.003% of total GDP of EU28 in 2030 under the PRIMES reference scenario.

The total impact is the sum of three partial effects (cf. Table 5-3):

1. the deployment effect caused by the change of investment, O&M and fuel expenditures, that increases value added by €270mln. The increase results from a decrease in bioenergy deployment and an overcompensating increase due to stronger deployment of other RES technologies;
2. the income effect induced by the change in employment and income, increasing value added by €100mln;
3. the budget effect triggered by the change of support expenditures, that leads to a decrease of value added by €40mln.

Table 5-3 Impacts of policy option 2 (EU biomass criteria for heat and power – default design) on gross value added in the EU 28, annual average 2021 – 2030

RES technology segment	Deployment effect €mln	Income effect €mln	Budget effect €mln	Total impact €mln
Absolute deviation from policy option 1				
Bioenergy deployment	-140			
Other RES deployment	410			
Total	**270**	**100**	**-40**	**330**
in % of EU28 total				0.003%

Source: calculation by Rütter Soceco

Impact on third countries

The implied chain of custody costs in policy option 2 are relatively small compared to the cost of imported wood pellets. The largest impact is observed when a GHG threshold of 70% is applied to all installations. Total import of solid biomass (pellets) is then increasing slightly (0.6% instead of 0.1% under default design) whereas Intra-EU trade of domestic feedstock increases by 2.4% (compared to a decline under default design). The applied GHG threshold of 70% to all installations has a larger impact to imported biofuels from third countries. Import of biofuels is 19% smaller compared to the baseline option 1. When GHG criteria are applied to large installations only, the impact to trade is smaller for solid biomass and negligible for import of liquid biofuels.

Table 5-4 Biomass feedstock trade by 2030 under all assessed design variants of policy option 2 (EU biomass criteria for heat and power – default design)

Overview on bioenergy trade: Intra-EU trade and Extra-EU imports	Case:	**Policy option 2, GHG 70, ALL (large) (default design option)**	**Policy option 2, GHG 70, ALL**	**Policy option 2, GHG 70, NEW (large)**	**Policy option 2, GHG 75, ALL (large)**	**Policy option 2, GHG 60, ALL (large)**
Bioenergy trade						
Domestic bioenergy:						
Agriculture total	Mtoe	3.5	3.6	3.5	3.5	3.5
Forestry total	Mtoe	8.1	8.5	8.3	8.5	8.2
Waste total	Mtoe	0.0	0.0	0.0	0.0	0.0
Domestic Bioenergy total	Mtoe	11.6	12.1	11.8	11.9	11.7
Change to baseline (PO1)		*-1.4%*	*2.4%*	*0.3%*	*1.3%*	*-1.0%*
Extra-EU imports (solid biomass)	Mtoe	10.7	10.8	10.5	10.7	10.6
Extra-EU imports (biofuels)	Mtoe	5.2	5.2	5.3	5.4	5.2
Extra-EU imports total	Mtoe	15.9	16.0	15.9	16.0	15.8
Change to baseline (PO1)		*0.1%*	*0.6%*	*-0.1%*	*1.0%*	*-0.2%*
Bioenergy total	**Mtoe**	**27.5**	**28.0**	**27.7**	**28.0**	**27.5**
Change to baseline (PO1)		*-0.6%*	*1.4%*	*0.1%*	*1.1%*	*-0.6%*

Impact on administrative costs

Policy option 2 is an extended version of the current RED EU sustainability criteria for biofuels and additionally covers solid biomass for heat and power sector, with variation in the GHG threshold levels in all sectors. Therefore, this option implies that sustainability criteria for biofuels will be continued (as in Baseline scenario – option 1), but that these will also be extended to solid biomass and biogas for heat and power production.

Steps 1 & 4: Identification and classification of information obligations and identification of target groups

In policy option 2, apart from the economic operators already involved in Baseline scenario – option 1, three extra private market participants need to comply with the land criteria, which are:

- Solid biomass producers from agriculture
- Forest owners
- Owners of heat and power bioenergy plants (above 4 MW)

Main legal obligations imposed by the RED to economic operators and Public Administration are the same as in the Baseline scenario – policy option 1.

Steps 2, 5, & 6: Identification of required actions, the frequency of required actions and relevant cost parameters

The required actions of economic operators remain the same, but as mentioned in Steps 1 & 4, more economic operators need to get a certification.
The main difference in policy option 2 is that there is a new obligation for Public Administration of MS's, thus, an extension of the sustainability criteria to solid biomass and bioenergy plants includes actions of Public Administration related with the transposition of new European normative. MS's need to develop of a new legal structure adapted to an extended version of RED EU criteria (one-off costs). Recurring actions of monitoring, verification and reporting activities remain the same, but considering the larger number of private operators involved, the monitoring and verification costs will increase.

New actions of Public Administration in policy option 2 (transposition of law, one off costs):

- Obtaining the new legislation and regulation
- Examining the new legislation and regulation
- Consulting the stakeholders
- Preparation and filing the document
- Communicating the effects of changes to legislation and regulations with the market participants

Steps 7 & 8: Choice of data sources to calculate the number of entities concerned in Policy Option 2 and assessment of the number of entities concerned

- Estimation of the number of solid biomass from agriculture producers

To estimate the number of solid biomass from agriculture producers official statistics about area used for energy crop production[53] and production of renewable energy from agriculture in 2005[54] were used to undertake the estimation.

[53] Biofuels in the European Union: An Agricultural Perspective (EC factsheet)
[54] Available at http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_renewable_energy_production

Considering that the area used for energy crop production in EU28 was 2,800,000 hectares and the production of renewable energy from agriculture was 4,132,000 toe in 2005, it is estimated that the number of farm groups were 1,120 (with a production value of 3,689 toe per operator). It is assumed that one farm group operates 2,500 hectares of arable land.

Using these assumptions and keeping the same productivity in toe, it is estimated that there will be approximately 9,133 farm groups producers of solid biomass from agriculture[55]. For the estimation was taken into account the production of solid biomass from agriculture projected for 2030 estimated by the Green-X model.

- Estimation of the number of forest owners

Taking into account its big size, usually a forest is certified as a single entity (composed of several landowners, who own parts of the forest and aggregate to share certifications costs in order to reach lower costs). Thus, in this study the administrative costs for forests were considered as entities (managed by a single forest owner) and not the administrative costs for the single landowners.

In order to estimate the number of forest owners, data regarding forests certified by FSC and PEFC schemes in 2009 was considered as a basis[56]. In the EU, in 2009, there were 481 forest entities (each composed on average by a group of 800 landowners) certified with the FSC/PEFC schemes for a total area of 72.8 Mha (corresponding to 36.7 Mtoe). From these figures, it can be estimated that a forest entity, on average, has a size of 0.15 Mha and produces 0.076 Mtoe. Considering these assumptions and taking in account the production of forest biomass estimated by the Green-X model for option 2 (110.8 Mtoe) the corresponding number of forests entities is estimated at 1,452, which would be equivalent to around 1.2 million forest owners[57].

- Estimation of the number of bioenergy plants for heat and power

For the estimation of the number of heat and power plants data and assumptions from the EU IEE project BASIS has been considered[58]. In this database the number used is that reported for 2015, the distribution and the fuel capacity in MW of electric, heat and CHP plants that use wood chips above 1 MW in Europe. This study shows that in 2015 there were 863 electricity and CHP plants above 1 MW fed with wood chips for a total fuel capacity of 38,200 MW in the EU (approximately 22 Mtoe).

Regarding the estimation of the number of biomass plants for electricity production, in 2013, the total input of energy for electricity and CHP plants was 42 Mtoe[59] (both for plants above and below 1 MW). Excluding wood chip plants above 1 MW (assuming they consume approximately 22 Mtoe), 20 Mtoe remains as primary energy for other plants (above and below 1 MW plants: biogas, biodiesel, other liquid biofuel, municipal waste) which produce electricity. Considering several studies[60], it has been possible to define that the remaining plants above 1 MW consume some 60% of the 20 Mtoe. Considering these assumptions we estimate that for 2013 that the total number of electricity and CHP plants above 1 MW is approximately 2,260. For 2030, the Green-X model foresees a biomass consumption for electricity and CHP plants above 1 MW of 80 Mtoe; applying the assumptions set for the

[55] This figure changes slightly depending on the projections of Green-X model for each policy option
[56] Technical assistance for an evaluation of international schemes to promote biomass sustainability - Specific invitation to Tender TREN/A2/143-2007 – Dec 2009 http://iet.jrc.ec.europa.eu/remea/sites/remea/files/international_schemes_biomass_sustainability.pdf
[57] This figure changes slightly depending on the projections of Green-X model for each policy option
[58] http://www.basisbioenergy.eu/fileadmin/BASIS/D3.6_Global_Country__analysis_version2.pdf
[59] AEBIOM – Statistical Report 2015
[60] Agri for energy 2 work package 4: biogas & biomethane; Rapporto Statistico 2014 GSE

estimation of number of plants, their size and capacity in 2013, the number of electricity and CHP plants above 1 MW is estimated at 5,330 and the number of electricity and CHP above 4 MW at 4,150[61].

Regarding the estimation of biomass plants for direct heating purposes, the project BASIS indicated that in 2015 there were 2,600 wood chip plants above 1 MW with a total fuel capacity of 13,700 MW (approximately 8 Mtoe). In 2013, the total input energy for heat plants for direct use (with the exception of residential, final use services and derived heat) amounted to 28 Mtoe[62], assuming that the remaining energy (20 Mtoe) is consumed approximately by the 60-70% by plants above 1 MW, the total number of plants in 2013 above 1 MW, have been estimated at approximately 10,000.

By 2030 the Green-X Model foresees a biomass consumption for direct use in non-residential heat plants of approximately 36 Mtoe; considering the same assumptions used to estimate the plants in 2013, it was estimated that for 2030 the related number of direct heat plants above 1 MW is 18,800 and the number of direct heat power plants above 4 MW is 7,600[63] (the number of non-residential direct heat plants > 1 MW and ≤ 5 MW is considerably high 11,200).

Summing up these results, the total number of all electricity, CHP and heat power plants above 4 MW considering the results of Green-X Model for 2030, is estimated at 11,750 plants (while in 2013 there were 6,000).

Step 9: Assessment of the performance of a "normally efficient entity" in each target group

This step explains the hours spent in each identified cost parameter (step 6). The cost parameters are composed of time spent on activities to respond to the requested actions and wage tariffs (as explained in Baseline scenario – option 1).

An additional analysis of the most relevant certification schemes has been conducted for solid biomass coming from agriculture and forest (for more details refer to 'Technical Annex F: Administrative cost analysis') in order to verify and improve the quality of the assumptions considered in the present analysis which applied the Standard Cost Model. It results that external costs from the present study are in line with the certification costs estimation from the analysis carried out to estimate certification costs referred in Technical Annex F (this estimation considered fees applied by various biomass certification schemes used in Europe).

In particular, external costs in €/tonne for the certification of solid biomass from agriculture and forest result to be around €0.11 - 0.20/tonne, assessed in Technical Annex F.

Table 5-5 Time spent (hours) on activities – Economic operators - policy option 2 (EU biomass criteria for heat and power – default design)

Obligation to get and maintain the certification	Type of cost by frequency	Time spent (number of hours by entity concerned)	
		Internal	External
Producers of agriculture biomass for biofuel	One-off	70	26
	Recurring	38	12
Producers of solid biomass from agriculture	One-off	98	38
	Recurring	48	18
Forest entities	One-off	1,256	1,086
	Recurring	632	214
Bioenergy plants	One-off	64	16
	Recurring	36	10

[61] The number of end users changes slightly depending on the projections of biomass consumption from Green-X model for each policy option
[62] AEBIOM – Statistical Report 2015
[63] The number of end users changes slightly depending on the projections of biomass consumption from Green-X model for each policy option

Table 5-6 Time spent (hours) on activities – Public Administration - policy option 2 (EU biomass criteria for heat and power – default design)

Obligations for Public Administration	Type of cost by frequency	Time spent (number of hours by MS)
Transposition of laws	One-off	169
Reporting to the EC	Recurring	368
		895

Steps 10 & 11: Extrapolation of validated data to EU level and final reporting and transfer to the database

The results of the assessment of the administrative costs are shown in Table 5-7. The costs resulting from the obligations considered are presented separately for each kind of actor involved. In order to show the differences in a clear way, one-off and recurring costs are presented separately. Administrative costs of Public Administration are presented in one-off and recurring costs.

Table 5-7 Results of administrative costs – Economic operators - policy option 2 (EU biomass criteria for heat and power – default design)

Market participants	Number of market participants	One-off costs (€mln)	Recurring costs (€mln)
Producers of agriculture biomass for biofuel	7,979	24 - 45	12 - 22
Producers of solid biomass from agriculture	9,133	40 - 75	19 - 36
Forest entities	1,452	158 - 294	38 - 70
Bioenergy plants	11,782	25 - 46	15 - 28
TOTAL	30,346	354 (average)	120 (average)

Table 5-8 Results of administrative costs – Public Administration - policy option 2 (EU biomass criteria for heat and power – default design)

Public Administration	One-off costs (€mln)	Recurring costs (€mln)
TOTAL	0.06 - 0.11	0.06 - 0.83

In average, for economic operators total one-off costs are €354 million while total recurring costs are €120 million. Unlike the baseline scenario, in this policy scenario Public Administration incur in one-off costs (transposition of laws), amounted to €0.06 - 0.11 million and recurring costs between €0.06-0.83 million.

Compared with the baseline scenario, administrative costs grow considerably for policy option 2 because of the wider extension of sustainability requirements and the higher number of economic operators involved. More economic operators need certification to comply with land requirements in this case. On the other hand, Public Administration have higher one-off and recurring costs because they need to adapt the extension of land criteria to national legislation and verify more biomass and end users. Results are also presented in the graphics below (Figure 5-11 and Figure 5-12).

Figure 5-11 Total administrative costs for private operators (one-off and recurring, in average) – policy option 2 (EU biomass criteria for heat and power – default design)

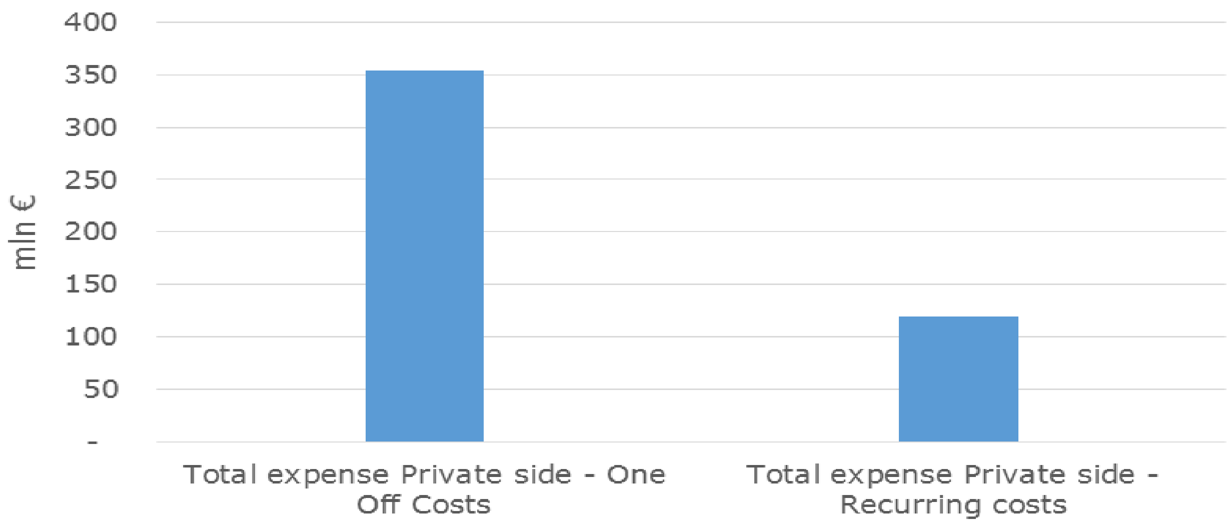
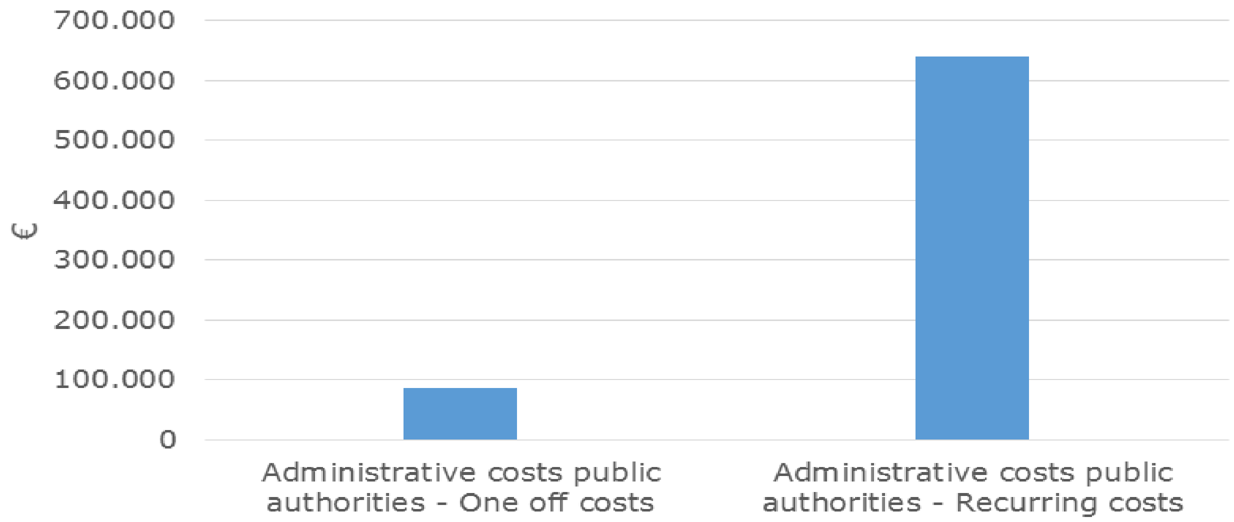


Figure 5-12 Total administrative costs for Public Administration (one-off and recurring, on average) policy option 2 (EU biomass criteria for heat and power – default design)



- **Assessment of policy option 2 considering only heat and power plants above 20 MW**

Policy option 2 implies the introduction of a specific size threshold applied to bioenergy plants. For sensitivity analysis reasons, a threshold of 20MW is considered; above this threshold, plants are obliged to follow sustainability requirements. It is assumed in this case that plants below the threshold do not need to start any procedure related to comply with sustainability criteria (i.e. through obtaining a certification) or self-declaration regarding the size of the plant.

From the administrative costs point of view, this threshold implies the addition of an extra procedure for plant operators above 20 MW to state the size of the installation. The logic behind is that likely big plants need to initiate a previous procedure to declare the size in order to receive a license or be entitled to receive green power certificates, therefore the operator has to prove compliance with the sustainability requirements.

On the public administration side, the authorities need to do an extra effort to verify and manage the declarations of the size of plant stated by operators.

Therefore, in this section an analysis was carried out of policy option 2 considering that the obligation of certification related to land criteria only applies to heat and power plants above 20 MW.

Number of heat and power plants above 20 MW

For the estimation of the number of heat and power plants above 20 MW, as described before in this section, several data and proportions have been considered. It results that in 2013 electricity and CHP power plants above 20 MW are 22% of the total number of electricity and CHP plants above 1 MW, while for heat plants above 20 MW they result to be the 2% of the total number of heat plants above 1 MW.

Considering these proportions and the total number of plants foreseen by the Green-X model for 2030 for electricity, CHP and heat above 1 MW, the total number of electricity, CHP and heat plants above 20 MW results to be approximately 1,400 plants (in 2013 they were approximately 680).

Number of economic market participants

With the exception of the obliged end users (as seen above), the number of economic market participants for this policy option remains the same than option 2 because it is assumed that all biomass produced under this option needs a certification, for logical and realistic reasons:

1- In order to keep an adequate level of sustainability, it appears unrealistic if the biomass used in plants below 20 MW does not need to be certified, consisting in a relevant amount, approximately 38 Mtoe, of biomass used in plants (>4 MW and < 20 MW) that, thought have no requirement of certification of their biomass use, remain still significant regarding sustainability topics.
2- It would be very difficult to determine and regulate the final use of products coming from different biomass origin (uncertified biomass used in bioenergy plants below 20 MW and certified biomass used for plants above 20 MW), with potential risks of market distortions.

With this reasoning, it has been considered that even biomass used by bioenergy plants below 20 MW needs to be certified. That means in practical terms that under this sub-option the number of other involved market participants (agriculture, solid and forest biomass producers) and their administrative costs remain the same with respect to the standard option 2.

Regarding the number of end users to be considered in this administrative cost assessment, as presented above, the estimation focused on the calculation of the number of bioenergy plants above 20 MW because they are the only affected by land criteria, and there are administrative costs associated to them. The rest of the end users (above 4 MW and below 20 MW), despite they still consume biomass, are not affected by land criteria and no administrative costs are associated to them.

Table 5-9 Time spent (hours) on activities – Economic operators - policy option 2 (EU biomass criteria for heat and power – default design)

Obligation to get and maintain the certification	Type of cost by frequency	Time spent (number of hours by entity concerned)	
		Internal	**External**
Producers of agriculture biomass for biofuel	One-off	70	26
	Recurring	38	12
Producers of solid biomass from agriculture	One-off	98	38
	Recurring	48	18
Forest owners	One-off	1,255	1086
	Recurring	633	214
Bioenergy plants (> 20 MW)	One-off	64	16
	Recurring	36	10

Table 5-10 Time spent (hours) on activities – Public Administration (policy option 2 (EU biomass criteria for heat and power – default design) - bioenergy plants >20MW)

Obligations for Public Administration	Type of cost by frequency	Time spent (number of hours by MS's)
Transposition of laws	One-off	169
Reporting to the EC	Recurring	368
Monitoring and verification	Recurring	651

Table 5-11 Results of administrative costs – Economic operators - policy option 2 (EU biomass criteria for heat and power – default design)

Market participants	Number of market participants	One-off costs (€mln)	Recurring costs (€mln)
Producers of agriculture biomass for biofuel	7,979	24 - 45	12 - 22
Producers of solid biomass from agriculture	9,133	40 - 75	19 - 36
Forest owners	1,452	158 - 294	38 - 70
Bioenergy plants (> 20 MW)	1,399	3 - 5	2 – 3
TOTAL	19,963	323 (average)	101 (average)

Table 5-12 Results of administrative costs – Public Administration - policy option 2 (EU biomass criteria for heat and power – default design)

Public Administration	One-off costs (€mln)	Recurring costs (€mln)
TOTAL	0.06 – 0.11	0.36 – 0.67

In this particular case, considering the obligation of certification only for bioenergy plants above 20 MW, overall costs for economic operators and Public Administration are lower than policy option 2 which consider all plants above 4 MW. In terms of percentage, for economic, operators, one-off overall costs are around 9% lower and recurring costs around 16% lower than policy option 2. For the public side, one-off remains the same but recurring costs are a 19% lower. This cost reduction is explained because of the lower number of bioenergy plants involved in this special case.

Considering just costs of bioenergy plants side (excluding the rest of economic market participants), it is interesting to see that the related one-off and the total recurring cost for policy option 2 with plants above 20MW represents 12% of the cost of all bioenergy plants involved in policy option 2. The results are also presented in the graphics below (Figure 5-13 and Figure 5-14).

Figure 5-13 Total administrative costs for private operators (one-off and recurring, average) - policy option 2 (EU biomass criteria for heat and power – default design)

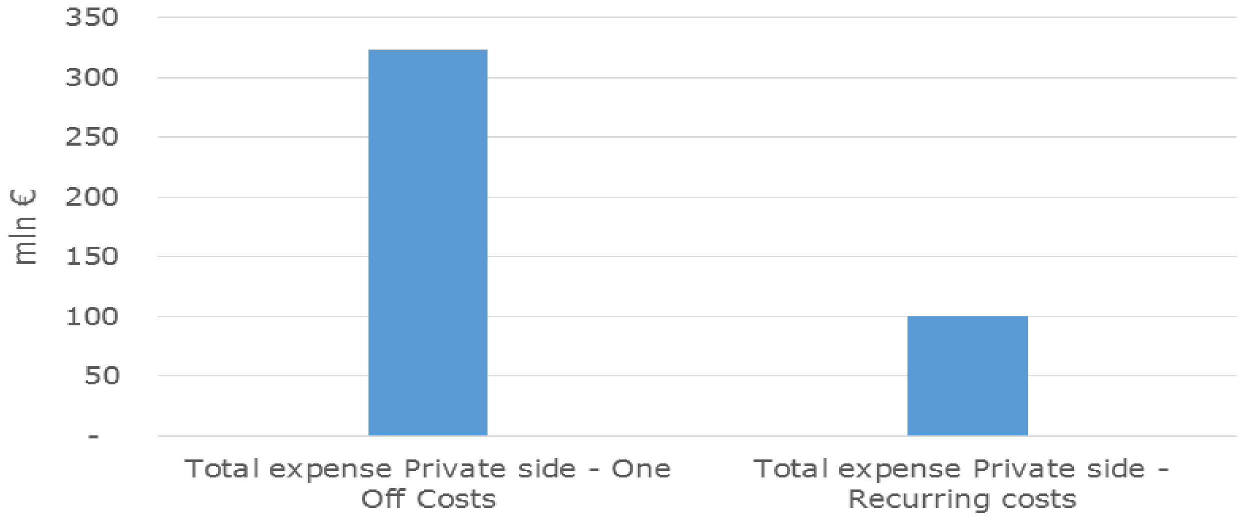
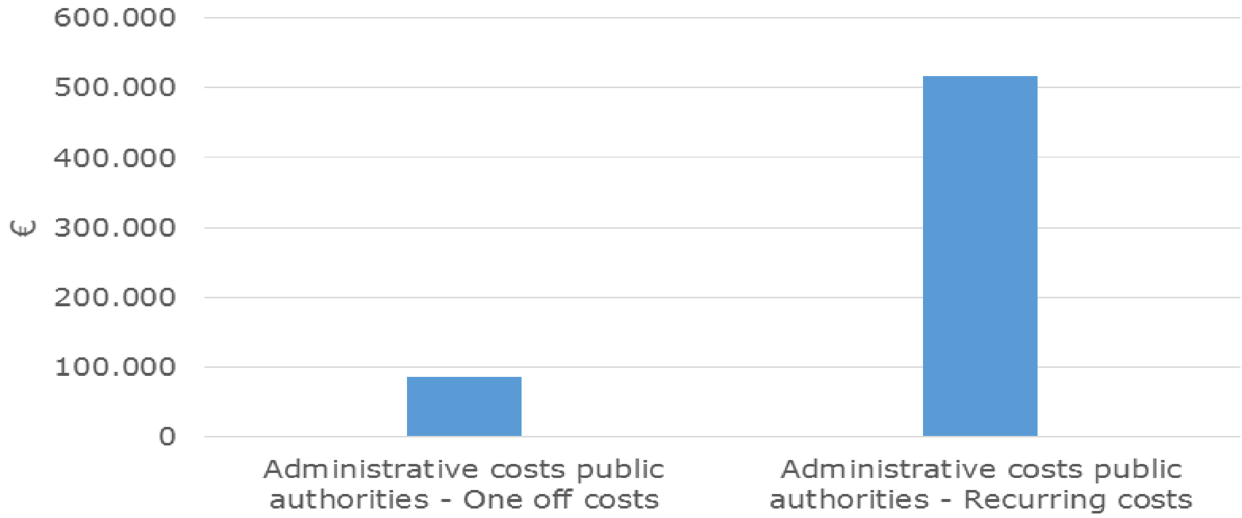


Figure 5-14 Total administrative costs for Public Administration (one-off and recurring, average) - policy option 2 (EU biomass criteria for heat and power – default design)



5.1.4 Social impact: impact on employment

Under policy option 2, employment increases by approx. 4,400 employed persons (cf. Table 5-13). The deployment effect generates 4,000 jobs with employment growth from other RES deployment clearly overcompensating job losses from reduced bioenergy deployment. The income effect is positive as well, whereas the budget effect leads to job losses. Overall, the impact on employment with a share of 0.002% of total employment in EU 28 is very low. Employment in SMEs increases by 3,500 jobs.

The results on employment are linked to the results on gross value added by the labour productivities of the economic activities involved in the value chains that are triggered by RES deployment and policy support expenditures. The labour productivities differ with regard to technologies, industries and countries and the modelling results reflect these differences.

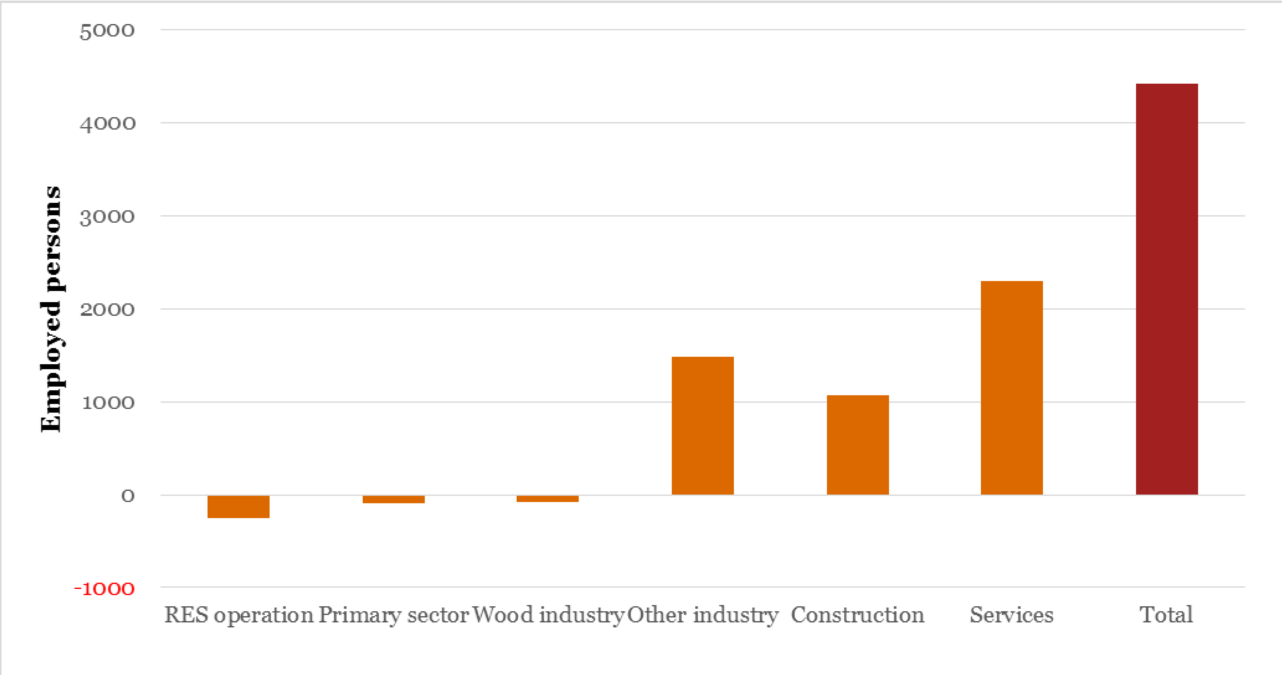
Table 5-13 Impacts of policy option 2 (EU biomass criteria for heat and power – default design) on employment in the EU 28, annual average 2021 – 2030

RES technology segment	Deployment effect EP	Income effect EP	Budget effect EP	Total impact EP
Employment				
Bioenergy deployment	-770			
Other RES deployment	4,810			
Total	**4,040**	**1,790**	**-1,410**	**4,420**
in % of EU 28 total				0.002%
Employment in SME				
Bioenergy deployment	50			
Other RES deployment	3,370			
Total	**3,420**	**1,460**	**-1,380**	**3,500**

Source: calculation by Rütter Soceco

Figure 5-15 displays the employment impacts for several industries and industry aggregates. The weaker use of biomass leads to small declines for operators of RES facilities, the primary sector and wood industry. Employment in other industry, construction and services grow marginally.

Figure 5-15 Impacts of policy option 2 (EU biomass criteria for heat and power – default design) on employment in the EU28 by industry, annual average 2021–2030



5.2 Policy option 3a – SFM certification

5.2.1 Bioenergy supply and demand

Strong impacts on bioenergy demand and supply can be expected from an implementation of *policy option 3a*. Thus, the imposed requirement of SFM, and the presumed reduction of forestry supply capacities – i.e. assuming a shift from the "reference" to the "restricted" scenario concerning the potential of bioenergy supply – shows strong impacts on bioenergy use: biomass demand in 2030 would decline by 16% compared to policy option 1 as shown in Table 5-14, offering a breakdown of the demand for bioenergy and other RES by 2030 at sectoral level. The complementary graphical illustration is given by Figure 5-16, showing the change of bioenergy demand and of overall RES demand compared to the baseline (policy option 1) – both in relative and in absolute terms. The corresponding overview on the supply of bioenergy under policy option 3a is presented in

Table 5-15 whereas trade aspects are discussed in a subsequent section.

Most affected is the heat sector where the direct use of biomass for heating & cooling in households, tertiary and industry is expected to decline by more than 30% compared to default. In total, demand for biomass heat is reduced by 24% since less pronounced impacts are applicable for derived heat (from CHP and district heating units) and for biomass use in the electricity sector, declining by about 5%. To compensate the decline of bioenergy use in heating & cooling and in power generation, other renewables have to take up and also biofuels in transport, specifically second generation biofuels using previously untapped domestic supply, experience a significant increase (e.g. by about 20% in the case of second generation biofuels). Generally, it is also possible to observe a shift in RES use from the heat to the electricity sector, where the RES share (in corresponding demand) increases from 48% to above 53% (compared to option 1).

Total biomass supply declines by about 12% compared to the baseline case. Thus, the strong decline of forestry biomass (by ca. 36% in relative terms, or 26 Mtoe concerning domestic supply and by 7 Mtoe in the case of Extra-EU imports) is only partly offset by an increased use of agricultural biomass, growing by 10 Mtoe more than default. Agricultural residues and lignocellulosic crops, also used in transport, are responsible for a large part of the increase.

Box 6: Scenarios on bioenergy supply capacities: from "reference" to "restricted" supply

Scenarios for sustainable supply of wood are based on National Forest Inventory (NFI) data and environmental and technical constraints. They were quantified separately for the different types of biomass (i.e. stemwood, logging residues and stumps). Within each type of biomass, environmental and technical constraints were quantified separately for the type of constraint (e.g. site productivity; soil and water protection: slope, soil depth, soil surface texture, soil compaction risk; biodiversity: protected forest areas, recovery rate, and soil bearing capacity). The following examples in thinnings demonstrate how constraints are applied.

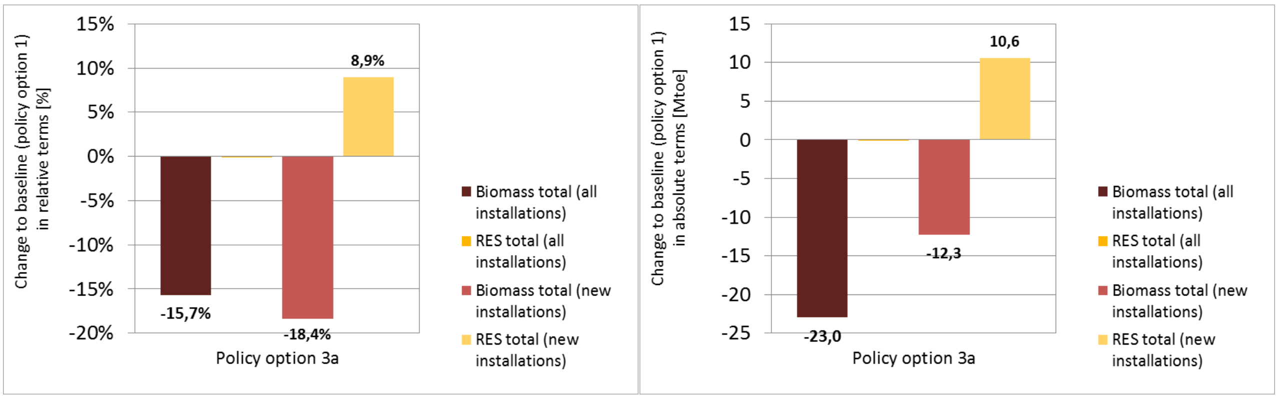
The maximum extraction rates for extracting logging residues from thinning operations are much more restricted. No residues from thinnings are extracted in the restricted scenario. In the "reference" scenario, site productivity restricts the extraction to 0% on poor soils and to 33% on other soils. In the "resource" scenario, it is restricted to 67% on all soils. Soil and water protection restricts the extraction on slopes up to 35%. Extraction from peatlands is only allowed in the "resource" scenario up to 33%. In the event extraction is not restricted by the above-mentioned circumstances the recovery rate is 67% on slopes up to 35%, 0% on slopes over 35%, but 47% if cable-crane systems are used.

In case of the "restricted" scenario this potential could be around 150 M m^3 less compared to the "reference" scenario. The differences between scenarios are mainly the results of the use of forest residues because there can be quite high environmental restrictions on the use of residues. The environmental effects of residue utilization are discussed controversially in relation to the extractions of nutrients and deadwood, which may be solved in accordance to forest stands.

Table 5-14 Breakdown of demand for bioenergy and other RES by 2030 under policy option 3a (SFM certification)

Demand for bioenergy and other RES in terms of final energy (electricity and heat generation, transport fuels) **by 2030**	**Policy option 3a**	*Change to baseline (policy option 1)*	
	[Mtoe]	*[Mtoe]*	*[%]*
Electricity sector			
Biogas	5.3	*-0.2*	*-3.5%*
Solid biomass (incl. bioliquids)	14.7	*-0.9*	*-5.9%*
Biowaste	2.8	*0.0*	*0.2%*
Total bio-electricity	**22.8**	***-1.1***	***-4.6%***
Other RES-electricity	138.1	*16.7*	*13.7%*
Total RES-electricity	**161.0**	***15.6***	***10.7%***
Heat sector			
Derived heat from biomass (CHP, district heat)	29.1	*-1.3*	*-4.1%*
Direct use of biomass	50.1	*-23.3*	*-31.7%*
Total bio-heat	**79.3**	***-24.6***	***-23.7%***
Other RES-heat	29.2	*6.2*	*27.2%*
Total RES-heat	**108.5**	***-18.3***	***-14.5%***
Transport sector			
Food-based biofuels (1G)	14.1	*1.5*	*11.6%*
Waste-based biofuels (advanced biofuels)	7.4	*1.2*	*20.3%*
Total biofuels	**21.4**	***2.7***	***14.5%***
Summary			
Total biomass	**123.5**	***-23.0***	***-15.7%***
Other RES	167.4	*22.9*	*15.9%*
Total RES	**290.9**	***0.0***	***0.0%***

Figure 5-16 Change in demand for bioenergy and RES total by 2030 compared to baseline (policy option 1) under policy option 3a (SFM certification), in relative (left) and in absolute terms (right)



Remark: "New installations" means all plants installed post-2020

Table 5-15 Biomass supply by 2030 under policy option 3a (SFM certification)

Bioenergy supply by 2030	Policy option 3a	*Change to baseline (policy option 1)*	
	[Mtoe]	*[Mtoe]*	*[%-change]*
Domestic supply			
Agriculture	63.8	*10.1*	*18.9%*
Forestry	76.5	*-26.5*	*-25.7%*
Waste	22.1	*-0.9*	*-3.9%*
Total domestic biomass	**162.4**	***-17.2***	***-9.6%***
Extra-EU imports			
Solid biomass	3.5	*-6.9*	*-66.3%*
Biofuels	6.4	*1.0*	*17.6%*
Total Extra-EU biomass imports	**9.9**	***-6.0***	***-37.7%***
Summary			
Total biomass	**172.3**	***-23.2***	***-11.9%***

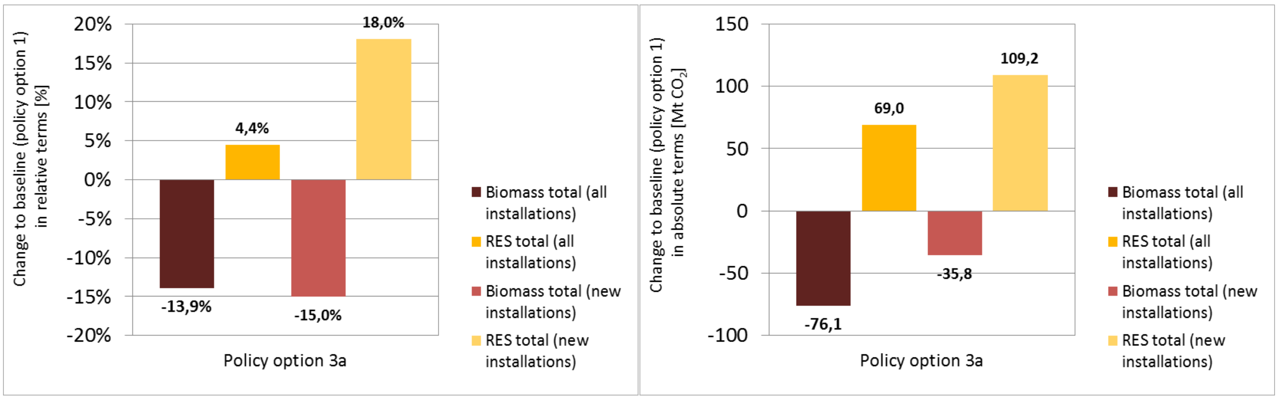
5.2.2 Environmental impacts

GHG emission savings for the supply chain

Figure 5-17 represents the outcomes of the assessment related to the GHG performance of biomass and other RES under policy option 3a, indicating the change of net supply chain GHG emission savings for biomass and RES total compared to the baseline (policy option 1). This graph includes a balance of GHG performance for new (post-2020) and for all installations, including also the bulk of RES plants installed in the years before a new EU-wide sustainability regulation is presumed to enter into force.

Whereas biomass-related GHG savings generally coincide with bioenergy deployment the most decisive figure is the balance made for RES total considering all RES installations. This figure shows the overall impacts, and, in contrast to the balance made for new RES installations, incorporates the phase-out of existing RES installations and the corresponding decline of GHG emission avoidance that come along with the GHG performance requirement.

Figure 5-17 Change in net (supply chain) GHG emission savings due to bioenergy and RES by 2030 compared to baseline (policy option 1) under policy option 3a (SFM certification)



Remark: "New installations" means all plants installed post-2020

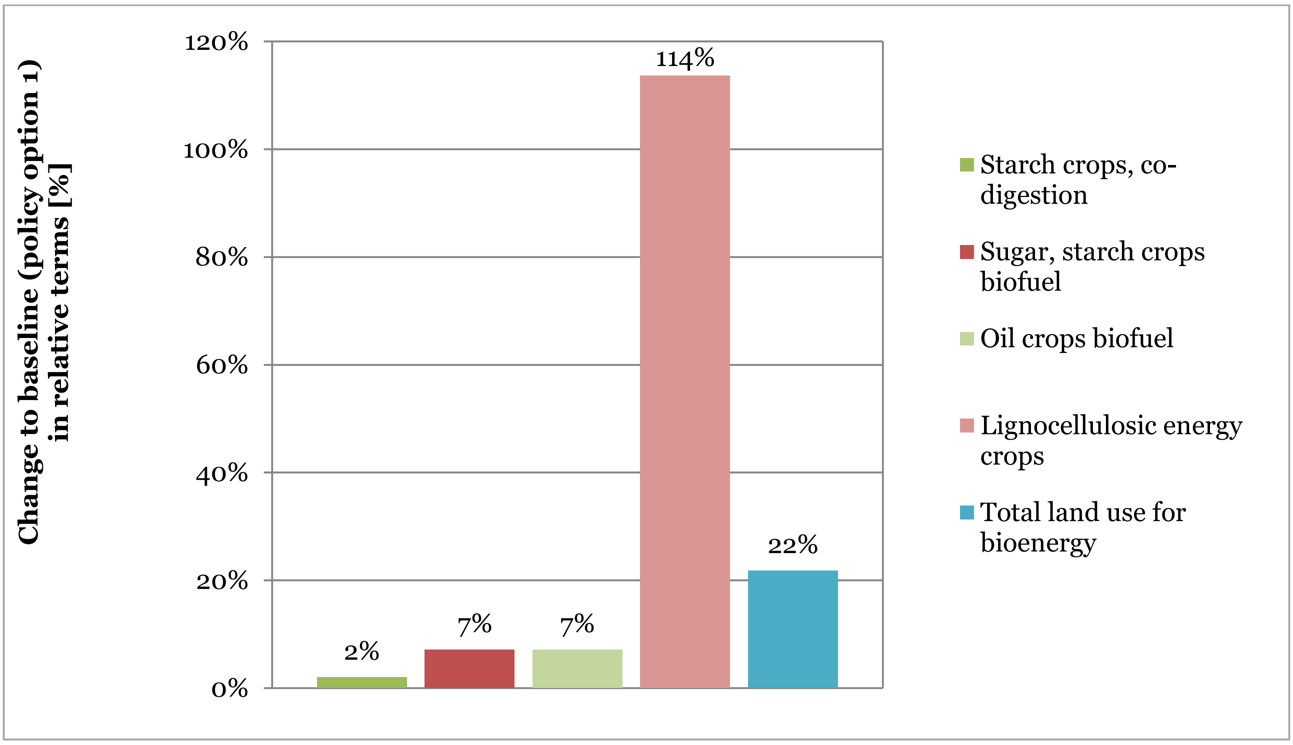
Similar to bioenergy demand and use, strong impacts are becoming apparent for the resulting net supply chain GHG avoidance. By 2030 about 69 Mt CO_2 can be additionally avoided under policy option 3a, corresponding to an increase in emission avoidance by 4.4% if total balance is made for all RES and the GHG reduction in the baseline case (policy option 1) is used as benchmark. This policy option implies an increase of GHG avoidance by 18% compared to the baseline for new RES installations i.e. installed post-2020, (policy option 1). This is also partly caused by the stronger demand for new installations (increasing by 9%) due to the strong restrictions of biomass use and, consequently, the partial phase-out of existing installations not coping with these restrictions. Generally, the strong improvements in GHG performance are because of the shift of RES demand from heating & cooling to the electricity sector. Since per unit of final energy more fossil fuels can be replaced in the electricity sector – a consequence of the higher carbon intensity due to the lower conversion efficiency in power generation compared to heat supply – a higher gross GHG avoidance is indispensable.

Impacts on land use and biodiversity

SFM certification requirements on all forest biomass have generally a positive environmental impact; however, the extent of this benefit depends very much on the country. In wealthy countries of the boreal zone, it could lead to more certification, if the certification scheme is not overambitious. In the tropical countries, less than two percent of the land area and less than a half percent of the roundwood production is certified, because most forest owners are not able to pay for the certification. In this case, a requirement will not lead to more certification. Roundwood trade will be redirected.

Because of decreased supply of forest biomass (stemwood, primary forest residues), this could result in a higher demand for secondary or tertiary wood (industrial residues or wood waste) that does not need to show compliance with SFM criteria. However, industrial residues are already largely used and furthermore, their potential increases or decreases with the production of wood products. If additional restrictions are implemented for the use of stemwood for materials, for example reducing the area of forest available for wood supply (FAWS) by increased forest protection, the potential of residues decreases in the same proportion. The reduced supply of forest biomass results therefore in a shift to lignocellulosic, perennial crops (e.g. willow) for bioenergy. In total, 2.2 Mha of lignocellulosic crops are cultivated compared to 1.0 Mha in the baseline by 2030. Furthermore, biofuels from food crops and biogas production also increase slightly because of the reduced supply of forest biomass and reduced generation of heat from biomass. The increased cultivation of lignocellulosic, perennial crops compared to the baseline can have positive impacts if cultivated on surplus cropland.

Figure 5-18 Change in land use for energy crop cultivation in the EU by 2030 in policy option 3a (SFM certification) compared to baseline (Option 1).

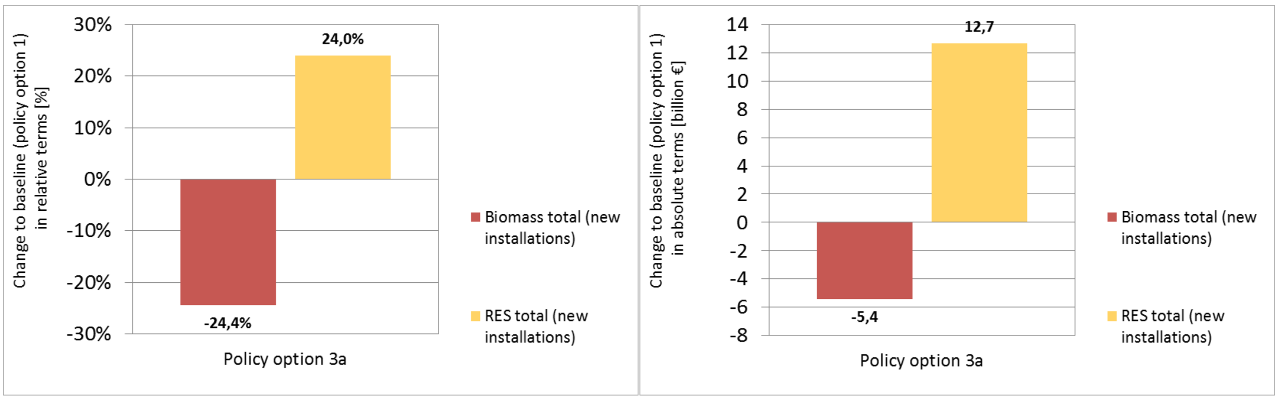


5.2.3 Economic impacts

Impact on CAPEX and OPEX for RES technology sectors

Figure 5-19 shows the change in average yearly capital expenditures for bioenergy and RES total in the period from 2021-2030. Similar to other effects as discussed above, resulting changes in investments are comparatively strong. Compared to the baseline (policy option 1), average CAPEX increases by 24% for RES in total within the focal period 2021-2030 (i.e. when the sustainability measures are presumably implemented), whereas a decrease of CAPEX by 24.4% can be seen for biomass total. Thus, the reduction in CAPEX for biomass is correlated with the decrease in biomass demand and supply. In absolute terms the increase of investments in RES total (+12.7 billion €) is more than twice as large as the decline of CAPEX for bioenergy (-5.4 billion €).

Figure 5-19 Change in average (2021-2030) annual capital expenditures for new biomass and RES installations compared to baseline (policy option 1) under policy option 3a (SFM certification), expressed in relative (left) and in absolute terms (right)

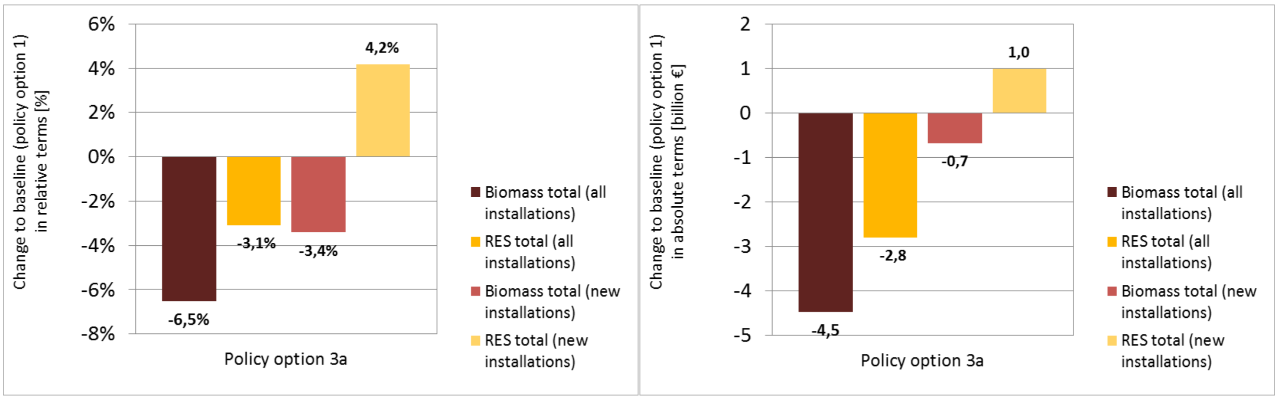


Remark: "New installations" means all plants installed post-2020

Complementary to Figure 5-19, Figure 5-20 indicates changes in operating expenditures (OPEX). Here the comparison is done for bioenergy and total RES considering newly installed plants (post-2020) as well as all installations, including additionally the large amount of RES plants installed in previous years. Similar trends are observable than for CAPEX if only new plants are taken into consideration. Relative changes of OPEX are smaller in magnitude than deviations of CAPEX. If in addition to new (post-2020) also existing RES installations are taken into consideration, a change of sign is becoming apparent: A 3.1% decline in OPEX can be seen concerning total RES when looking at average impacts in the forthcoming decade (2021-2030), whereas biomass total exhibits a decrease of about 6.5%.

Under a combined consideration of both CAPEX and OPEX the increase in CAPEX clearly outweighs the decline of OPEX for RES total – i.e. an increase of CAPEX+OPEX by about 10 billion € on average per year throughout the period 2021-2030 can be identified. Contrarily, in the case of bioenergy OPEX reach similar levels, and the combined consideration of CAPEX+OPEX indicates a decline by ca. 10 billion € on average (2021-2030) per year. This makes clear that investments in other RES increase significantly under this policy options – i.e. by almost 20 billion € on average per year – of which two thirds go to RES technologies in the electricity sector.

Figure 5-20 Change in average (2021-2030) annual operating expenditures for all biomass and RES installations compared to baseline (policy option 1) under policy option 3a (SFM certification), expressed in relative (left) and in absolute terms (right)



Remark: "New installations" means all plants installed post-2020

Impact on non-energy sectors

Certification schemes (PEFC/FSC) are widely used in forestry and document or safeguard a high level of sustainable forest management. The competition of certification systems leads to competition in restrictions. The nationwide valid FSC standards for Germany states that wood below a diameter of 7 cm (below threshold for wood in the rough) should remain in the forest. The aim is a nutrient sustainability for the long-term vitality of the forest[64]. It may be questioned if the use of forest residues must be banned completely or in a more qualified way, as in the scenarios. It will definitely lead to a situation in which the additional reserves for bioenergy will diminish. The traditional use of stemwood for firewood (splitwood) will remain. If only roundwood above 7 cm (wood in the rough) can be used for energy the additional potential will be quite low because softwood is already used intensively and hardwood capacities may be mobilised for high price household fuelwood but not for larger scale energy production (e.g. in CHPs).

This example shows the dependency of the impact from certification requirement for all forest biomass from the certification scheme itself: if standards restrict biomass use generally

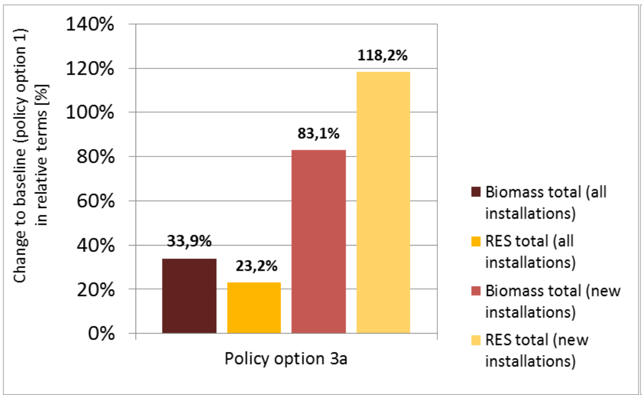
64 http://www.fsc-deutschland.de/de-de/aktuelles/aktueller-fsc-newsletter/newsletterarchiv/august-2014

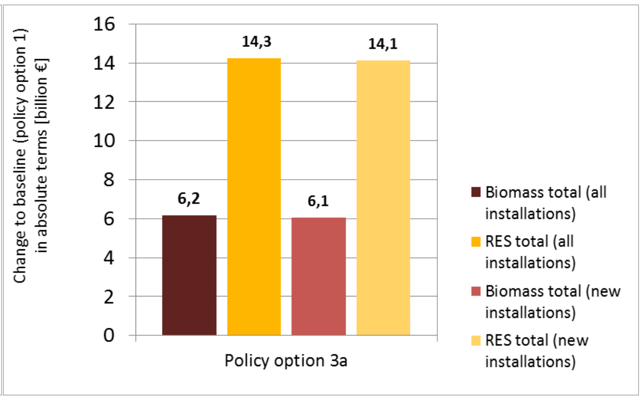
without considering different regional sustainability conditions, the effect on available biomass is negative.

Impact on support expenditures

Support expenditures are another relevant indicator for assessing the impacts of biomass-related policy options. As shown in Figure 5-21, strong increases in support expenditures for RES total as well as for bioenergy are applicable. Effects are generally more pronounced for new installations post-2020 than for all plants since support for existing plants (installed prior to the presumed implementation of a sustainability measure post-2020) is not directly affected, they will not be subjected to change retroactively. Due to the significant changes in available RES capacities post-2020, i.e. a large part of "low hanging fruit" is already taken out of the market, and the phase-out of existing bioenergy plants, more expensive RES (including bioenergy) technologies have to enter the market. In addition, these technologies require higher financial incentives, leading to an increase of related expenditures. Summing up, RES support expenditures increase by about €14bln pa on average in the period post-2020, corresponding to an increase of expenditures for all RES (including also existing installations) by 23% whereas support for newly installed plants rises by 118%, meaning more than a doubling compared to the baseline (policy option 1).

Figure 5-21 Change in average (2021-2030) annual support expenditures for biomass and RES compared to baseline (policy option 1) under policy option 3a (SFM certification), expressed in relative (left) and in absolute terms (right)





Remark: "New installations" means all plants installed post-2020

It is assumed that support expenditures are entirely passed on to households, thus leading to a decrease of real purchasing power of households.

Impact on gross value added

Compared to other policy options, option 3a is characterised by the largest shift from bioenergy to other RES use and the largest increase of policy support expenditures. This results in an overall increase of value added by €4.9bln, which is equal to 0.038% of total EU28 GDP.

The total impact is the sum of three partial effects:

- the deployment effect causes value added from bioenergy deployment to decrease by €7.7bln, whereas value added from other RES deployment increases by €18.3bln
- the income effect increases value added by €3.4bln
- whereas the budget effect decreases value added by €9bln.

Table 5-16 Impacts of policy option 3a (SFM certification) on gross value added in the EU 28, annual average 2021 – 2030

RES technology segment	Deployment effect €mln	Income effect €mln	Budget effect €mln	Total impact €mln
Absolute deviation from policy option 1				
Bioenergy deployment	-7,730			
Other RES deployment	18,250			
Total	**10,520**	**3,360**	**-9,030**	**4,850**
in % of EU 28 total (2030)				0.038%

Source: calculation by Rütter Soceco

The large increase in value added is partly due to the substitution of less capital-intensive bioenergy plants to more capital intensive technologies like wind power. Higher capital intensity leads c.p. to larger direct value added impacts. Furthermore, indirect effects occur in the supply chains of RES technologies on one hand (deployment effect) and of goods and services purchased by households on the other hand (income and budget effect). They are a result of complex shifts between industries and countries active in the respective supply chains.

Impact on non-EU countries

As a result of decreased supply of solid biomass from non-EU countries that cannot meet sustainable forest management criteria (SFM) in the projected time period, import of solid biomass is 66% smaller compared to baseline option 1 (Table 5-17). In contrast to import of solid biomass, import of liquid biofuels from third countries is 18% larger compared to baseline (option 1). Imported biofuels are not produced from forest biomass and the potential of liquid biofuels for export to the EU is therefore not affected by this option.

SFM criteria affect stemwood, but also primary forest residues. Forest residues are projected to become the main source of wood pellets in the US Southeast by 2030 and include residues that are categorized as 'other removals'[65]. These forest residues are generated form pre-commercial thinning operations, but also land clearing activities. Although these wood sources have low market value, if not replanted, these land-clearing activities could lead to substantial net carbon losses. Under the Sustainable Forest Initiative (SFI) Fibre sourcing, replanting after land clearing is recommended, but it is not obligatory (Hoefnagels et al. 2014). Under more strict SFM criteria (e.g. FSC), that require replanting after land clearing, we therefore assumed that these wood sources are no longer available for export to the EU and thereby reducing the supply potential of solid biomass from non-EU countries.

[65] Fingerman et al. 2016: "This category includes identified volume as trees removed from the timberland inventory due to land use change to some non-forest use, and any trees felled in timber stand improvement activities, like pre-commercial thinnings, weedings, etc., that are not directly associated with roundwood product harvests."

Table 5-17 Biomass feedstock supply and trade by 2030 under policy option 3a (SFM certification)

Biomass trade by 2030	Policy option 3a	Change to baseline (policy option 1)	
	[Mtoe]	[Mtoe]	[%-change]
Intra-EU trade			
Agriculture	6.8	+3.5	+106.3%
Forestry	4.8	-3.7	-43.3%
Waste	0.0	0.0	-
Total domestic biomass	**11.6**	**-0.2**	**-1.6%**
Inter-EU trade (imports)			
Solid biomass	3.5	-6.9	-66.3%
Biofuels	6.4	+1.0	+17.6%
Total Extra-EU biomass imports	**9.9**	**-6.0**	**-37.7%**
Summary			
Total biomass	**21.5**	**-6.2**	**-22.3%**

Impact on administrative costs

Policy option 3a starts from the same context as policy option 2 but including the Sustainable Forest Management Criterion for forest biomass (replacing land criteria). In this case, the main economic market participants affected by new criteria are forest owners. Under this policy option, they have to follow SFM criteria (and no the land criteria as it was in option 2) and need to be certified through specific schemes on SFM.

Steps 1 & 4: Identification and classification of information obligations and identification of target groups

The economic operators are the same as in policy option 2 but forest owners need to comply with Sustainable Forest Management criteria. Therefore, the same obligation remains for forest owners because SFM should be demonstrated through certification.

It is assumed that the obligations for Public Administration remain the same: actions regarding transposition of EU laws to national legislation (one-off), reporting to EC and monitoring and verification (recurring).

Steps 2, 5, & 6: Identification of required actions, the frequency of required actions and relevant cost parameters

Required actions, frequency and relevant cost parameters of economic operators and Public Administration remain the same. It is worth mentioning that national authorities spend more working hours to undertake transposition of laws actions because they have to adapt national laws to land criteria for agriculture biomass and Sustainable Forest Management criteria for forest biomass.

Steps 7 & 8: Choice of data sources to calculate the number of entities concerned in Policy Option 3a and assessment of the number of entities concerned

In policy option 3a the same kind of economic operators listed for policy option 2 are involved. However, the number of economic operators changes depending on the projections of the Green-X Model for option 3a with respect to option 2.

Step 9: Assessment of the performance of a "normally efficient entity" in each target group

This step explains the hours spent in each identified cost parameter (step 6). The cost parameters are composed of time spent on activities to respond to the requested actions and wage tariffs (as explained in the Baseline scenario – option 1).

An additional analysis of the most relevant SFM certification schemes has been conducted for forest biomass (for more details refer to Technical Annex F: Administrative cost) in order to verify and improve the quality of the assumptions considered in the present analysis which applied the Standard Cost Model. The external costs from the present study are in line with the certification costs estimation from the analysis carried out to estimate certification costs referred in Technical Annex F: Administrative cost (this estimation considered fees applied by the German certification body DIN CERTCO for the FSC scheme).

In particular, external costs in €/ha/pa for the certification of forest biomass result to be around €0.27/ha/pa considering an average area of 150,000 hectares (Technical Annex F: Administrative cost analysis).

Table 5-18 Time spent (hours) on activities –Economic operator – policy option 3a – SFM certification

Obligation to get and maintain the certification	Type of cost by frequency	Time spent (number of hours by entity concerned)	
		Internal	External
Producers of agriculture biomass for biofuel	One-off	70	26
	Recurring	38	12
Producers of solid biomass from agriculture	One-off	98	38
	Recurring	48	18
Forest entities	One-off	2,435	2,090
	Recurring	1,745	400
Bioenergy plants	One-off	64	16
	Recurring	36	10

Table 5-19 Time spent (hours) on activities –Public Administration - policy option 3a – SFM certification

Obligations for Public Administration	Type of cost by frequency	Time spent (number of hours by MS's)
Transposition of laws	One-off	338
Reporting to the EC	Recurring	368
Monitoring and verification	Recurring	1.049

Steps 10 & 11: Extrapolation of validated data to EU level and final reporting and transfer to the database

The results of the assessment of the administrative costs are shown in Table 5-20. The costs resulting from the obligations considered are presented separately for each kind of market participant involved. In order to show the differences in a clear way, one-off and recurring costs are presented separately. Administrative costs of Public Administration are presented as one-off and recurring costs.

Table 5-20 Results of administrative costs – Economic operators - policy option 3a – SFM certification

Economic operators	Number of market participants	One-off costs (€mln)	Recurring costs (€mln)
Producers of agriculture biomass for biofuel	8,613	26 - 49	13 - 23
Producers of solid biomass from agriculture	10,490	46 - 86	22 - 41
Forest entities	1,047	221 - 410	58 - 108
Bioenergy plants	9,077	19 - 35	12 - 21
TOTAL	29,227	446 (average)	149 (average)

Table 5-21 Results of administrative costs – Public Administration - policy option 3a – SFM certification

Public Administration	One-off costs (€mln)	Recurring costs (€mln)
TOTAL	0.12 - 0.22	0.48 - 0.88

For all economic operators total one-off costs are €446 million on average while recurring costs are €149 million on average. For Public Administration one-off costs are between €0.12-0.22 million and recurring costs between €0.48-0.88 million.

For economic operators, overall one-off and recurring costs in policy option 3a result to be higher than policy option 2 because of the new forest certification requests. For forest operators activities regarding SFM certification are more costly than land criteria.

For Public Administration, one-off and recurring costs are higher than policy option 2 due to the higher effort to adapt national laws to the extension of land criteria jointly with SFM certification and for the related monitoring and reporting activities. The results are also presented in the graphics below (Figure 5-22 and Figure 5-23).

Figure 5-22 Total administrative costs for private operators (one-off and recurring, in average) – policy option 3a (SFM certification)

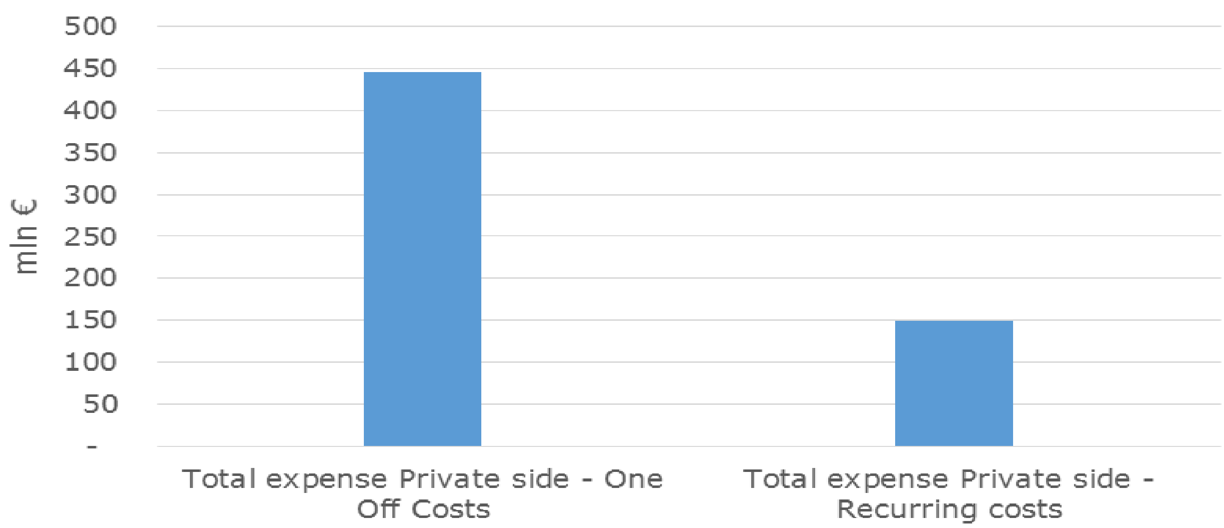
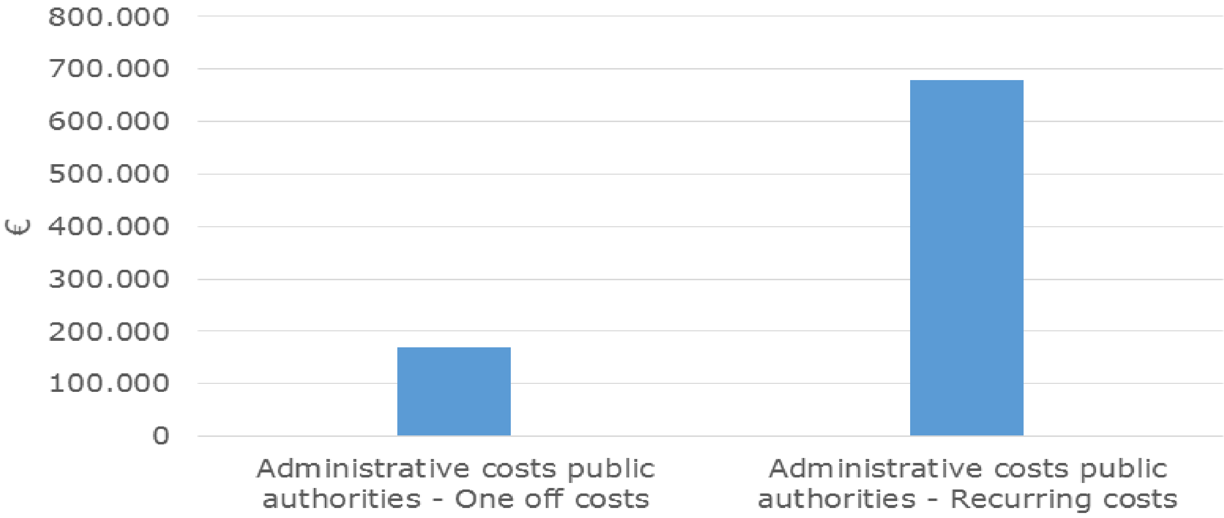


Figure 5-23 Total administrative costs for Public Administration (one-off and recurring, in average) – policy option 3a (SFM certification)



Box 7 – Costs of forest certification found in literature and comparison with the administrative costs estimation for this report in the Option 3a (SFM certification)

Costs of forest certification found in literature

In Option 3a, forest operators have to comply with SFM requirements. To carry out the estimation of administrative costs of this study, for the case of forest operators, it was taken into account the direct costs supported by forest operators to be certified in order to comply with SFM criteria.

This said, the purpose of this Box is to compare and contrast the results obtained in the present study for the Option 3a with other publication that also estimated forest certification costs using data of real cases. Some results from other publications are presented below:

- Savcor (2005) used real data to estimate forest certification costs of six locations in three Nordic Countries (Finland, Sweden, Norway). Their estimation presents forest certification costs between €0.02-0.79/ha/pa, taking into account direct costs (related with external and internal auditing). In order to be comparable with the present study indirect costs were excluded (which were distinguished in two kind: organisational costs to comply with the sustainability criteria and loss of stumpage revenues);
- FSC (2001) estimated FSC certification costs of six different forests in Germany, with costs ranging between €0.20-0.53/ha/pa. The costs per ha/year implies a 5 year-cycle of the SFM, which is typical of FSC. Those costs depend of the size of the area; the larger the area the lower certification costs per ha.
- Y. Ryckmans and N. André[66] stated that the certification procedure of the Laborelec certification scheme costs less than 0.1% of biomass fuel costs. Assuming that the price of a ton of wood pellet is around 200€, certification costs are below €0.20/tonne.

Comparison with the administrative costs estimation carried out in this study (administrative costs for forest operators – Option 3a)

Similar results were obtained for the estimation of administrative costs in this report, carried by forest operators: one-off and recurring costs are €0.52/ha/pa and €0.24/ha/pa respectively. Considering a normal 5 year-cycle of SFM certification the average results to be €0.29/ha/pa. These figures are close to those presented in Savcor (2005) and FSC (2001).

Under certain assumptions, results can be converted from €/ha into €/tonne[67]. Considering

[66] In publication: Novel Certification Procedure for the Sustainable Import of Wood Pellets To Power Plants in Belgium

the results obtained in this study (mentioned in the paragraph above: €0.52/ha/pa of one-off costs and €0.24/ha/pa of recurring costs), forest certification costs of forest operators are approximately €0.25/tonne of one-off costs and €0.11 of recurring costs (€0.14/tonne on average if a normal 5 year-cycle of SFM certification is considered). Those figures are close to the certification costs of the Laborelec scheme, presented above. Of course, costs will depend on forest size, and the amount of biomass harvested.

5.2.4 Social impact: impact on employment

Under policy option 3a, employment increases by approx. 6,100 employed persons (cf. Table 5-18). Yet this policy option exhibits large shifts between bioenergy and other RES deployment and between the three separate effects. The deployment effect generates roughly 106,000 jobs with employment growth from other RES deployment clearly overcompensating job losses from reduced bioenergy deployment. The income effect is also significantly positive with a job increase of approx. 51,000 employed persons. On the other hand, the budget effect leads to significant job losses. On balance, the impact on employment with a share of 0.003% of total employment in EU 28 is still very low. Employment in SME increases by roughly 2,100 jobs.

Table 5-22 Impacts of policy option 3a (SFM certification) on employment in the EU28, annual average 2021 – 2030

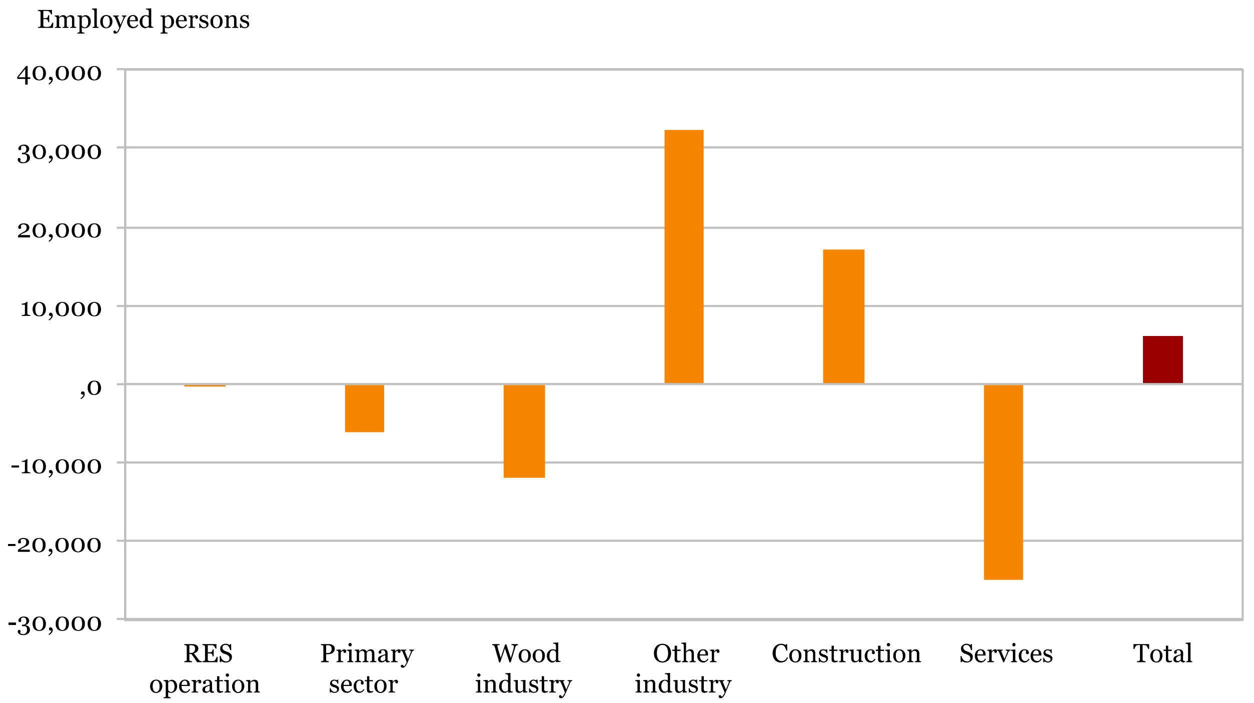
RES technology segment	Deployment effect EP	Income effect EP	Budget effect EP	Total impact EP
Employment				
Bioenergy deployment	-99,590			
Other RES deployment	204,490			
Total	**104,900**	**50,800**	**-149,610**	**6,090**
in % of EU 28 total				0.003%
Employment in SME				
Bioenergy deployment	-65,390			
Other RES deployment	142,620			
Total	**77,230**	**38,140**	**-113,290**	**2,080**

Source: calculation by Rütter Soceco

Even though the overall impact on employment is low, this policy option may lead to some structural change. Employment in the primary sector and wood industry decrease due to less biomass use (cf. Figure 5-24). Employment in other industry and construction increases because of stronger use of other RES technologies. The impact of employment in the services sector is negative since employment increases due to the deployment and the income effect are offset by decreases due to the budget effect.

[67] Assuming a harvest of 3 m^3/ha/yr and 0.7 tonne/m^3

Figure 5-24 Impacts of policy option 3a (SFM certification) on employment in the EU28 by industry, annual average 2021 – 2030



Source: Rütter Soceco

5.3 Policy option 3b – Risk-based criterion for forest biomass

5.3.1 Bioenergy supply and demand

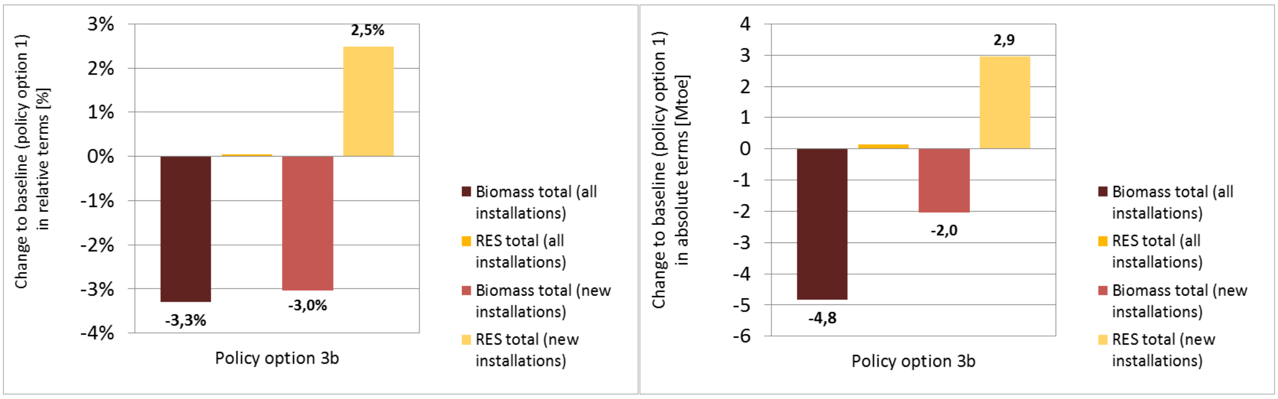
A breakdown of the demand for bioenergy and other RES by 2030 at the sectoral level is given in Table 5-23 for policy option 3b. Complementary to this table, Figure 5-25 provides an illustration of arising changes, showing the change of bioenergy demand and of overall RES demand compared to policy option 1 both in absolute and in relative terms. The corresponding overview on bioenergy supply is shown in Table 5-24 whereas trade aspects are discussed in a subsequent section.

Compared to policy option 3a, less pronounced impacts could be identified for policy option 3b, where SFM is also introduced through a risk-based approach, but the approval/certification is required only for regions or producers classified as risky. In the modelling exercise the assumption is taken that this affects only Extra-EU imports of forestry biomass, where again the "restricted supply potential" scenario is consequently used to set the upper boundary for the use.

Table 5-23 Breakdown of demand for bioenergy and other RES by 2030 under policy option 3b (Risk-based criterion)

Demand for bioenergy and other RES in terms of final energy (electricity and heat generation, transport fuels) **by 2030**	**Policy option 3b**	*Change to baseline (policy option 1)*	
	[Mtoe]	*[Mtoe]*	*[%]*
Electricity sector			
Biogas	5.2	*-0.3*	*-5.0%*
Solid biomass (incl. bioliquids)	15.6	*0.0*	*0.0%*
Biowaste	2.8	*0.0*	*0.1%*
Total bio-electricity	**23.7**	***-0.3***	***-1.2%***
Other RES-electricity	125.8	*4.4*	*3.6%*
Total RES-electricity	**149.5**	***4.1***	***2.8%***
Heat sector			
Derived heat from biomass (CHP, district heat)	30.0	*-0.3*	*-1.1%*
Direct use of biomass	68.8	*-4.6*	*-6.3%*
Total bio-heat	**98.9**	***-5.0***	***-4.8%***
Other RES-heat	23.6	*0.6*	*2.7%*
Total RES-heat	**122.5**	***-4.3***	***-3.4%***
Transport sector			
Food-based biofuels (1G)	12.8	*0.2*	*1.3%*
Waste-based biofuels (advanced biofuels)	6.4	*0.2*	*4.0%*
Total biofuels	**19.1**	***0.4***	***2.2%***
Summary			
Total biomass	**141.7**	***-4.8***	***-3.3%***
Other RES	149.4	*5.0*	*3.4%*
Total RES	**291.1**	***0.2***	***0.1%***

Figure 5-25 Change in demand for bioenergy and RES total by 2030 compared to baseline (policy option 1) under policy option 3b (Risk-based criterion), in relative (left) and in absolute terms (right)



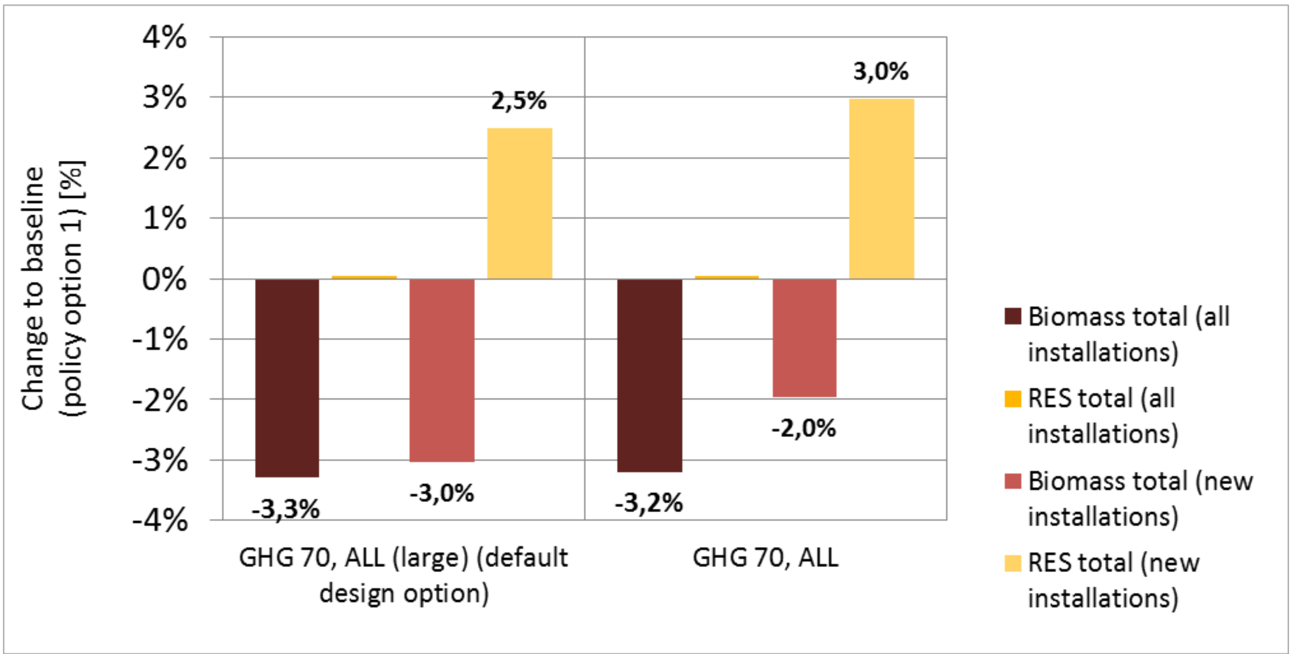
Remark: "New installations" means all plants installed post-2020

Concerning biomass supply it can be seen that the decline of imports (by 7 Mtoe or 66% compared to default) is partly offset by an increased use of domestic supply stemming from both agriculture (+2 Mtoe) and forestry (+1 Mtoe). Total final energy demand for biomass declines by about 3% compared to baseline (policy option 1), where strongest effects, i.e. a reduction by 5%, can be seen in heating & cooling (- 5% compared to baseline). The reduced contribution of biomass towards overall 2030 RES target fulfilment, specifically the decline of biomass in the heat and in the electricity sector, is offset by a moderate increased use of biofuels in transport (+2%) and by an increased use of other RES for power generation (+4%) and for heating & cooling (+3%).

Table 5-24 Biomass supply by 2030 under policy option 3b (Risk-based criterion)

Bioenergy supply by 2030	Policy option 3b [Mtoe]	*Change to baseline (policy option 1)* [Mtoe]	*Change to baseline (policy option 1)* [%-change]
Domestic supply			
Agriculture	55.9	*2.2*	*4.1%*
Forestry	103.8	*0.8*	*0.8%*
Waste	22.0	*-1.0*	*-4.3%*
Total domestic biomass	**181.7**	***2.0***	***1.1%***
Extra-EU imports			
Solid biomass	3.5	*-6.9*	*-66.3%*
Biofuels	5.2	*-0.2*	*-4.3%*
Total Extra-EU biomass imports	**8.7**	***-7.2***	***-45.2%***
Summary			
Total biomass	**190.4**	***-5.1***	***-2.6%***

Figure 5-26 Sensitivity assessment of alternative design options: Change in demand for bioenergy and RES total by 2030 compared to baseline (policy option 1) under all assessed design variants of policy option 3b (Risk-based criterion), expressed in relative terms



Remark: "New installations" means all plants installed post-2020

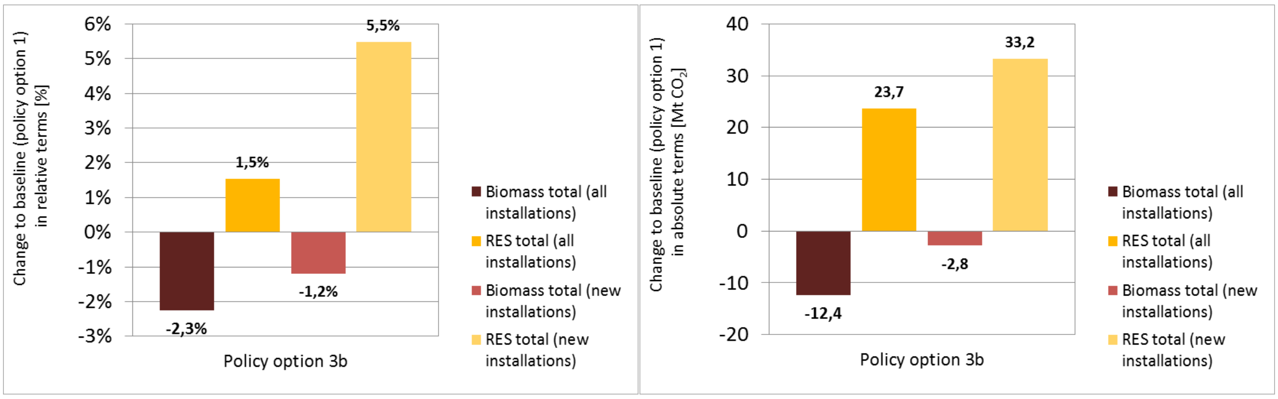
Figure 5-26 (above) sheds light on the detailed design of EU-wide harmonised sustainability measures and related impacts, indicating the change in bioenergy and total RES demand for all analysed design options concerning policy option 3b. In particular, a smaller impact on bioenergy demand (and supply) can be expected if all market participants (except direct use in households) are included in the regulation, i.e. not only large-scale facilities (above 4-5 MW fuel capacity) in electricity, heat and CHP supply as presumed under default design. A smaller decline by 3.2% (compared to baseline) instead of 3.3% under default design can be seen, thanks to an increased penetration of new bioenergy installations concerning the direct use in households and tertiary because of improved viability compared to (gird-connected) derived heat supply.

5.3.2 Environmental impacts

GHG emission savings for the supply chain

Figure 5-27 illustrates the GHG performance of biomass and other RES under policy option 3b, showing the change of net supply chain GHG emission savings for biomass and RES total compared to policy option 1. This overview includes a balance of GHG performance for new installations (post-2020) and for all installations, including also the bulk of RES plants that have been installed in the years before a new EU-wide sustainability regulation is presumed entering into force (by 2021). As a general pattern, it can be seen that biomass-related GHG savings generally coincide with bioenergy deployment.

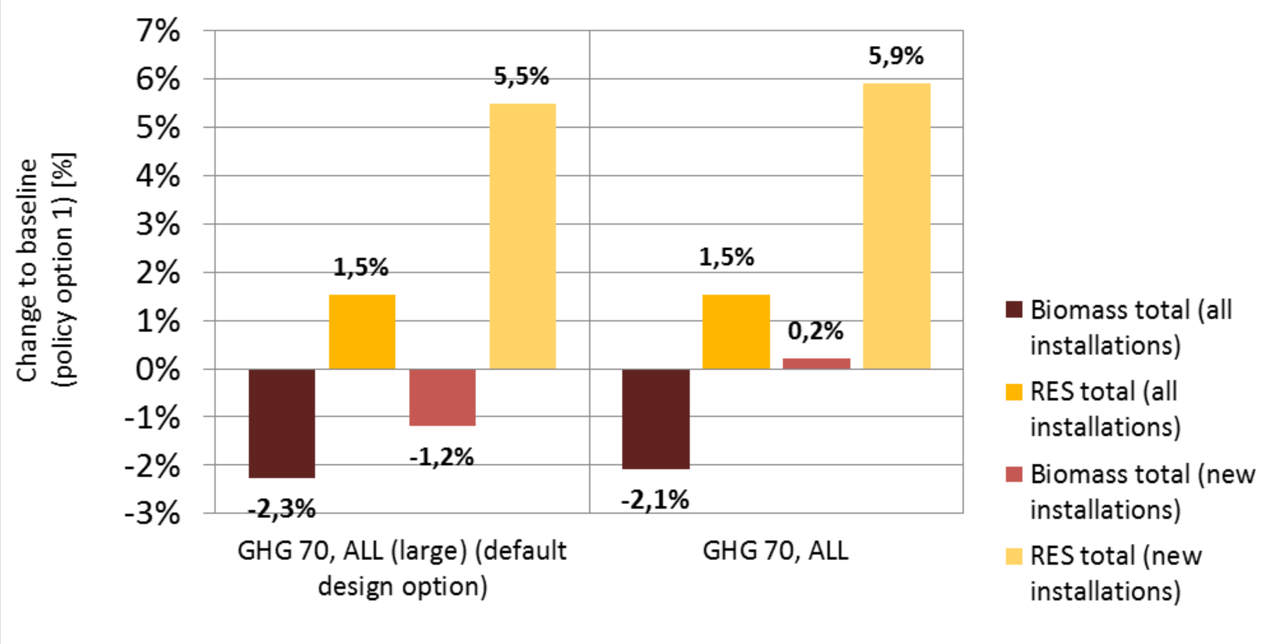
Figure 5-27 Change in net (supply chain) GHG emission savings due to bioenergy and RES by 2030 compared to baseline (policy option 1) under policy option 3b (Risk-based criterion), in relative (left) and in absolute terms (right)



Remark: "New installations" means all plants installed post-2020

The most relevant figure is however the balance made for RES total considering all RES installations. This figure shows the overall impacts and in contrast to the balance made for new RES installations, incorporates also the phase-out of existing installations and the corresponding decline of GHG emission avoidance that come along with the GHG performance requirement. Apparently, policy option 3b shows improvements in terms of overall impacts on GHG performance compared to baseline (policy option 1): an increase by about 24 Mt additional CO2 savings is applicable, corresponding to a change by 1.5% if expressed in relative terms. This is caused by the reduction of biomass demand, or more specifically, by the decline of solid biomass imports to the EU (whereas domestic biomass use is expected to increase). Additionally, also the increased use of other RES in the electricity sector and in heating & cooling contributes to the improvements in GHG performance.

Figure 5-28 Change in net (supply chain) GHG emission savings due to bioenergy and RES by 2030 compared to baseline (policy option 1) under all assessed design variants of policy option 3b (Risk-based criterion), expressed in relative terms



Remark: "New installations" means all plants installed post-2020

Regarding the impact on GHG performance arising from alternative designs of the EU-wide harmonised sustainability measures, Figure 5-28 points out the change in GHG emissions savings due to bioenergy and total RES by 2030 considering all analysed design options of policy option 3b. Key result is that almost no impact of the GHG performance can be expected from an enlargement of the actor scope by including also small market participants (below 4-5 MW_{fuel}) in regulation. It is possible to see the change in GHG performance of new bioenergy installations that comes along with changes in market penetration.

Impacts on land use and biodiversity

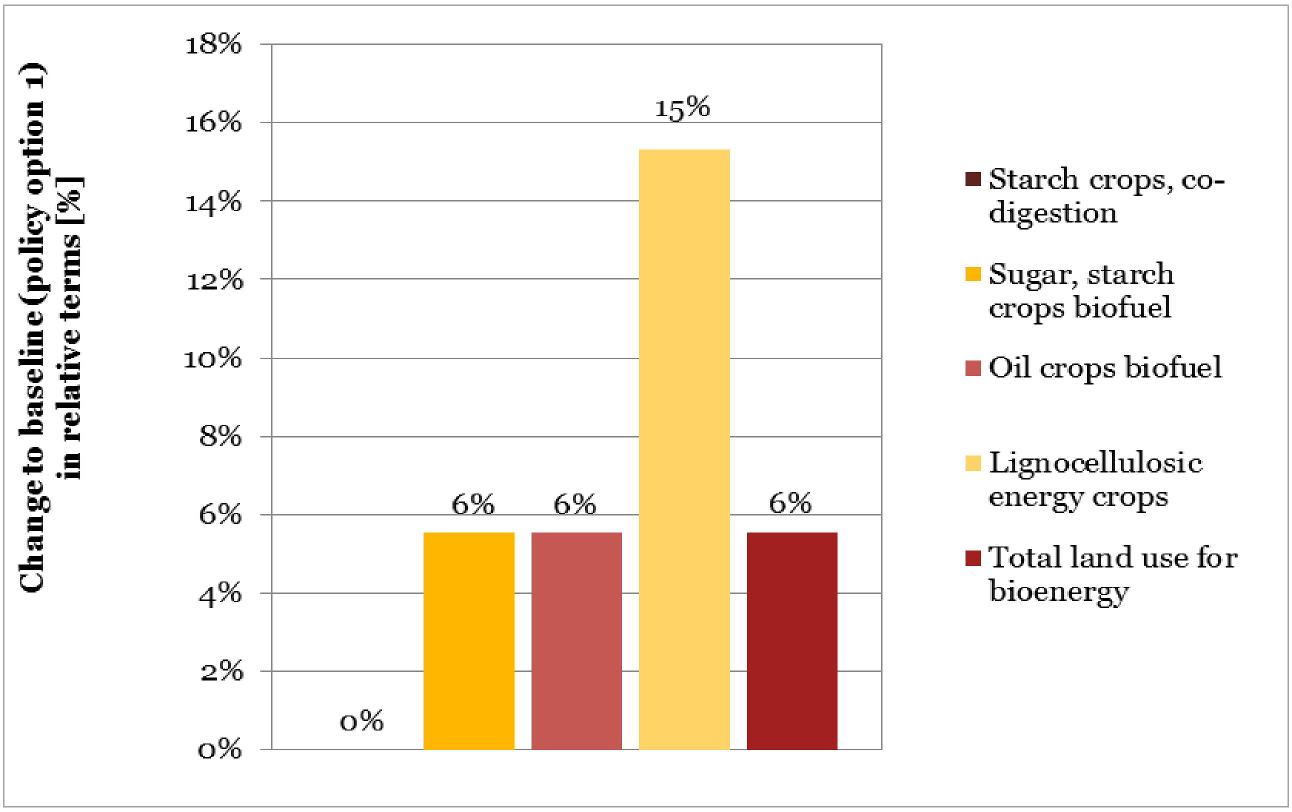
In general, trade regulations should be simplified. Clear rules and regulations foster business in general and biomass is no exception – clarity under international law is always preferred over that of any individual country. The impact on felling volumes in the EU would however not be significant. The environmental pressure on forests in the EU will not be significantly affected, as the risk-based approach focuses where the risks are highest. The risk-based approach mainly addresses non-EU imports. Imports are relatively small and exporting countries will largely be from countries from boreal and temperate zones in the northern hemisphere (for example Canada, USA, Russia). Imports of tropical wood from more problematic regions are quite small and already strongly restricted. It should be noted that if the EU does not buy, other regions or countries will.

As SFM requires more handling activities to harvest, capital and operational costs for forest managers are higher, it takes more time and equipment compared to non-SFM.

As mentioned before, the impact of SFM certification depends very much on the definition of SFM criteria. They could lead to a higher quality management of forest or just simply to a competition of high restrictions, which lead to less biomass availability. Thus, before certification schemes are promoted as such, they should be evaluated as to which extent they cover the overall environmental impact of forest biomass.

Total land use for energy crop cultivation in the EU is 6% larger by 2030 compared to baseline (option 1) (Figure 5-29). The effect is similar to policy option 3a, but less pronounced because of the higher domestic forest biomass supply in this scenario compared to policy option 3a. The decreased supply of pellet Extra-EU imports leads to additional cultivation of food-based and lignocellulosic energy crops in the EU. In absolute terms, however, land increases for food-based crops are higher than land use increases for lignocellulosic crops. A net positive impact on biodiversity and land use in agriculture is therefore not foreseen.

Figure 5-29 Change in land use for energy crop cultivation in the EU by 2030 in policy option 3b (Risk-based criterion) compared to baseline (option 1).



5.3.3 Economic impacts

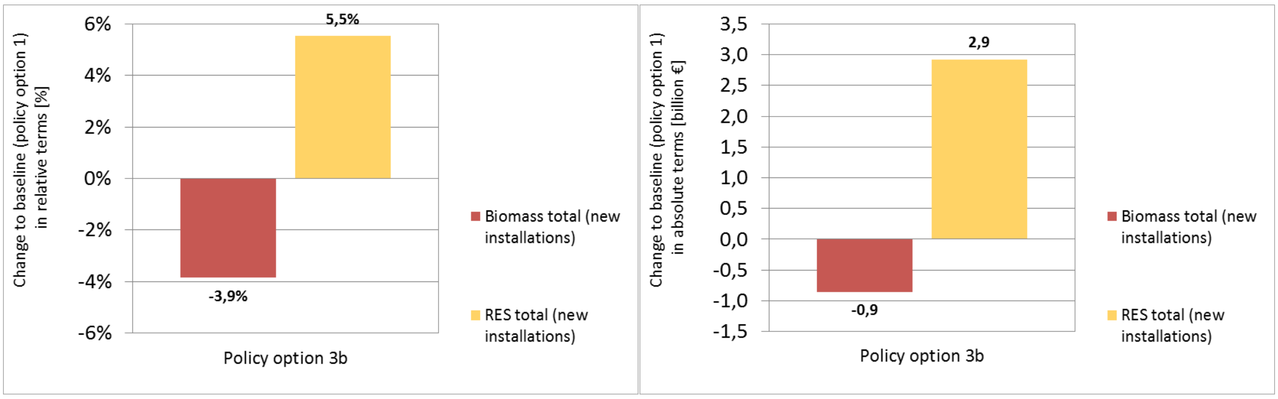
Impact on CAPEX and OPEX for RES technology sectors

Figure 5-30 provides an overview of resulting changes in capital expenditures while implementing policy option 3b instead of option 1 (baseline). It can be seen that in the years post-2020 CAPEX for bioenergy decline by about 4% on average, corresponding to a decrease of investments by slightly less than €1.0bln pa on average. On the other hand, a moderate increase in investments for RES total is apparent, amounting to €2.9bln pa on average, or 5.5% if expressed relatively. This increase for RES total is because of the stronger penetration of wind and solar in the electricity sector as well as of solar collectors and heat pumps in heating & cooling to compensate the reduced contribution of existing biomass installations (as a consequence of the newly introduced GHG regulation).

If OPEX are considered only for new post-2020 RES installations, a similar tendency as in the consideration of CAPEX can be identified, cf. Figure 5-31 Relative changes of OPEX in comparison to baseline (option 1) are nevertheless smaller on average. For bioenergy, here a change of sign is applicable, caused by the shift from comparatively cheap forestry biomass (imported from abroad) to more expensive agricultural feedstock. If additionally also existing

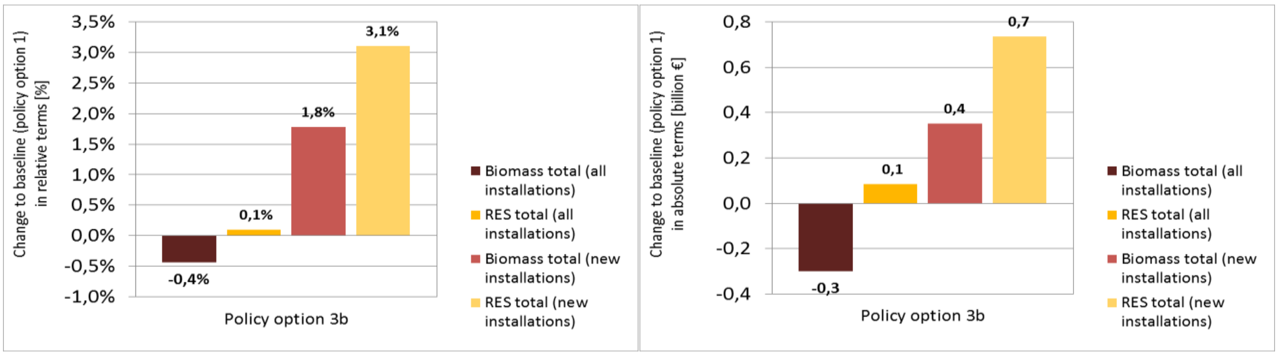
RES installations are taken into consideration, impacts are smaller in magnitude – e.g. for RES total almost no change compared to baseline can be identified.

Figure 5-30 Change in average (2021-2030) annual capital expenditures for new biomass and RES installations compared to baseline (policy option 1) under policy option 3b (Risk-based criterion), in relative (left) and in absolute terms (right)



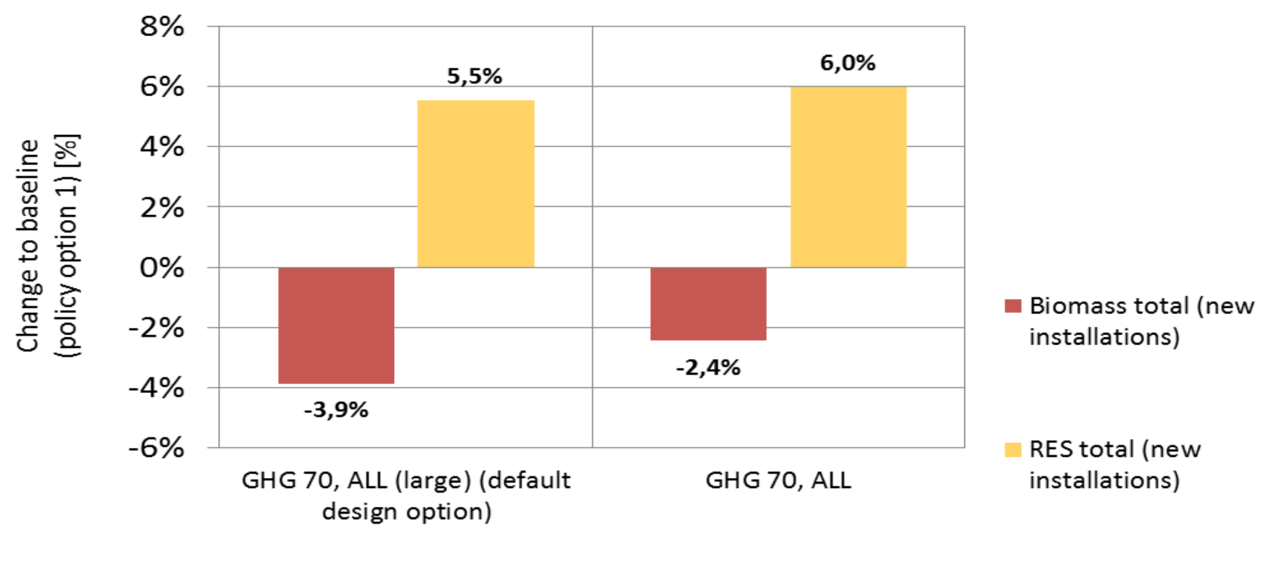
Remark: "New installations" means all plants installed post-2020

Figure 5-31 Change in average (2021-2030) annual operating expenditures for all biomass and RES installations compared to baseline (policy option 1) under policy option 3b (Risk-based criterion), in relative (left) and in absolute terms (right)



Under a combined consideration of CAPEX+OPEX, the increase in CAPEX dominates for RES total an increase by about €3.0bln pa on average over 2021-2030 can be identified. In contrast to total RES, in the case of bioenergy the combined consideration of CAPEX+OPEX indicates a decline by -€1.2bln pa on average over 2021-2030.

Figure 5-32 Change in average (2021-2030) annual capital expenditures for new biomass and RES installations compared to baseline (policy option 1) under all assessed design variants of policy option 3b (Risk-based criterion), expressed in relative terms



Remark: "New installations" means all plants installed post-2020

Finally, within a sensitivity analysis alternative designs of the EU-wide harmonised sustainability measures are taken into consideration. Figure 5-32 shows the change in CAPEX for bioenergy and total RES on average in the period 2021-2030 considering both analysed design options of policy option 3b. In accordance with the changes concerning new installations, moderate impacts on CAPEX can be expected if all market participants are covered by the sustainability scheme. Thus, CAPEX for total RES increase by 5.5% instead of 6.0% whereas investments in bioenergy increase by 1.5% compared to default design. As discussed above, this moderate difference is caused by the shift in biomass supply and demand towards direct use in households and in tertiary.

Impact on non-energy sectors

There will be a much higher restriction of forest biomass availability i.e. lower imports, especially from non-EU countries. For instance, a very low share of US forest is certified. There could be an indirect effect that these certified regions direct their exports to the EU28, and non-EU importers buy from uncertified sources.

Possible adverse employment effects for forest owners or farmers could arise due to the additional costs associated to SFM criteria. This could be minimized by exempting small forest holdings from compliance and by promoting group certification. The assumption is made that the cost of higher SFM criteria would not be offset by higher prices, which is normally the case.

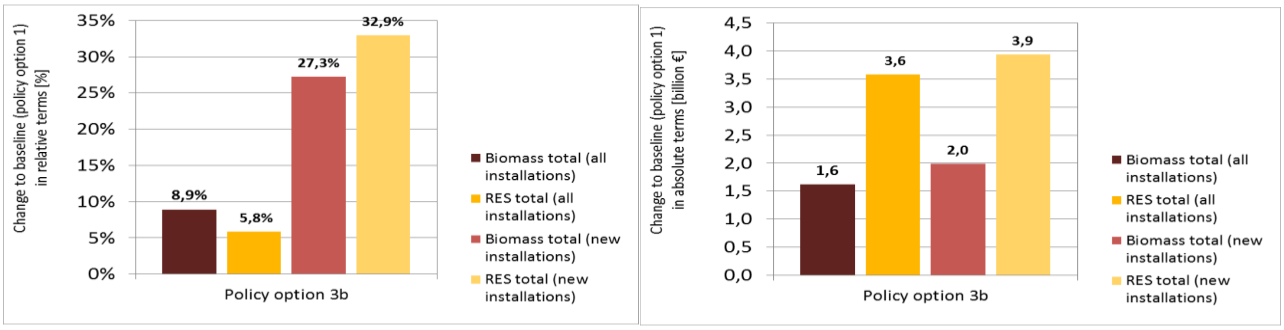
By promoting forest management planning or certification, the risks of negative social i.e. employment impacts on biomass exporting non-EU countries would be reduced. However, in general, if the prices do not increase with the standards, employment decreases.

It is important to consider the regional differences of effects. Certification is widely spread in wealthy societies with a large amount of people living in cities, which normally have no relevant problem of low employment standards. In poor southern hemisphere countries certification is not a suitable measure to improve social standards, because it is almost non-existent due to the high cost of certification itself or because of higher production cost in forest management. Without a financial support to forestry owners to compensate the cost of certification nothing will change. Combined, Latin America, Africa, Asia and Oceania account for only a bit more than 10% of certified forests worldwide, even though these regions contain 60% of the global forest estate (UNECE/FAO, 2015). The EUTR is an attempt to scope with this problem and points in the right direction. However, so far not many countries achieved a "Voluntary Partnership Agreements (VPA's) which ensure that the timber and timber products from these countries are from legal sources.

Impact on support expenditures

A relevant indicator in the economic evaluation of impacts arising from policy options are the support expenditures[68] for biomass and for RES in total, respectively. A graphical illustration of changes arising from policy option 3b in comparison to baseline (policy option 1) is given in Figure 5-33. The comparison for RES total indicates strong increases by around 33% on average for the assessed period between 2021 and 2030 when only new RES installations are taken into consideration. Changes of similar order of magnitude are also applicable for new biomass installations (i.e. installed post-2020). When looking at all installations (existing and newly installed post-2020) relative changes become smaller in magnitude but in absolute numbers, they are in same order. Summing up, support expenditures for RES total (including all installations) increase by 5.8% or €3.6bln on average per year. This can be classified as small increase in comparison to the strong changes applicable under policy option 3a (where SFM is required for all) – but the magnitude of changes is higher than the default design variant of policy option 2.

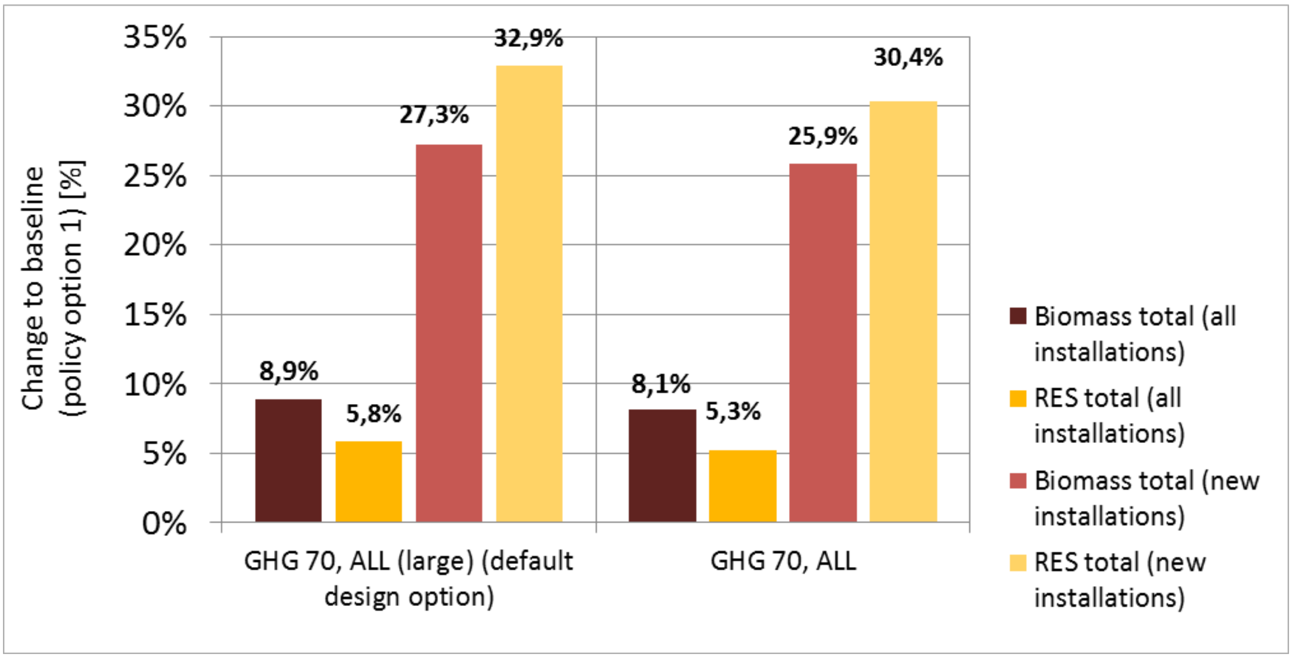
Figure 5-33 Change in average (2021-2030) annual support expenditures for biomass and RES compared to baseline (policy option 1) under policy option 3b (Risk-based criterion), in relative (left) and in absolute terms (right)



Remark: "New installations" means all plants installed post-2020

[68] Support expenditures, that is the transfer costs for consumers (society) due to RES support, are defined as the financial transfer payments from the consumer to the RES producer that comes along with the RES policy intervention. Thereby, only direct payments and no indirect costs, nor benefits are taken into consideration.

Figure 5-34 Change in average (2021-2030) annual support expenditures for biomass and RES compared to baseline (policy option 1) under all assessed design variants of policy option 3b (Risk-based criterion), expressed in relative terms



Remark: "New installations" means all plants installed post-2020

The outcomes of the sensitivity analysis on alternative designs of the EU-wide harmonised sustainability measures are discussed. Figure 5-34 presents the change in support expenditures for bioenergy and total RES on average in the period 2021-2030 considering all analysed design options of policy option 2 (EU criteria for heat and power). In particular, a moderate decline of support costs can be expected if all market participants (except households) are covered by the sustainability scheme. Support expenditures for all new RES installations post-2020 would then increase by 30.4% (compared to baseline) whereas a rise by 32.9% can be expected under default design. The reason for that perhaps surprising trend is that direct use of biomass is increasing more strongly under this design variant, which has a small but positive impact on overall support expenditures.

It is assumed that support expenditures are entirely passed on to households, thus leading to a decrease in real purchasing power of households.

Impact on gross value added

Policy option 3b is characterised by moderate shifts between technologies and moderate support expenditures. The impacts on value added are moderate too. On balance value added increases by €1.4bln, equal to 0.011% of total EU28 GDP.

Shifts in RES deployment expenditures lead to an increase by €2.7bln, with the decrease of value added induced by bioenergy being offset by the increase of value added induced by other RES technologies. The positive deployment effect leads to a positive employment and income effect that contributes another €0.9bln in value added. On the other hand, the budget effect induced by increasing support expenditures causes lower household expenditures and dampens value added by €2.3bln.

Table 5-25 Impacts of policy option 3b (Risk-based criterion) on gross value added in the EU 28, annual average 2021 – 2030

RES technology segment	Deployment effect €mln	Income effect €mln	Budget effect €mln	Total impact €mln
Absolute deviation from policy option 1				
Bioenergy deployment	-1,060			
Other RES deployment	3,780			
Total	**2,720**	**920**	**-2,260**	**1,380**
- in % of EU28 total				0.011%

Source: calculation by Rütter Soceco

Impact on third countries

The impact of solid biomass import to the EU is similar to policy option 3a because of the assumed impact to the potential. In both policy option 3a and 3b, import of solid biomass is 66% smaller compared to baseline option 1 (Table 5-26). Because of large domestic forest biomass supply compared to option 3a, the impact to liquid biofuel import is not as large compared to policy option 3a. By 2030, import of liquid biofuels is 4.3% smaller compared to baseline option 1.

Table 5-26 Biomass trade by 2030 under policy option 3b (Risk-based criterion)

Biomass trade by 2030	Policy option 3b [Mtoe]	*Change to baseline (policy option 1)* *[Mtoe]*	*[%-change]*
Intra-EU trade			
Agriculture	4.0	*0.7*	*20.6%*
Forestry	8.6	*0.1*	*0.7%*
Waste	0.0	*0.0*	-
Total domestic biomass	**12.5**	***0.7***	***6.2%***
Inter-EU trade (imports)			
Solid biomass	3.5	*-6.9*	*-66.3%*
Biofuels	5.2	*-0.2*	*-4.3%*
Total Extra-EU biomass imports	**8.7**	***-7.2***	***-45.2%***
Summary			
Total biomass	**21.2**	***-6.4***	***-23.3%***

Impact on administrative costs

Policy option 3b starts from the same context as policy option 2, but this option **includes the application of risk-based approach on forest biomass instead of land-based criteria**, which requires operators to minimise the risk of unsustainable forest biomass by gathering evidence of meeting requirements, firstly on national level, and if evidence are not sufficient, on forest holding level.

The concept of the risk-based approach for Sustainable Forest Management is based on gathering evidence of meeting criteria in countries or regions certifying their governance of forest in a sustainable way.

Evidence should be gathered first at the national level and, only if additional evidence is required on the forest holding level, a certification or other third party verified schemes should be used.

In this case, the burden for forest biomass operators will depend on the category of the region where they are sourcing. The costs for operators sourcing from countries where evidence will be sufficient on national level will be lower. While if evidence will be required on forest holding level, higher costs will be inccured to gather sufficient evidence or require forest certification.

Steps 1 & 4: Identification and classification of information obligations and identification of target groups

The economic operators are the same as in policy option 2. In this case, operators sourcing from low risk countries do not need to demonstrate SFM criteria through certification, but only need to show evidence to Public Administration regarding sustainable forest management practices, while operators sourcing from high-risk countries need to apply for SFM certification or gather additional evidence themselves.
For Public Administration, it is assumed that obligations are the same as in policy option 2 (law transposition, monitoring and reporting).

Steps 2, 5, & 6: Identification of required actions, the frequency of required actions and relevant cost parameters

Except for forest operators, required actions, frequency and relevant cost parameters (regarding information obligation activities) for the rest of economic operators remain the same.

Actions taken by forest operators located in “low-risk” regions:

- Gathering information to show evidence to national authorities
- Submitting and filing a report

The verification process has to be the same as for Renewable Energy Directive (current system for biofuels). The operator gathers evidence and it provides them to the "voluntary scheme accredited by EC". The scheme will evaluate and issue a proof of compliance, which will be a requirement to claim support.

Actions taken by forest operators located in “high-risk” regions:

- Gathering information to show evidence to forest holding level or certification or other third party verified schemes
- If there is no evidence there is the need to request SFM forest certification
- Submitting and filing a report

Public administrations will only have to verify the proof of compliance.

Steps 7 & 8: Choice of data sources to calculate the number of entities concerned in Policy Option 3b and assessment of the number of entities concerned

In policy option 3b, the same kind of economic operators as considered in policy option 2 (with the differentiation of “low” and “high” risk forest operators) are involved. However, the number of economic operators changes depending on the projections of the Green-X model, where forest biomass production comes from both kinds of regions (low and high-risk regions).
Step 9: Assessment of the performance of a “normally efficient entity” in each target group
This step explains the hours spent in each identified cost parameter (step 6). The cost parameters are composed of time spent on activities to respond to the requested actions and wage tariffs (as explained in the Baseline scenario – option 1).

Table 5-27 Time spent (hours) on activities – Economic operators - policy option 3b (Risk-based criterion)

Obligation to get and maintain the certification	Type of cost by frequency	Time spent (number of hours by entity concerned)	
		Internal	**External**
Producers of agriculture biomass for biofuel	One-off	70	26
	Recurring	38	12
Producers of solid biomass from agriculture	One-off	98	38
	Recurring	48	18
Forest operators "high-risk"	One-off	1,461	1,264
	Recurring	1,047	240
Forest operators "low-risk"	One-off	440	0
	Recurring	180	0
Bioenergy plants	One-off	64	16
	Recurring	36	10

Table 5-28 Time spent (hours) on activities –Public Administration - policy option 3b (Risk-based criterion)

Obligations for Public Administration	Type of cost by frequency	Time spent (number of hours by MS's)
Transposition of laws	One-off	254
Reporting to the EC	Recurring	368
Monitoring and verification	Recurring	876

Steps 10 & 11: Extrapolation of validated data to EU level and final reporting and transfer to the database

The results of the assessment of the administrative costs are shown in Table 5-25. The costs resulting from the obligations considered are presented separately for each kind of market participant. In order to show the differences in a clear way, one-off and recurring costs are presented separately. Administrative costs of Public Administration are presented in one-off and recurring costs.

Table 5-29 Results of administrative costs – Economic operators - policy option 3b (Risk-based criterion)

Market participants	Number of market participants	One-off costs (€mln)	Recurring costs (€mln)
Producers of agriculture for biofuel	7,813	24 - 44	11 - 21
Producers of solid biomass from agriculture	9,402	42 - 77	20 – 37
Forest operators "high-risk"	46	6 - 11	2 - 3
Forest operators "low-risk"	1,338	7 - 12	3 - 5
Bioenergy plants	11,318	24 - 44	14 - 26
TOTAL	29,917	145 (average)	70 (average)

Table 5-30 Results of administrative costs – Public Administration - policy option 3b (Risk-based criterion)

Public Administration	One-off costs (€mln)	Recurring costs (€mln)
TOTAL	0.09 - 0.17	0.44 - 0.77

On average, for economic operators, total one-off costs are €145mln while total recurring costs are €70mln. For Public Administration one-off costs are between €0.09-0.17mln and recurring costs between €0.44-0.77mln.

For this option, the Green-X model foresees a higher production of forest biomass compared with policy option 3a. In this case, all forest landowners within EU are considered "low-risk" producers (1,338 market participants); therefore, they can get access to the market without the use of certification. On the other hand, imported biomass from non-EU countries is considered "high-risk" and SFM certification is still needed for them.

It is worth remarking, as mentioned in Step 2, that operators sourcing from countries as "low-risk" need to spend time to collect and show evidences of SFM practices, but this effort results to be lower compared with the effort to get additional evidence on forest holding level or use a SFM certification.

In consequence, in policy option 3b the overall one-off and recurring costs for economic operators are significantly lower than policy option 3a and option 2 mainly because most of the forest operators source from the EU Market, which is considered "low-risk" and thus have less effort in showing evidence of SFM practices.

For Public Administration, policy option 3b presents slightly higher one-off costs with respect to policy option 2 (but lower with respect to policy option 3a) because of the law transposition; recurring costs are lower with respect to policy option 2 and 3a because of the lower amount of effort requested to the public side in this option. The results are also presented in the graphics below (Figure 5-35 and Figure 5-36).

Figure 5-35 Total administrative costs for private operators (one-off and recurring, in average) – policy option 3b (Risk-based criterion)

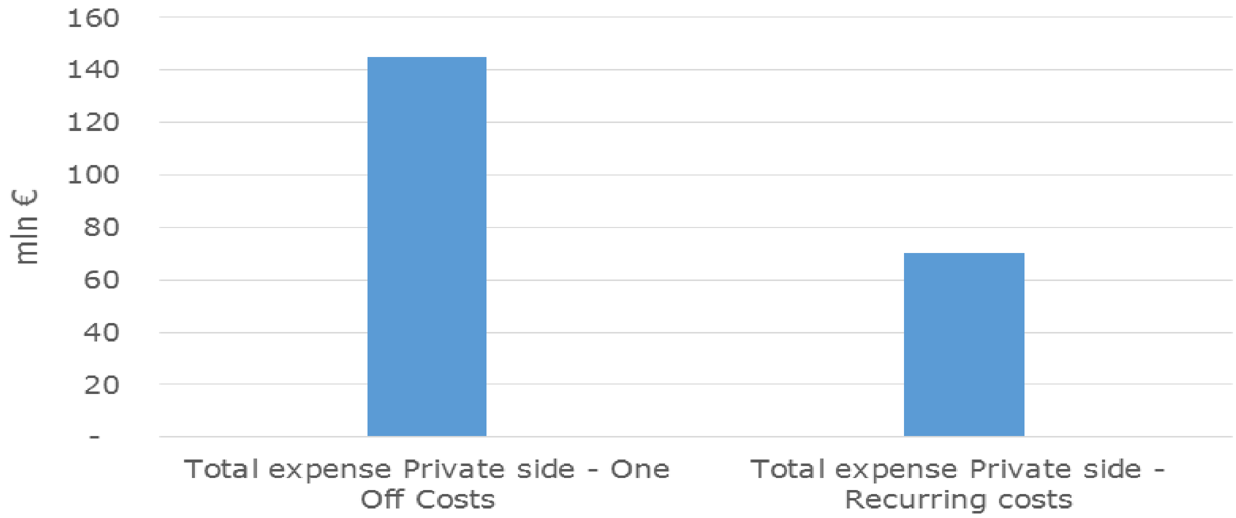
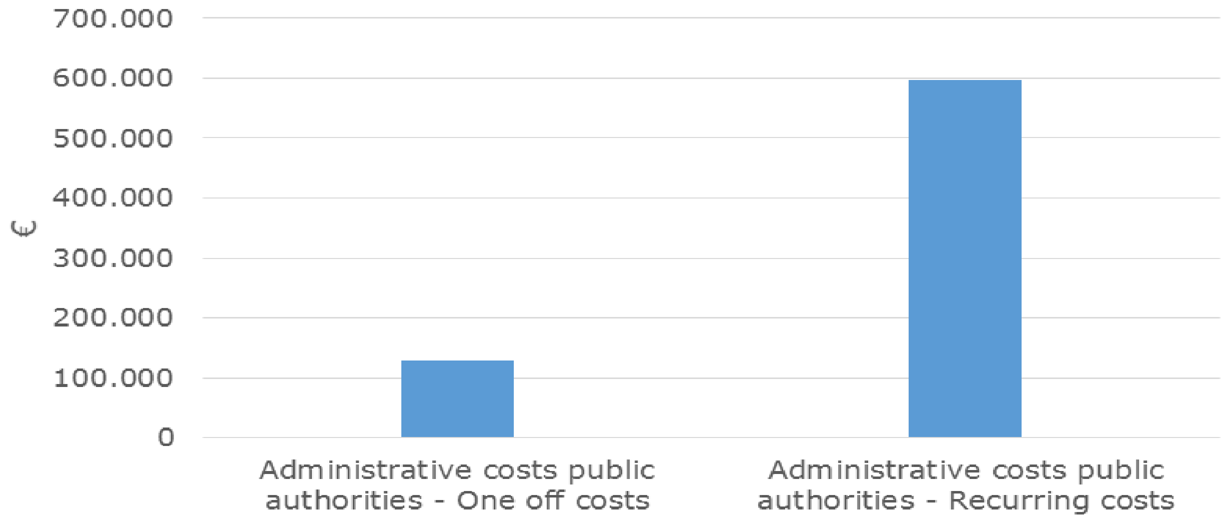


Figure 5-36 Total administrative costs for private operators (one-off and recurring, in average) – policy option 3b (Risk-based criterion)



5.3.4 Social impact: impact on employment

Under policy option 3b, employment increases by approx. 7,100 employed persons (cf. Table 5-27). With a share of 0.003% of total employment in the EU28, the impact on employment is rather low. Employment in SMEs increases by roughly 5,200 jobs.

The deployment effect generates roughly 31,000 jobs with employment growth from other RES deployment overcompensating job losses from reduced bioenergy deployment. The income effect is also positive with a job increase of approx. 14,300 employed persons. On the other hand, the budget effect leads to about 38,500 job losses.

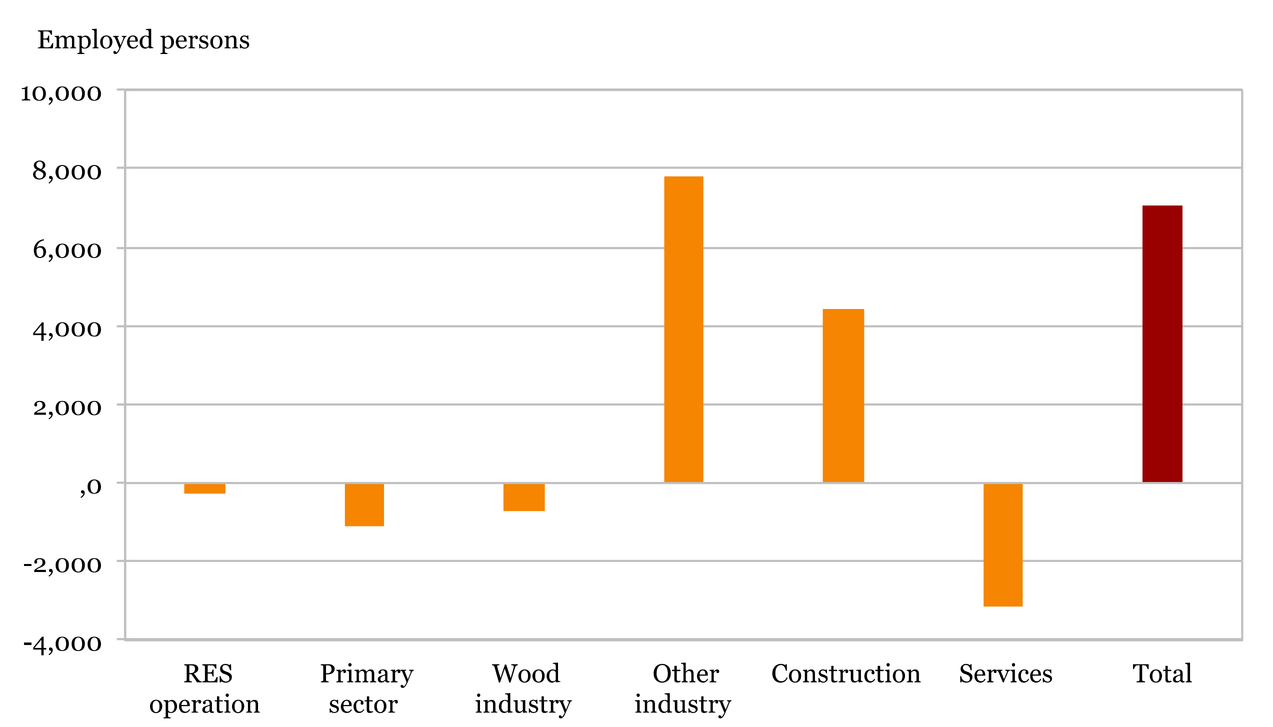
Table 5-31 Impacts of policy option 3b (Risk-based criterion) on employment in the EU28, annual average 2021 – 2030

RES technology segment EP – Employed Persons	Deployment effect EP	Income effect EP	Budget effect EP	Total impact EP
Bioenergy deployment	-11,660			
Other RES deployment	42,860			
Total	**31,200**	**14,340**	**-38,480**	**7,060**
in % of EU28 total				0.003%
Employment in SME				
Bioenergy deployment	-6,550			
Other RES deployment	30,170			
Total	**23,620**	**10,970**	**-29,430**	**5,160**

Source: calculation by Rütter Soceco

Figure 5-37 displays the employment impacts for several industries and industry aggregates. As with policy option 3a, job increases mainly materialise for other industry and construction. Job losses may be expected in the service sector and to a small extent in the bio-based primary sector and wood industry.

Figure 5-37 Impacts of policy option 3b (Risk-based criterion) on employment in the EU 28 by industry, annual average 2021 – 2030



Source: Rütter Soceco

5.4 Policy option 4 – Energy efficiency requirement

5.4.1 Bioenergy supply and demand

A breakdown of the bioenergy demand as well as that of the demand for other RES by 2030 at the sectoral level is presented in Table 5-32 for policy option 4. Supplementing table, Figure 5-38 provides a graphical summary of resulting changes, showing the change of bioenergy demand and of overall RES demand compared to baseline (policy option 1), both in absolute and in relative terms. The corresponding overview on bioenergy supply is shown in Table 5-33 whereas trade aspects are discussed in a subsequent section.

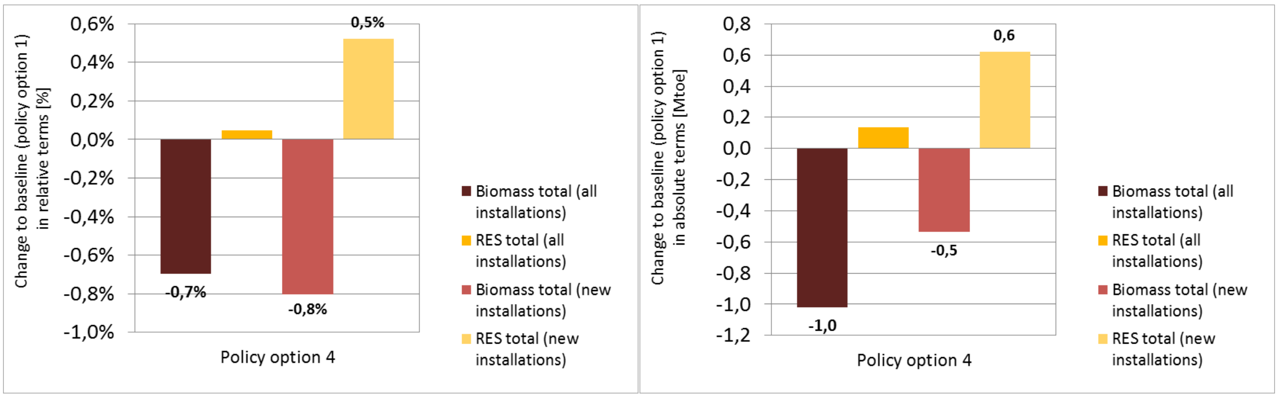
Under policy option 4, in addition to the GHG threshold i.e. the underlying concept of policy option 2, also a minimum efficiency standard of 65% for the conversion of biomass is introduced as obligatory requirement for new (large-scale) bio-based facilities in electricity and heat supply. In practical terms, this implies a redirection of biomass use in the electricity sector towards efficient CHP production, affecting investment decisions in the years post-2020. In consequence, a small increase of CHP production is applicable (+1% compared to baseline) but more pronounced appears the decline of overall biomass demand in the electricity sector (-5% compared to baseline) since bio-based electricity-only generation is phased out. This decline of demand and supply is offset mainly by an increased use of other renewables in both the electricity sector and in heating & cooling, and with respect to total biomass demand, a reduction by about 0.7%, corresponding to 1 Mtoe, is noticeable in 2030.

In general terms, it has to be noted that only small changes both in RES demand as well as in bioenergy demand and supply are applicable under this policy option. As consequence, it can be expected that also other impacts remain small in magnitude.

Table 5-32 Breakdown of demand for bioenergy and other RES by 2030 under policy option 4 (Energy efficiency requirement)

Demand for bioenergy and other RES in terms of final energy (electricity and heat generation, transport fuels) **by 2030**	**Policy option 4**	*Change to baseline (policy option 1)*	
	[Mtoe]	*[Mtoe]*	*[%]*
Electricity sector			
Biogas	5.2	*-0.3*	*-5.7%*
Solid biomass (incl. bioliquids)	14.7	*-0.9*	*-5.9%*
Biowaste	2.8	*0.0*	*0.0%*
Total bio-electricity	**22.7**	***-1.2***	***-5.1%***
Other RES-electricity	122.3	*0.9*	*0.7%*
Total RES-electricity	**145.0**	***-0.4***	***-0.3%***
Heat sector			
Derived heat from biomass (CHP, district heat)	30.7	*0.3*	*1.0%*
Direct use of biomass	73.4	*-0.1*	*-0.1%*
Total bio-heat	**104.1**	***0.3***	***0.2%***
Other RES-heat	23.3	*0.3*	*1.3%*
Total RES-heat	**127.4**	***0.6***	***0.4%***
Transport sector			
Food-based biofuels (1G)	12.5	*-0.1*	*-0.7%*
Waste-based biofuels (advanced biofuels)	6.2	*0.0*	*0.7%*
Total biofuels	**18.7**	***0.0***	***-0.2%***
Summary			
Total biomass	**145.5**	***-1.0***	***-0.7%***
Other RES	145.6	*1.2*	*0.8%*
Total RES	**291.1**	***0.1***	***0.0%***

Figure 5-38 Change in demand for bioenergy and RES total by 2030 compared to baseline (policy option 1) under policy option 4 (Energy efficiency requirement), in relative (left) and in absolute terms (right)



Remark: "New installations" means all plants installed post-2020

Table 5-33 Biomass supply by 2030 under policy option 4 (Energy efficiency requirement)

Bioenergy supply by 2030	**Policy option 4**	*Change to baseline (policy option 1)*	
	[Mtoe]	*[Mtoe]*	*[%-change]*
Domestic supply			
Agriculture	52.0	*-1.7*	*-3.1%*
Forestry	102.5	*-0.4*	*-0.4%*
Waste	21.9	*-1.1*	*-4.8%*
Total domestic biomass	**176.5**	***-3.2***	***-1.8%***
Extra-EU imports			
Solid biomass	10.7	*0.2*	*2.3%*
Biofuels	5.3	*-0.1*	*-1.3%*
Total Extra-EU biomass imports	**16.0**	***0.2***	***1.1%***
Summary			
Total biomass	**192.5**	***-3.0***	***-1.5%***

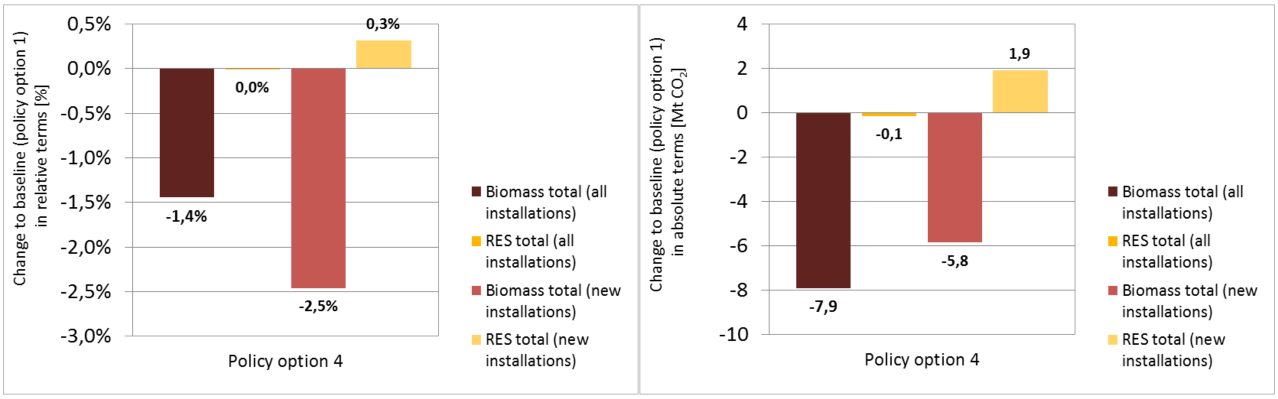
5.4.2 Environmental impacts

GHG emission savings for the supply chain

Figure 5-39 indicates the GHG performance of biomass and other RES under policy option 4, showing the change in net supply chain GHG emission savings for biomass and RES total compared to baseline (policy option 1). This overview includes a balance of GHG performance both for new installations (post-2020) and for all installations, including also the bulk of RES plants that have been installed in the years before a new EU-wide sustainability regulation is presumed entering into force (i.e. by 2021). As a general pattern, it can be seen that deviations in biomass-related GHG savings generally coincide with changes in bioenergy use. Consequently, since changes in bioenergy demand and supply are small, the GHG impacts are small in magnitude.

However, the most relevant figure results to be the balance made for RES total considering all RES installations, showing the overall impacts that may arise. Apparently, policy option 4 brings about no improvements in terms of overall GHG performance compared to baseline (policy option 1). The reason for this is the sectoral shift anticipated by the decline of bio-electricity, offset by an increase of RES in heating & cooling. Despite the fact that bio-based power supply with rather low efficiency is avoided under this policy option, sectoral shift towards heating & cooling has negative consequences on GHG performance. Because of the higher carbon intensity of fossil generation in electricity compared to heat, a decline of RES demand in the electricity causes this trend.[69]

Figure 5-39 Change in net (supply chain) GHG emission savings due to bioenergy and RES by 2030 compared to baseline (policy option 1) under policy option 4 (Energy efficiency requirement), in relative (left) and in absolute terms (right)



Remark: "New installations" means all plants installed post-2020

Impacts on land use and biodiversity

Biodiversity in forests is not directly affected by higher efficiency in biomass end conversion. Nevertheless, an important effect can be that less biomass is needed for the same amount of energy; this is mainly important when market pressure is high and sustainable harvesting levels are almost reached. A very important effect is that new biomass installations have much lower emissions than older stoves or fireplaces, so this may lead to much lower air emissions.

Land use for crop cultivation in policy option 4 is similar to the baseline because efficiency measures do not directly affect sectors that use energy crops.

5.4.3 Economic impacts

Impact on CAPEX and OPEX for RES technology sectors

Figure 5-40 shows an overview of changes in capital expenditures while implementing policy option 4 instead of option 1 (baseline). It is apparent that post-2020 CAPEX for bioenergy increase by about 0.4% on average, corresponding to an increase of investments by slightly less than €0.1bln on average per year. This negligible increase comes along with a 0.7% decline of bioenergy use, indicating that more efficient but also more expensive bio-based generation options are facilitated by this policy approach. For total RES moderate increase in investments can be expected, amounting to €1.1bln pa on average, or 2.1% if expressed in relative terms. This increase for RES total is because of the stronger penetration of wind and solar in the electricity sector as well as of solar collectors and heat pumps in heating & cooling to compensate the reduced penetration of specifically bio-electricity installations (as a consequence of the newly introduced minimum efficiency standard).

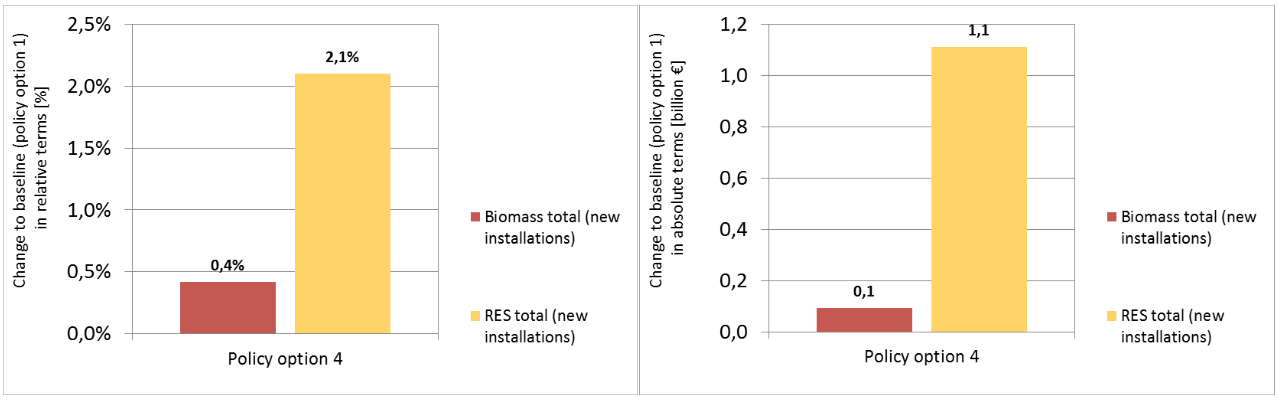
Figure 5-41 allows for a comparison of impacts on operating expenditures. Relative changes of OPEX in comparison to baseline (option 1) are here generally of similar magnitude as changes in CAPEX. OPEX show for all categories a decline, most pronounced in the case of new

[69] GHG savings per unit of final energy are higher in the electricity sector than in heating & cooling or transport due to the higher carbon intensity of fossil-based generation. In the calculations this is reflected in the different fossil fuel comparators as defined by JRC and outlined in section 1.4. Thus, any shift of RES use from electricity to heat or transport would consequently have a negative impact on overall GHG performance.

bioenergy installations (post-2020) (i.e. -3% compared to baseline) and less strong in magnitude if all RES are taken into consideration (-1%).

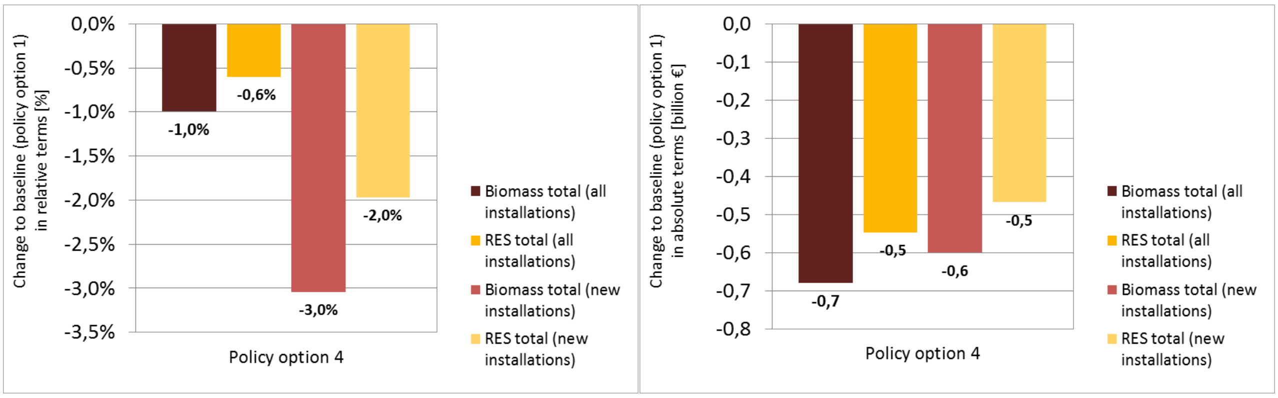
Under a combined consideration of both CAPEX and OPEX the increase in CAPEX outweighs the decline of OPEX for RES total – i.e. an increase of about €0.6bln on average per year throughout the period 2021-2030 can be identified. In contrast to total RES, in the case of bioenergy the combined consideration of CAPEX+OPEX indicates a decline by - €0.6bln on average (2021-2030) per year.

Figure 5-40 Change in average (2021-2030) annual capital expenditures for new biomass and RES installations compared to baseline (policy option 1) under <u>policy option 4</u> (Energy efficiency requirement), in relative (left) and in absolute terms (right)



Remark: "New installations" means all plants installed post-2020

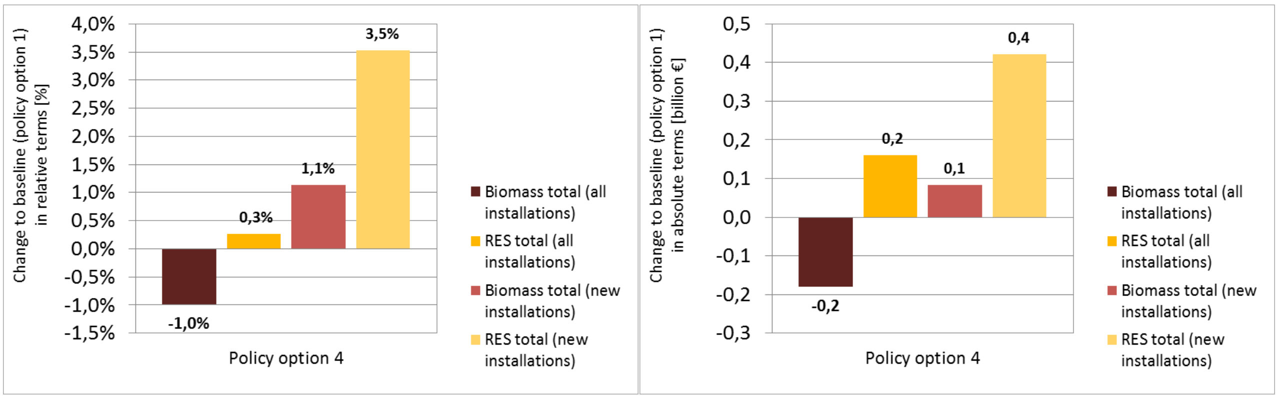
Figure 5-41 Change in average (2021-2030) annual operating expenditures for all biomass and RES installations compared to baseline (policy option 1) under <u>policy option 4</u> (Energy efficiency requirement), in relative (left) and in absolute terms (right)



Impact on support expenditures

Another important indicator in the economic evaluation of impacts arising from policy options are the support expenditures for biomass and for RES in total, respectively. A graphical illustration of resulting changes under policy option 4 in comparison to baseline policy option 1 is given in Figure 5-42. The comparison for RES total indicates a moderate increase by 3.5% on average for the assessed period between 2021 and 2030 when only new RES installations are taken into consideration. Changes of smaller magnitude are applicable for new biomass installations i.e. installed post-2020, namely +1.1% compared to option 1. When looking at all installations (i.e. existing and newly installed post-2020) changes are getting smaller in magnitude. Thus, support expenditures for RES total incl. all installations increase by 0.3% or €0.2bln pa on average. This can be classified as a small increase when compared to the increases applicable under policy options 3a or 3b.

Figure 5-42 Change in average (2021-2030) annual support expenditures for biomass and RES compared to baseline (policy option 1) under policy option 4 (Energy efficiency requirement), in relative (left) and in absolute terms (right)



Remark: "New installations" means all plants installed post-2020

It is assumed that support expenditures are entirely passed on to households, thus leading to a decrease of real purchasing power of households.

Impact on gross value added

Policy option 4 is characterised by weak shifts between technologies and rather low support expenditures. The impacts on value added are limited as well. On balance, value added increases by €0.9bln, equalling 0.007% of total EU 28 GDP.

Shifts in RES deployment lead to an increase by €0.8bln, with the decrease for bioenergy technologies overoffset by the increase observed for other RES technologies. The positive income effect adds another €200mln. On the other hand, the budget effect, induced by larger support expenditures that cause lower household consumption, dampens value added by €100mln.

Table 5-34 Impacts of policy option 4 (Energy efficiency requirement) on gross value added in the EU28, annual average 2021 – 2030

RES technology segment	Deployment effect €mln	Income effect €mln	Budget effect €mln	Total impact €mln
Absolute deviation from policy option 1				
Bioenergy deployment	-400			
Other RES deployment	1,210			
Total	**810**	**190**	**-100**	**900**
in % of EU28 total				0.007%

Source: calculation by Rütter Soceco

Impact on third countries

Table 5-35 Biomass trade by 2030 under policy option 4 (Energy efficiency requirement)

Biomass trade by 2030	**Policy option 4**	*Change to baseline (policy option 1)*	
	[Mtoe]	*[Mtoe]*	*[%-change]*
Intra-EU trade			
Agriculture	2.7	*-0.6*	*-18.5%*
Forestry	8.7	*0.2*	*2.3%*
Waste	0.0	*0.0*	*-*
Total domestic biomass	**11.4**	***-0.4***	***-3.5%***
Inter-EU trade (imports)			
Solid biomass	10.7	*0.2*	*2.3%*
Biofuels	5.3	*-0.1*	*-1.3%*
Total Extra-EU biomass imports	**16.0**	***0.2***	***1.1%***
Summary			
Total biomass	**27.4**	***-0.2***	***-0.9%***

The market for stand-alone power generation is still one of the largest demand sectors for imported solid biomass today. The UK for example consumed 1.9 Mtoe (4.7 Mt) of industrial wood pellets in 2014, mostly imported for dedicated power generation (AEBIOM, 2015). Future import of solid biomass is however largely consumed in heat sectors (83% in policy option 4 in 2030) that are not affected by the imposed minimum efficiency criterion. Solid biomass import is therefore similar in policy option 4 compared to baseline (option 1) whereas import of liquid biofuels is only marginally smaller by 2030 (1.3%). The net impact to non-EU countries of policy option 4 is therefore negligible as shown in Table 5-35.

Impact on administrative costs

This option takes over the provisions of option 2 in terms of GHG and land criteria, adding a requirement that the final energy conversion process in new large/mid CHP and heat plants (>4 MW) reaches a minimum efficiency of 65%.

Steps 1 & 4: Identification and classification of information obligations and identification of target groups

The economic operators are the same as in policy option 2 but in this case, new bioenergy plants for heat and power above 4 MW have the obligation to comply with efficiency requirements as mentioned above. It is also assumed that the way to comply with this requirement is through auditing.

Steps 2, 5, & 6: Identification of required actions, the frequency of required actions and relevant cost parameters

The required actions are the same as policy option 2, plus the new requirements for new CHP (> 4 MW) plants owners, which, apart from the actions taken to get the energy efficiency certification, need to undertake actions related to the informative obligations under the new efficiency requirements, these are:

- Data gathering of the energy efficiency of the plant
- Training the employees

For Public Administration it is assumed that costs are the same as policy option 2 adding a one-off costs for the transposition of EU energy efficiency laws to national legislation and considering higher recurring costs because national authorities need to make a more effort in verification and monitoring new CHP plants to check the compliance with new efficiency requirements.

Steps 7 & 8: Choice of data sources to calculate the number of entities concerned in Policy Option 4 and assessment of the number of entities concerned

The economic operators are the same as in policy option 2 plus the addition of an efficiency requirement for new bioenergy power plants above 4 MW.

For the estimation of the number of new heat and power plants above 4 MW with efficiency above 65% installed post-2020 the same assumptions and results described for option 2 were used. It is estimated that the total number of heat and power plants above 4 MW is 6,000 in 2013 and, taking into account the results of the Green X model, for policy option 4 a total number of 11,642 plants above 4 MW for 2030 is estimated. Taking in consideration a linear progression of the installation of plants from 2013 to 2030, the number of new heat and power plants above 4MW (with efficiency above 65% installed post-2020) is estimated at approximately 3,300 plants.

Step 9: Assessment of the performance of a "normally efficient entity" in each target group

This step explains the hours spent in each identified cost parameter (step 6). The cost parameters are composed of time spent on activities to respond to the requested actions and wage tariffs (as explained in Baseline scenario – policy option 1).

Table 5-36 Time spent (hours) on activities –Economic operators - policy option 4 (Energy efficiency requirement)

Obligation to get and maintain the certification	Type of cost by frequency	Time spent (number of hours by entity concerned)	
		Internal	**External**
Producers of agriculture biomass for biofuel	One-off	70	26
	Recurring	38	12
Producers of solid biomass from agriculture	One-off	107	38
	Recurring	48	18
Forest entities	One-off	1,256	1,086
	Recurring	632	214
New CHP plants	One-off	182	48
	Recurring	81	22
Bioenergy plants	One-off	64	16
	Recurring	36	10

Table 5-37 Time spent (hours) on activities –Public Administration - policy option 4 (Energy efficiency requirement)

Obligations for Public Administration	Type of cost by frequency	Time spent (number of hours by MS's)
Transposition of laws	One-off	338
Reporting to the EC	Recurring	460
Monitoring and verification	Recurring	938

Steps 10 & 11: Extrapolation of validated data to EU level and final reporting and transfer to the database

The results of the assessment of the administrative costs are shown in in one-off and recurring costs.

Table 5-38. The costs resulting from the obligations considered are presented separately for each kind of actor involved. In order to show the differences in a clear way, one-off and recurring costs are presented separately.

Administrative costs of Public Administration are also presented in one-off and recurring costs.

Table 5-38 Results of administrative costs – Economic operators - policy option 4 (Energy efficiency requirement)

Market participants	Number of market participants	One-off costs (€mln)	Recurring costs (€mln)
Agriculture biomass producers for biofuel	7,451	23 - 42	11 - 20
Solid biomass from agriculture producers	8,723	40 - 73	18 - 34
Forest entities	1,458	159 - 295	38 - 71
New CHP plants	3,272	20 - 38	9 - 17
Bioenergy plants	11,642	24 - 45	15 - 27
TOTAL	32,546	380 (average)	130 (average)

Table 5-39 Results of administrative costs – Public Administration - policy option 4 (Energy efficiency requirement)

Public Administration	One-off costs (€mln)	Recurring costs (€mln)
TOTAL	0.12 - 0.22	0.47 - 0.88

On average, for economic operators total one-off costs are €380mln while total recurring costs are €130mln. For Public Administration one-off costs are between €0.12-0.22mln and recurring costs between €0.47-0.88mln.

In policy option 4, one-off and recurring costs for economic operators are higher with respect to policy option 2 because new CHP plants above 4 MW installed post-2020 (3,272) need to demonstrate compliance with the energy efficiency requirement.

For public administrations and with respect to policy option 2 (EU requirement for heat and power) overall one-off costs are higher because national laws need to be adapted to the energy efficiency criteria. Recurring costs are higher because in this case there is more effort made by Public Administration in monitoring and verification activities (new CHP plants need to be verified with respect to their energy efficiency). The results are also presented in the graphics below (Figure 5-43 and Figure 5-44).

Figure 5-43 Total administrative costs for private operators (one-off and recurring, in average) – policy option 4 (Energy efficiency requirement)

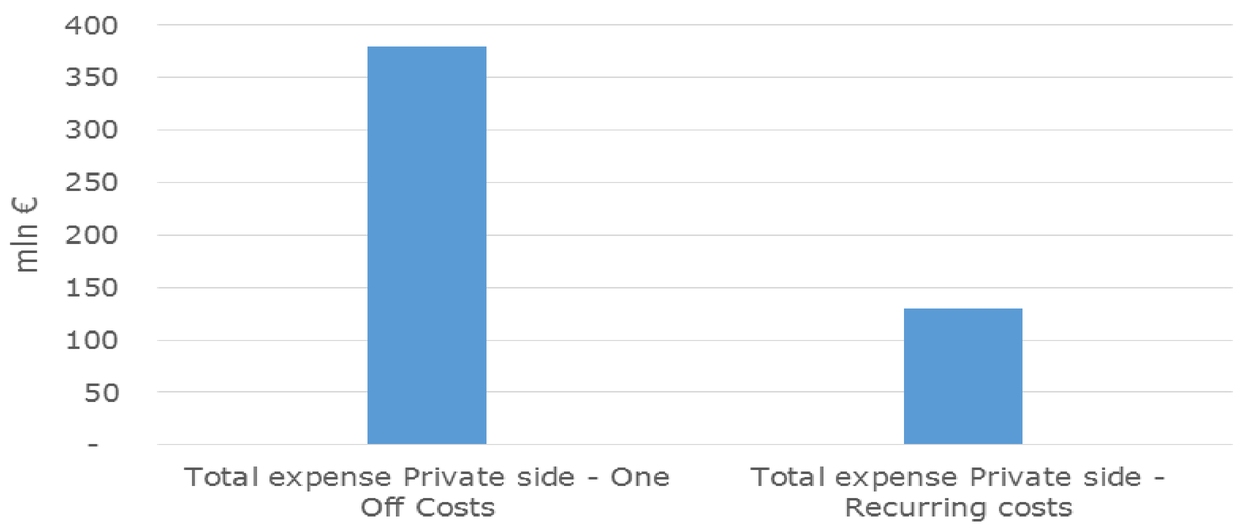
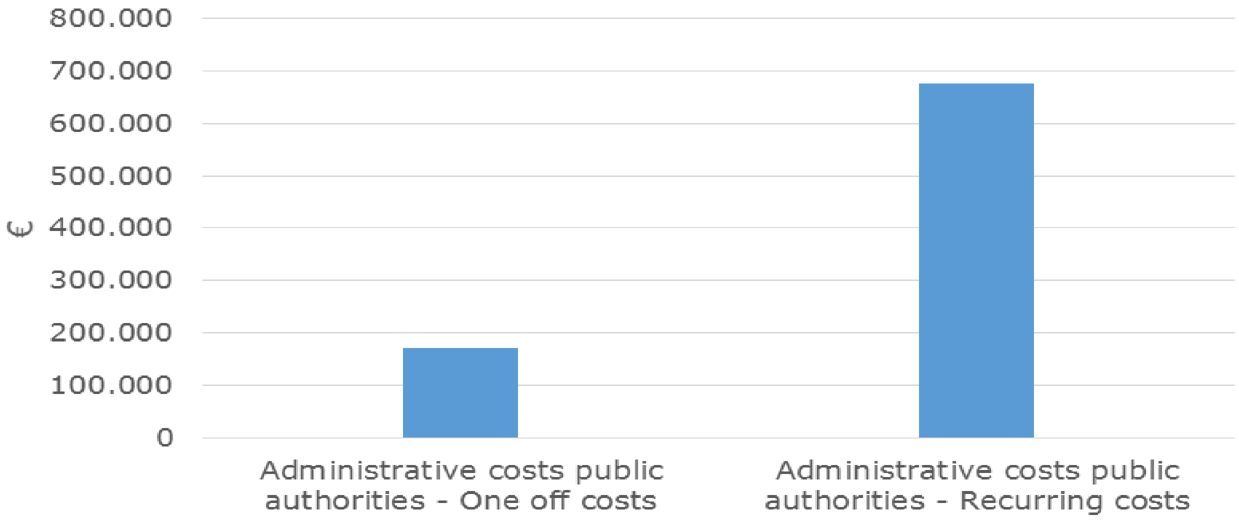


Figure 5-44 Total administrative costs for Public Administration (one-off and recurring, in average) – policy option 4 (Energy efficiency requirement)



5.4.4 Social impact: impact on employment

Under policy option 4, employment increases by approx. 2,900 employed persons (cf. Table 5-40). Thus, the impact on employment with a share of 0.001% of total employment in EU28 is rather low. Employment in SMEs increases by roughly 2,200 jobs.

The deployment effect generates roughly 2,600 jobs with employment growth from other RES deployment slightly overcompensating job losses from reduced bioenergy deployment. The income effect is also positive with a job increase of approx. 3,200 employed persons. On the other hand, the budget effect leads to about 2,800 job losses.

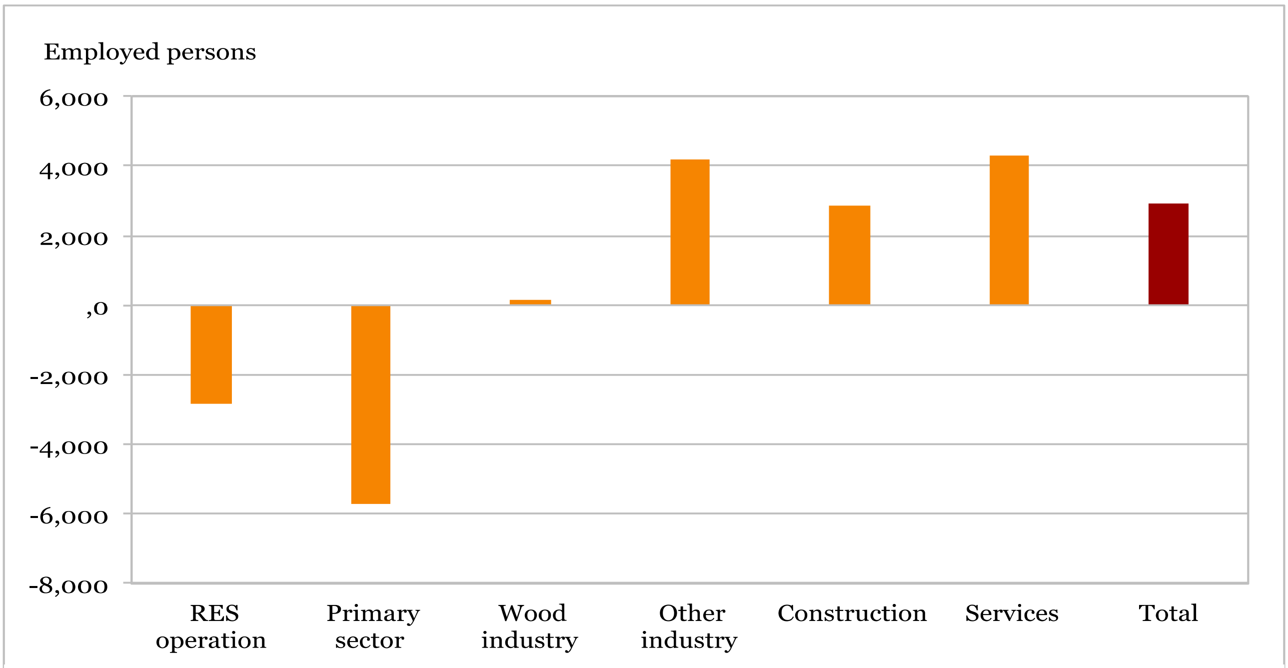
Table 5-40 Impacts of policy option 4 (Energy efficiency requirement) on employment in the EU 28, annual average 2021 – 2030

RES technology segment EP – Employed Persons	Deployment effect EP	Income effect EP	Budget effect EP	Total impact EP
Employment				
Bioenergy deployment	-10,800			
Other RES deployment	13,370			
Total	**2,570**	**3,160**	**-2,800**	**2,930**
- in % of EU28 total				0.001%
Employment in SME				
Bioenergy deployment	-7,330			
Other RES deployment	9,600			
Total	**2,270**	**2,480**	**-2,520**	**2,230**

Source: calculation by Rütter Soceco

Figure 5-45 displays the employment impacts for several industries and industry aggregates. Job losses mainly occur in operation of RES facilities (e.g. biomass power plants) and the primary sector. Job increases are foreseen in the other industry sectors, such as construction and services. Under this policy option, the employment effect of the services sector is positive, since job losses from the budget effect do not overcompensate job gains from the deployment and the income effect. Yet at the EU level, impacts are low across all industry aggregates.

Figure 5-45 Impacts of policy option 4 (Energy efficiency requirement) on employment in the EU 28 by industry, annual average 2021 – 2030



Source: Rütter Soceco

5.5 Policy option 5 – stemwood cap

5.5.1 Bioenergy demand and supply

Under policy option 5, in addition to the GHG criteria (in policy option 2), restrictions on the use of stemwood are imposed, modelled through a sharp increase of related feedstock prices of both domestic and imported supply in the years post-2020. 'Technical Annex G: Price increases for Scenario Option 5' describes the data sources that were used as a proxy for price increases.

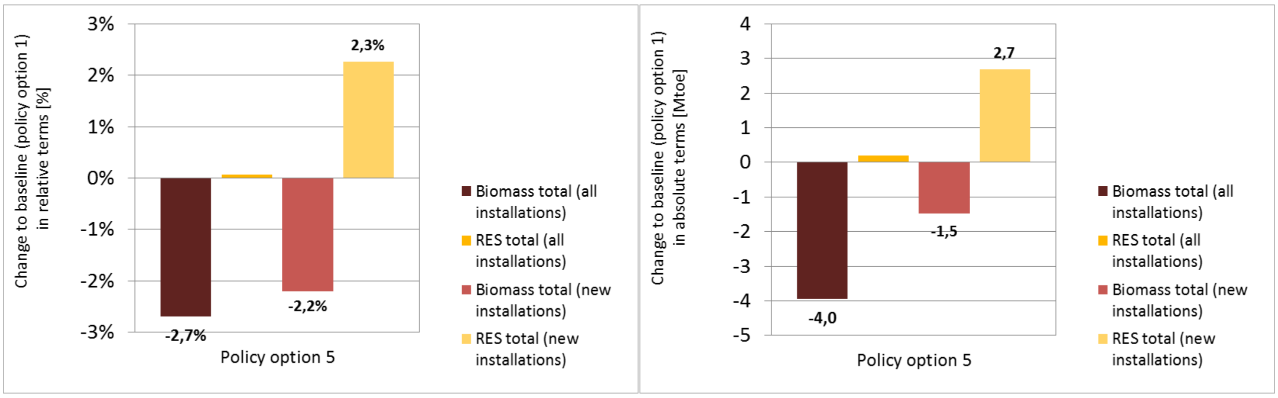
This has significant impacts on the demand for biomass in heating & cooling, declining in total by 4% (compared to baseline) and by 5% concerning the direct use (in households, tertiary and industry). A smaller demand for biomass is also becoming apparent in the electricity sector (-1.6%) whereas a strongly increased use of biofuels arises in transport (+1.5%). The decrease in overall biomass use is offset by a strongly increased use of other RES – i.e. wind and solar show an increase in electricity production by 3% in 2030, and heat pumps, geothermal heat and solar collectors contribute by 2% more than default to heating & cooling. Considering biomass supply, in total a decline by 2% can be seen, affecting imports (-6%) more than domestic supply (-2%) since the reduction of domestic forestry resources is partly offset by an enhanced use of agricultural feedstock.

Below, Table 5-37 provides a breakdown of the demand for bioenergy and other RES by 2030 at sectoral level for policy option 5. Complementary to this table, Figure 5-46 displays the resulting changes, showing the change of bioenergy demand and of overall RES demand compared to baseline (policy option 1) both in absolute and in relative terms. The corresponding overview on bioenergy supply is shown in Table 5-42 whereas trade aspects are discussed in a subsequent section.

Table 5-41 Breakdown of demand for bioenergy and other RES by 2030 under policy option 5 (stemwood cap)

Demand for bioenergy and other RES in terms of final energy (electricity and heat generation, transport fuels) **by 2030**	**Policy option 5**	*Change to baseline (policy option 1)*	
	[Mtoe]	*[Mtoe]*	*[%]*
Electricity sector			
Biogas	5.2	*-0.3*	*-5.1%*
Solid biomass (incl. bioliquids)	15.5	*-0.1*	*-0.6%*
Biowaste	2.8	*0.0*	*0.1%*
Total bio-electricity	**23.6**	***-0.4***	***-1.6%***
Other RES-electricity	125.1	*3.7*	*3.0%*
Total RES-electricity	**148.7**	***3.3***	***2.3%***
Heat sector			
Derived heat from biomass (CHP, district heat)	30.0	*-0.3*	*-1.1%*
Direct use of biomass	70.0	*-3.5*	*-4.8%*
Total bio-heat	**100.0**	***-3.9***	***-3.7%***
Other RES-heat	23.5	*0.5*	*2.1%*
Total RES-heat	**123.4**	***-3.4***	***-2.7%***
Transport sector			
Food-based biofuels (1G)	12.7	*0.1*	*0.6%*
Waste-based biofuels (advanced biofuels)	6.3	*0.2*	*3.3%*
Total biofuels	**19.0**	***0.3***	***1.5%***
Summary			
Total biomass	**142.5**	***-4.0***	***-2.7%***
Other RES	148.6	*4.2*	*2.9%*
Total RES	**291.1**	***0.2***	***0.1%***

Figure 5-46 Change in demand for bioenergy and RES total by 2030 compared to baseline (policy option 1) under policy option 5 (stemwood cap), in relative (left) and in absolute terms (right)



Remark: "New installations" means all plants installed post-2020

Table 5-42 Biomass supply by 2030 under policy option 5 (stemwood cap)

Bioenergy supply by 2030	Policy option 5	*Change to baseline (policy option 1)*	
	[Mtoe]	*[Mtoe]*	*[%-change]*
Domestic supply			
Agriculture	55.5	*1.9*	*3.5%*
Forestry	98.7	*-4.2*	*-4.1%*
Waste	22.0	*-1.0*	*-4.4%*
Total domestic biomass	**176.3**	***-3.4***	***-1.9%***
Extra-EU imports			
Solid biomass	9.7	*-0.8*	*-7.7%*
Biofuels	5.2	*-0.3*	*-4.6%*
Total Extra-EU biomass imports	**14.8**	***-1.1***	***-6.7%***
Summary			
Total biomass	**191.1**	***-4.4***	***-2.3%***

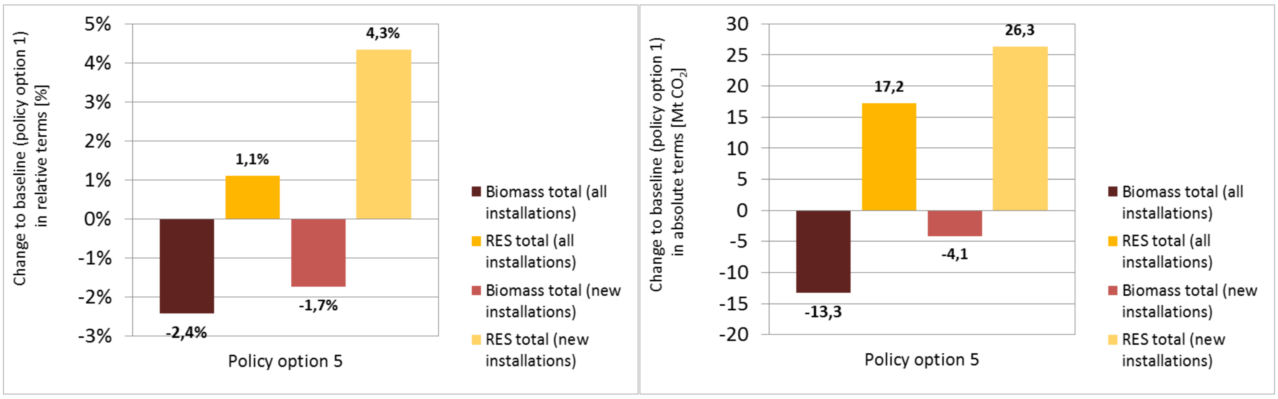
5.5.2 Environmental impacts

GHG emission savings for the supply chain

The GHG performance of biomass and other RES under policy option 5 is displayed in Figure 5-47, indicating the change of net supply chain GHG emission savings for biomass and RES total compared to baseline (policy option 1). This graph shows the GHG performance both for new installations (post-2020) and for all installations, including also the bulk of RES plants that have been installed in the years before a new EU-wide sustainability regulation is presumed entering into force (i.e. by 2021). As a general pattern, it can be seen that deviations in biomass-related GHG savings generally coincide well with changes in bioenergy use.

The most relevant figure is however the balance made for RES total considering all RES installations, showing the overall impacts that may arise. Apparently, policy option 5 brings moderate improvements in terms of overall GHG performance compared to baseline (policy option 1): GHG savings can be increased by 1.1% in 2030, corresponding to 17.2 Mt CO_2. Generally, the strong improvements in GHG performance are because of the shift of RES demand from heating & cooling to the electricity sector. Since per unit of final energy more fossil fuels can be replaced in the electricity sector – a consequence of the higher carbon intensity due to lower conversion efficiency in power generation compared to heat supply – a higher gross GHG avoidance is indispensable.

Figure 5-47 Change in net (supply chain) GHG emission savings due to bioenergy and RES by 2030 compared to baseline (policy option 1) under policy option 5 (stemwood cap), in relative (left) and in absolute terms (right)

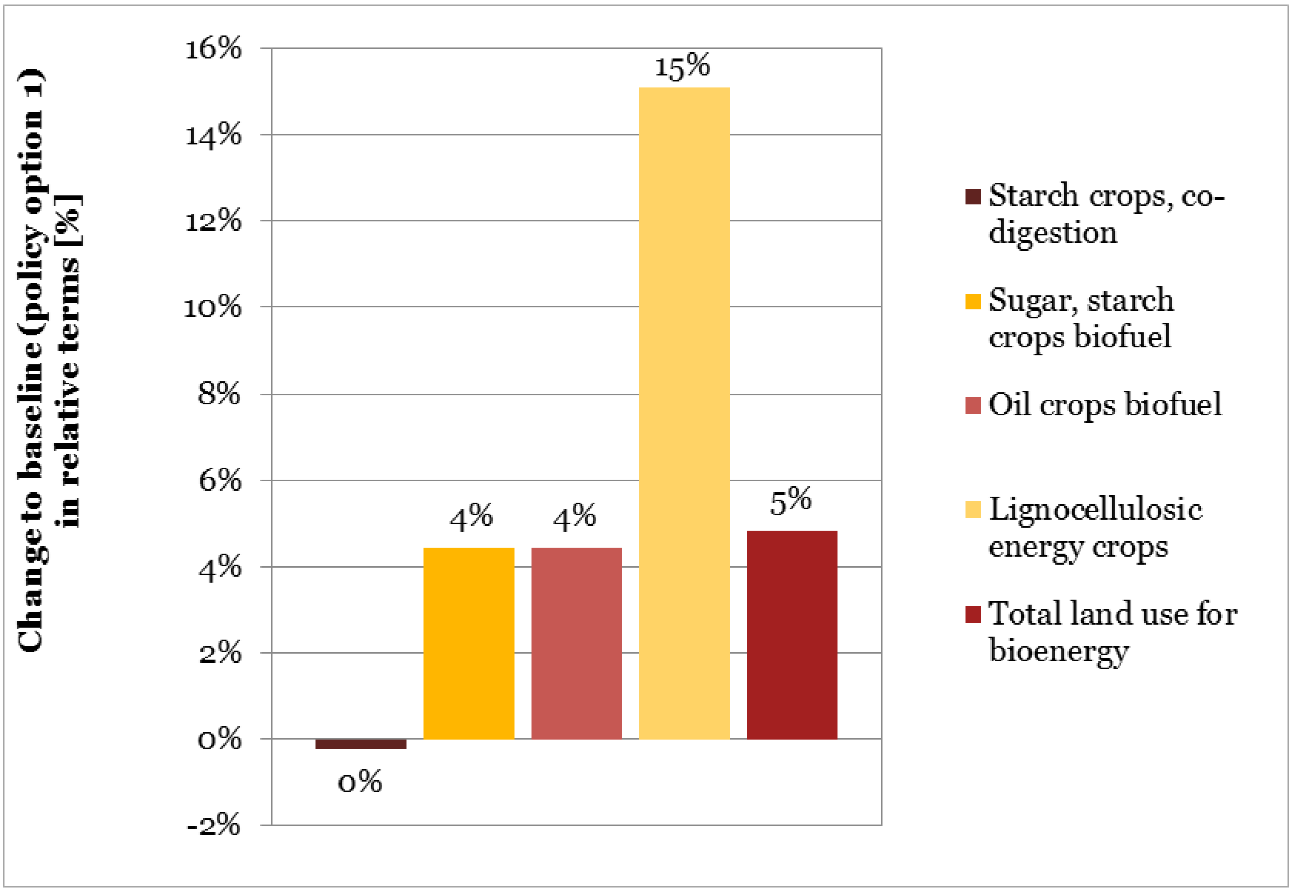


Remark: "New installations" means all plants installed post-2020

Impacts on land use and biodiversity

The impact of land use under policy option 5 relative to land use in the baseline scenario (policy option 1) is shown in Figure 5-48. The high cost for stemwood reduces its economic potential for bioenergy, which is partly offset by increased supply of biomass from agriculture, resulting in a 5% larger land use compared to baseline (option 1). Both land used for the cultivation of lignocellulosic energy crops and land used for biofuel crops (oil crops, starch, sugar) are slightly larger (0.2 Mha) compared to baseline. The pressure on additional agricultural land use between baseline and option 5 remains modest because of the shift to other RESs including electricity from wind and solar power, heat pumps, geothermal heat and solar collectors.

Figure 5-48 Change in land use for energy crop cultivation in the EU by 2030 in policy option 5 (stemwood cap) compared to baseline (Option 1).

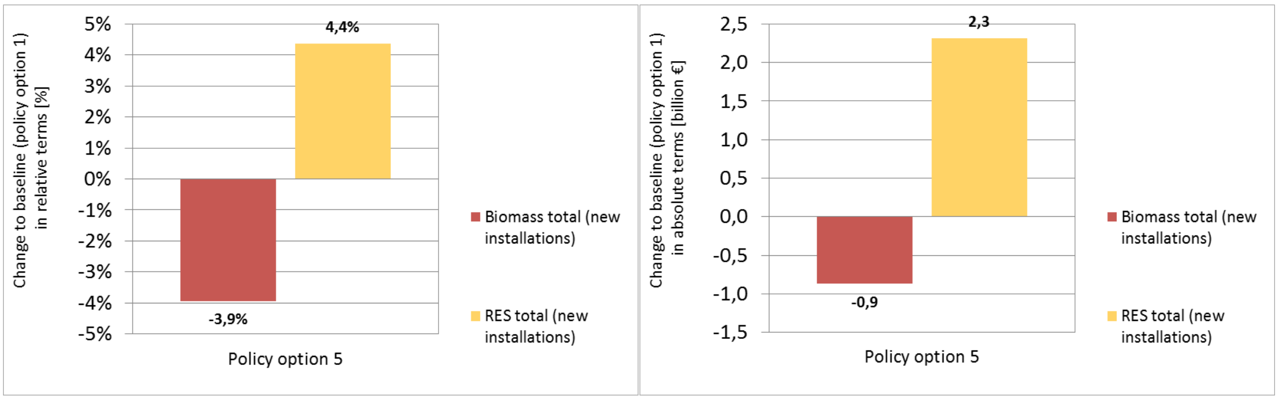


5.5.3 Economic impacts

Impact on capital (CAPEX) and operating expenditures (OPEX) for RES technology sectors

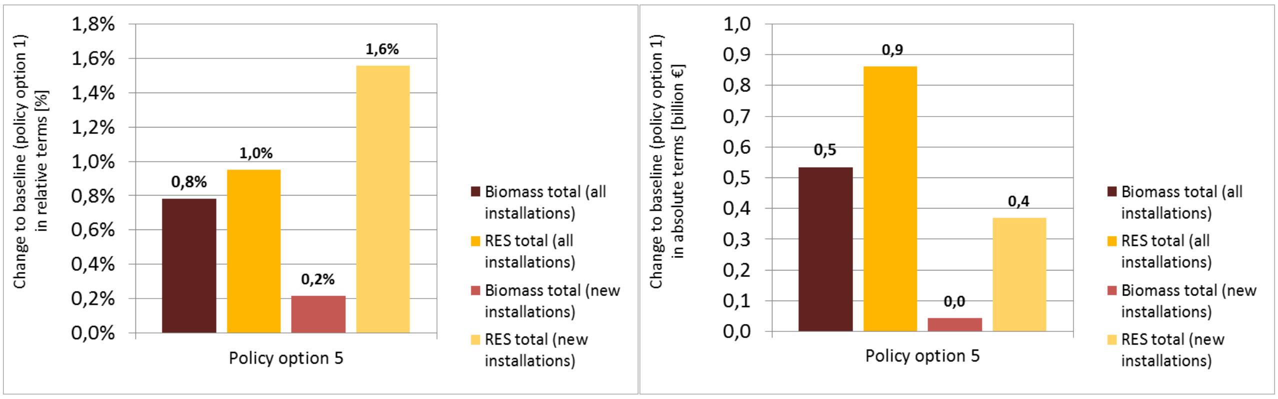
Figure 5-49 provides an overview of changes in capital expenditures that can be expected if policy option 5 is implemented instead of option 1 (baseline). It is apparent that in the years post-2020 CAPEX for bioenergy decline by about 3.9% on average, corresponding to a decrease by slightly less than €1.0bln pa, on average. For total RES a comparatively strong increase in investments can be expected, amounting to €2.3bln pa, on average, or 4.4% if expressed in relative terms. This increase for RES total is a consequence of the stronger penetration of wind and solar in the electricity sector as well as of solar collectors and heat pumps in heating & cooling to compensate the reduced demand for specifically bio-heat (as a consequence of the newly introduced sustainability regulation and the arising limitations for stemwood).

Figure 5-49 Change in average (2021-2030) annual capital expenditures for new biomass and RES installations compared to baseline (policy option 1) under <u>policy option 5</u> (stemwood cap), in relative (left) and in absolute terms (right)



Remark: "New installations" means all plants installed post-2020

Figure 5-50 Change in average (2021-2030) annual operating expenditures for all biomass and RES installations compared to baseline (policy option 1) under <u>policy option 5</u> (stemwood cap), in relative (left) and in absolute terms (right)



A comparison of impacts on operating expenditures is displayed in Figure 5-50. Relative changes of OPEX in comparison to baseline are here generally of smaller magnitude than changes in CAPEX. OPEX shows for all categories an increase, most pronounced in the case of RES total considering all installations, where OPEX increases by €0.9bln pa.

Under a combined consideration of both CAPEX and OPEX the increase in CAPEX coincides with a rise of OPEX, leading to an combined increase by about €3.2bln pa on average throughout the period 2021-2030. In contrast to total RES, in the case of bioenergy the combined consideration of CAPEX+OPEX indicates a decline by -€0.4bln pa on average (2021-2030).

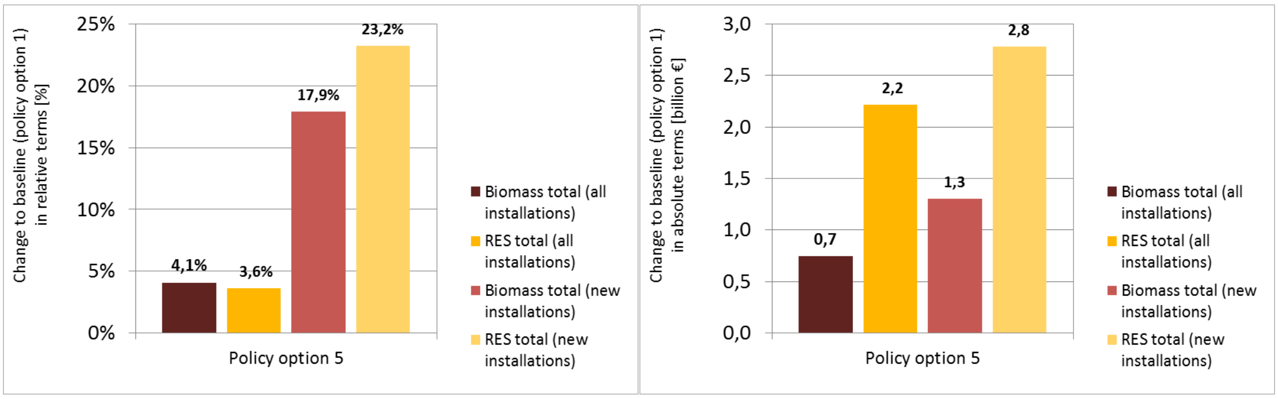
Impact on non-energy sectors

As discussed earlier, a cap on the use of stemwood for energy is very problematic, although so far, stemwood is not used in large quantities for CHP. The socio-economic impact is therefore low. To a large extent, trade flows will be redirected, but if no alternate buyer than CHP is found it will potentially dramatically alter trade flows.

Impact on support expenditures

A graphical illustration of resulting changes in support expenditures for bioenergy and RES total under policy option 5 in comparison to baseline (policy option 1) is given in Figure 5-51. The comparison for RES total indicates a strong increase by ca. 23% on average for the assessed period between 2021 and 2030 when only new RES installations are taken into consideration. Changes of smaller magnitude are applicable for new biomass installations i.e. installed post-2020, +17.9% compared to option 1. When looking at all installations i.e. existing and newly installed post-2020, changes are smaller. Thus, support expenditures for RES total i.e. including all installations, increase by 3.6% or €2.2bln pa on average. This can be classified as a strong increase in comparison to several other policy options.

Figure 5-51 Change in average (2021-2030) annual support expenditures for biomass and RES compared to baseline (policy option 1) under policy option 5 (stemwood cap), in relative (left) and in absolute terms (right)



Remark: "New installations" means all plants installed post-2020

It is assumed that support expenditures are entirely passed on to households, thus leading to a decrease of real purchasing power of households.

Impact on gross value added

Policy option 5 is characterised by moderate shifts between technologies and moderate support expenditures. The impacts on value added are moderate too. On balance value added increases by €2.1bln, equalling 0.016% of total EU28 GDP.

Shifts in RES deployment lead to an increase by €2.6bln, with the decrease for bioenergy technologies strongly offset by the increase for other RES technologies. This impact is directly related to the changes in investment and O&M expenditures mentioned above. The positive deployment effect consequently increases employment and household income, causing the income effect to add another €900mln of value added. On the other hand, the larger support expenditures have a negative impact on household budget and consumption expenditures, so that the budget effect dampens value added by €1.4bln.

Table 5-43 Impacts of policy option 5 (stemwood cap) on gross value added in the EU28, annual average 2021–2030

RES technology segment	Deployment effect €mln	Income effect €mln	Budget effect €mln	Total impact €mln
Absolute deviation from policy option 1				
Bioenergy deployment	-640			
Other RES deployment	3,230			
Total	**2,590**	**880**	**-1,400**	**2,070**
- in % of EU28 total				0.016%

Source: calculation by Rütter Soceco

Impact on third countries

Increasing the cost of roundwood has a larger effect to domestic forest biomass supply compared to imported wood pellets. Raw biomass feedstock contributes between 27% and 31% to Free On Board (FOB) prices of wood pellets. FOB prices of wood pellets from non-EU countries are estimated to increase by 24% because of an 85% increase in raw feedstock prices[70]. This explains why imports of solid biomass are only 8% smaller in policy option 5 whereas imports of liquid biofuels are 5% smaller compared to baseline option 1 (Table 5-44).

Table 5-44 Biomass trade by 2030 under policy option 5 (stemwood cap)

Biomass trade by 2030	Policy option 5	*Change to baseline (policy option 1)*	
	[Mtoe]	*[Mtoe]*	*[%-change]*
Intra-EU trade			
Agriculture	3.8	*0.5*	*16.7%*
Forestry	7.1	*-1.4*	*-16.4%*
Waste	0.0	*0.0*	*-*
Total domestic biomass	**10.9**	***-0.8***	***-7.2%***
Inter-EU trade (imports)			
Solid biomass	9.7	*-0.8*	*-7.7%*
Biofuels	5.2	*-0.3*	*-4.6%*
Total Extra-EU biomass imports	**14.8**	***-1.1***	***-6.7%***
Summary			
Total biomass	**25.8**	***-1.9***	***-6.9%***

[70] Extra-EU biomass are based on the increased cost of raw material compared to the Free On Board (FOB) prices of wood pellets in export terminals. Raw biomass feedstock is calculated to contribute between 27% and 31% to FOB prices of wood pellets (105 – 117 €/t). Raw material cost are derived from Ehrig et al. 2014 and range between 28.06 – 33.5 €/t pellets.

Impact on administrative costs

Policy option 5 starts from the same context as policy option 2 and additionally includes restrictions on the use of stemwood.

Table 5-45 Time spent (hours) on activities –Economic operators - policy option 5 (stemwood cap)

Obligation to get and maintain the certification	Type of cost by frequency	Time spent (number of hours by entity concerned)	
		Internal	**External**
Producers of agriculture biomass for biofuel	One-off	70	26
	Recurring	38	12
Producers of solid biomass from agriculture	One-off	98	38
	Recurring	48	18
Forest entities	One-off	1,256	1,086
	Recurring	632	214
Bioenergy plants	One-off	102	26
	Recurring	55	16

Table 5-46 Time spent (hours) on activities –Public Administration - policy option 5 (stemwood cap)

Obligations for Public Administration	Type of cost by frequency	Time spent (number of hours by MS's)
Transposition of laws	One-off	169
Reporting to the EC	Recurring	377
Monitoring and verification	Recurring	931

Steps 10 & 11: Extrapolation of validated data to EU level and final reporting and transfer to the database

The results of the assessment of the administrative costs are shown in Table 5-47 Results of administrative costs – Economic operators. The costs resulting from the obligations considered are presented separately for each kind of actor involved. In order to show the differences in a clear way, one-off and recurring costs are presented separately. Administrative costs of Public Administration are presented in one-off and recurring costs.

Table 5-47 Results of administrative costs – Economic operators - policy option 5 (stemwood cap)

Market participants	Number of market participants	One-off costs (€mln)	Recurring costs (€mln)
Agriculture biomass producers for biofuel	7,738	24 - 44	11 - 21
Solid biomass from agriculture producers	9,359	41 - 77	20 - 37
Forest entities	1,399	153 - 284	36 - 68
Bioenergy plants	11,516	39 - 72	23 - 43
TOTAL	30,012	366 (average)	129 (average)

Table 5-48 Results of administrative costs – Public Administration - policy option 5 (stemwood cap)

Public Administration	One-off costs (€mln)	Recurring costs (€mln)
TOTAL	0.06 - 0.11	0.45 - 0.83

In average, for economic operators, total one-off costs are €366mln while recurring costs are €129mln. For Public Administration one-off costs are between €0.06-0.11mln and recurring costs between €0.45-0.83mln.

In Option 5, for economic operators, overall one-off and recurring costs are higher than in Option 2 because more effort is needed to demonstrate the roundwood cap requirement.

From the public side, the cap has cost implications: recurring costs are higher because more time is spent to verify the compliance of bioenergy plants. There is no significant differences in one-off costs with respect to Option 2 because it is assumed that the cap on roundwood use is already considered in EU legislation (therefore no transposition of additional legislation is needed). The results are also presented in the graphics below (Figure 5-52 and Figure 5-53).

Figure 5-52 Total administrative costs for private operators (one-off and recurring, in average) – policy option 5 (stemwood cap)

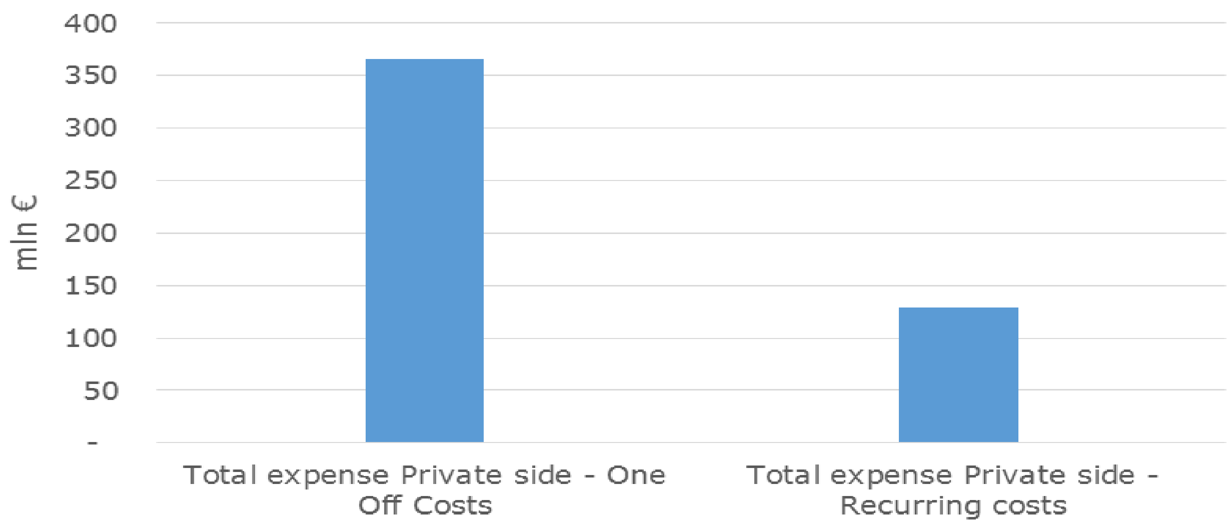
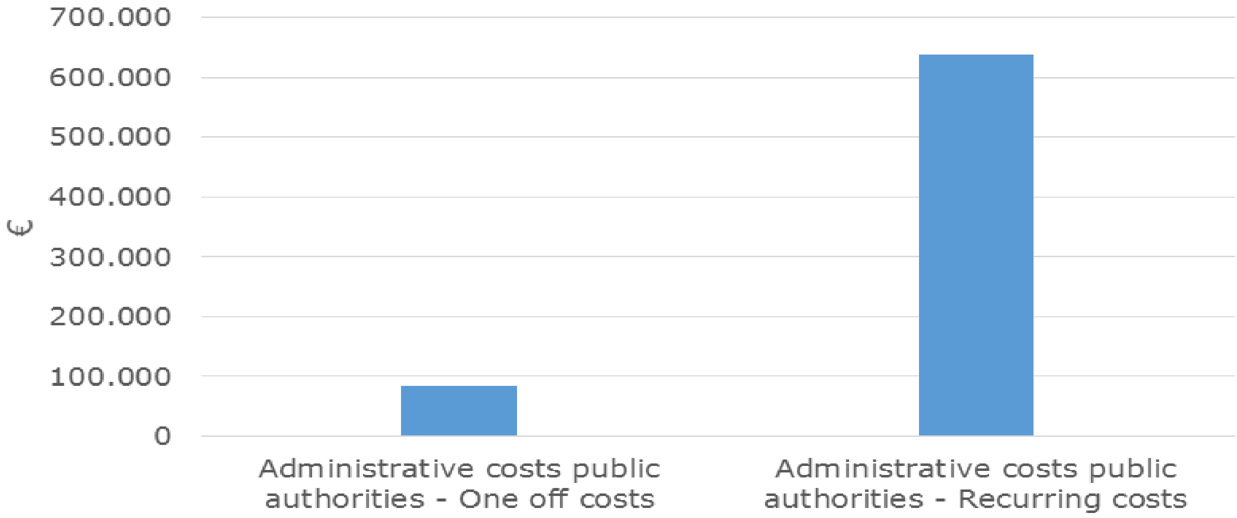


Figure 5-53 Total administrative costs for Public Administration (one-off and recurring, in average) – policy option 5 (stemwood cap)



5.5.4 Social impact: impact on employment

Under policy option 5, employment increases by approx. 20,000 employed persons (cf. Table 5-45), equalling 0.009% of total employment in EU 28. Employment in SME increases by roughly 12,900 jobs. The employment impact of this option is the largest among the considered policy options, since policy option 5 has the largest positive economic impulse in absolute terms, measured as RES deployment expenditures minus support expenditures. Still at the EU level, the employment impact can be considered as small.

Turning to the partial effects amounting to the total impact, the deployment effect generates roughly 29,800 jobs with employment growth from other RES deployment significantly overcompensating job losses from reduced bioenergy deployment. The income effect is also positive with a job increase of approx. 14,000 employed persons. On the other hand, the budget effect leads to about 23,800 job losses.

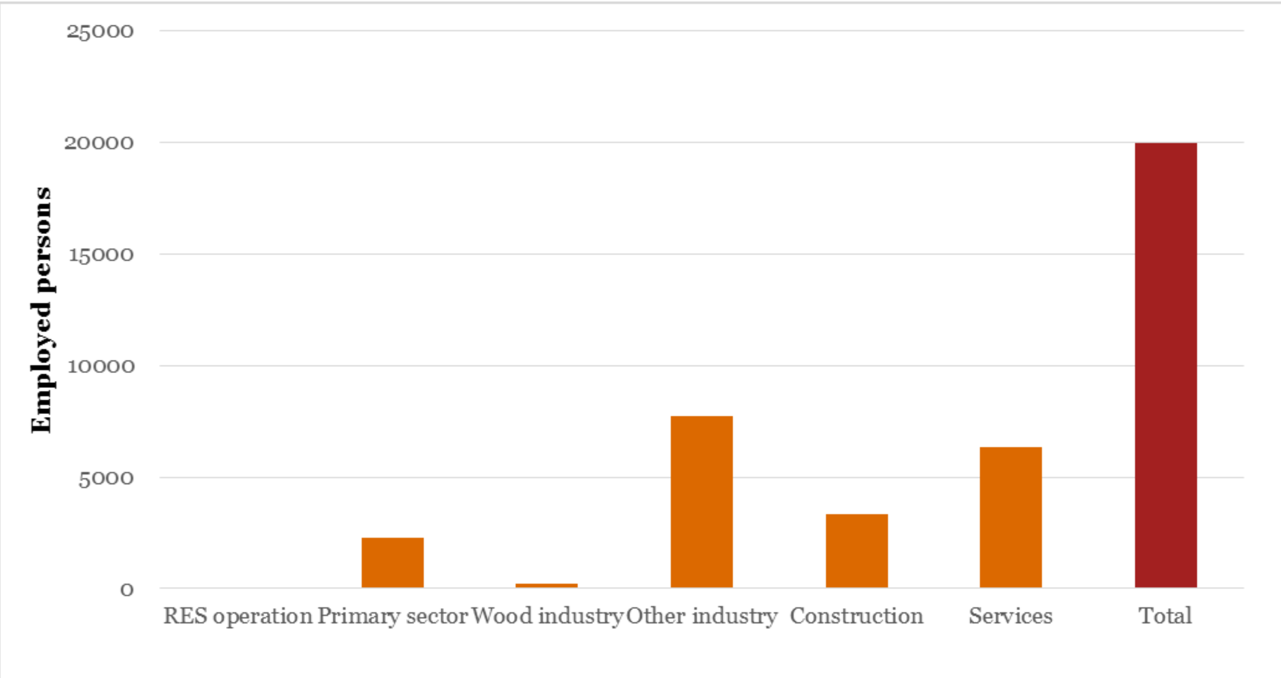
Table 5-49 Impacts of policy option 5 (stemwood cap) on employment in the EU28, annual average 2021 – 2030

RES technology segment	Deployment effect	Income effect	Budget effect	Total impact
EP Employed Persons	EP	EP	EP	EP
Employment				
Bioenergy deployment	-6,510			
Other RES deployment	36,290			
Total	**29,780**	**14,040**	**-23,840**	**19,980**
in % of EU28 total				0.009%
Employment in SME				
Bioenergy deployment	-4,900			
Other RES deployment	25,530			
Total	**20,630**	**10,660**	**-18,350**	**12,940**

Source: calculation by Rütter Soceco

Figure 5-54 displays the employment impacts for several industries and industry aggregates. Job increases occur in all sectors, especially in other industry. Employment in the primary sector also increases due to larger fuel expenditures under policy option 5. Yet at the EU level, impacts at the industry level remain rather low.

Figure 5-54 Impacts of policy option 5 (stemwood cap) on employment in the EU 28 by industry, annual average 2021 – 2030



5.6 Comparison of policy options

In this section, a semi-quantitative comparison is performed on the five policy options against baseline, using the following assessment criteria:

- Effectiveness: the extent to which the option achieves the specified objectives that are relevant for the problem addressed by the option;
- Cost-efficiency: the extent to which the specified objectives can be achieved for a given level of resources at least cost. Within this study, the cost-efficiency indicator is CAPEX in €/tonne of CO2eq avoided for new post-2020 installations. This criterion also addresses the administrative burden of the option in general terms; specific administrative costs are discussed under the economic impacts;
- Consistency: the extent to which options are coherent with the overarching objectives of EU CEP as well as other climate and energy policies;
- Environmental, Economic and Social impact.

The magnitude of impacts as compared with the baseline scenario is indicated by means of the following semi-quantitative scoring:

++ strongly positive; + positive; ≈ marginal-neutral; – negative; – – strongly negative
The scoring is based on the quantitative results that are derived from the model-based assessment as well as on the subsequent qualitative analysis, described in chapter 5. In Table 5-50, advantages and drawbacks are identified for each policy option in terms of its impacts.

Table 5-50 Summary of the impacts of the policy options against the baseline (policy option 1)

Impacts on: (compared to option 1 - baseline)	Policy option 2 EU biomass criteria for heat and power	Policy option 3a SFM certification	Policy option 3b Risk-based approach for forest biomass	Policy option 4 Energy efficiency requirement	Policy option 5 Stemwood cap
Biomass supply and demand	0.5% decline in biomass demand.	16% decline in biomass demand. Strong shift from RES heat to (non-biomass) RES electricity and biofuels. Strong decline of forest biomass supply (under modelling assumptions), only partly offset by an increased use of agricultural biomass.	3.0% decline of biomass demand. Small shift from RES heat to (non-biomass) RES electricity. Strong reduction of Extra-EU import of forest biomass (under modelling assumptions).	1.5% decline of overall biomass demand.	2.3% decline of overall biomass demand, in particular for heat production from biomass (-4%). Mainly counter-balanced by a growth of (non-biomass) electricity.
Direct GHG savings	+0.1% GHG savings	+4.4% GHG savings	+1.5% GHG savings	no impact	+1.1% GHG savings
Land use change	No additional agricultural land use.	Reduced supply of forest biomass results in shift to energy crops (+1.4 Mha).	Reduced supply of forest biomass results in shift to energy crops (+0.4 Mha).	No additional agricultural land use.	Reduced supply of forest biomass results in shift to energy crops (+0.3 Mha).
Overall investments and operational costs	+€0.4bln pa increase in CAPEX for RES. Combined effect of CAPEX+OPEX of +€0.3bln pa.	+€12.7bln pa increase in CAPEX for RES. Combined effect of CAPEX+OPEX of +€10.0bln pa.	+€2.9bln pa increase in CAPEX for RES, minor impact on OPEX. Combined effect of CAPEX+OPEX of +€3.0bln pa.	+€1.1bln pa increase in CAPEX for RES. Combined effect of CAPEX+OPEX of +€0.6bln pa.	+€2.3bln pa increase in CAPEX; OPEX increases. Combined effect of CAPEX+OPEX of +€3.2bln pa.
Support expenditures/household energy costs	+0.1% (€0.06bln pa) increase of renewable energy support	+23% (€14.0bln pa) increase of renewable energy support	+6% (€3.6bln pa) increase of renewable energy support	+0.3% (€0.2bln pa) increase of renewable energy support	+4.0% (€2.2bln pa) increase of renewable energy support

	expenditures	expenditures	expenditures	expenditures	expenditures
Gross value added	Value added increase of €0.33bln	Value added increase of €4.80bln	Value added increase of €1.40bln	Value added increase of €0.90bln	Value added increase of €2.1bln
Employment (including SMEs)	4,400 extra jobs SMEs: 3,500 extra jobs	6,000 extra jobs SMEs: 2,000 extra jobs	7,000 extra jobs SMEs: 5,000 extra jobs	3,000 extra jobs SMEs: 2,200 extra jobs	20,000 extra jobs SMEs: 13,000 extra jobs
Administrative costs *(Private recurring costs are dominant)*	Administrative cost estimation on average €30mln pa higher than baseline	Administrative cost estimation on average €55mln pa higher than baseline	Administrative cost estimation on average €22mln pa higher than baseline	Administrative cost estimation on average €43mln pa higher than baseline	Administrative cost estimation on average €43mln pa higher than baseline
Extra-EU Imports	Marginal impact on Extra-EU imports (+0.1%)	66% (6.9Mtoe) reduction of solid biomass imports from non-EU countries. 18% (1.0 Mtoe) higher Extra-EU imports of liquid biofuels	66% (6.9Mtoe) reduction of solid biomass imports from non-EU countries. 4% (0.2 Mtoe) lower Extra-EU imports of liquid biofuels	Limited increase of Extra-EU imports (+1%, +0.2Mtoe)	8% (0.8Mtoe) reduction of solid biomass imports from non-EU countries. 5% (0.3 Mtoe) lower Extra-EU imports of liquid biofuels

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