Forest Research

Assessment of EU LULUCF Regulation

The EU LULUCF Regulation: Help or hindrance to sustainable forest biomass use?

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1 Introduction

1.1 Historical context

The burning of the biomass of plants and trees to produce heat and light goes back to pre-history, and it has been used to generate power since the industrial revolution. However, since the second half of the 20th century, biomass has been increasingly recognised as a potential renewable energy source since it can be purposely grown and re-grown for burning to produce energy, or for conversion to liquid and gaseous fuels. The idea that burning biomass-derived energy sources could involve low or possibly zero net emissions of greenhouse gases (GHGs) to the atmosphere, particularly carbon dioxide (CO_2), became popular in the final decades of the twentieth century. This was based on the observation that, in a simplistic sense, growing biomass and then burning it could involve a closed cycle of exchanges of carbon between the atmosphere (as CO_2) and plant and tree biomass. That is, CO_2 was 'removed' from the atmosphere as the plants and trees grew and retained as carbon in the form of biomass until released back to the atmosphere when the biomass was burnt.

1.2 Rationale for policy on bioenergy

These ideas led to biomass-derived energy (bioenergy) being promoted (at least implicitly) as potentially having a very important role in efforts to increase the deployment of renewable energy and achieve reductions in GHG emissions. This has been reflected in the policies of many national governments and also in the EU since at least the start of the 21st century. In the EU, the Renewable Electricity (RES) Directive[1] (2001) set targets for 2010 that 12% of gross national energy consumption, and 22% of electricity, should be produced from renewable energy sources. Although no specific target was set for biomass consumption specifically, it was explicitly referred to as a relevant source of renewable energy. In 2009 the Renewable Energy Directive (RED)[2] set mandatory targets for Member States, so that the Community as a whole would achieve at least 20% of energy from renewable sources (including biomass) in 2020. Again, there were no specific targets for solid biomass, however sustainability and conversion efficiency requirements for its use were included. This has been updated further in the recast

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.156.01.0026.01.ENG
[2] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32009L0028

Renewable Energy Directive (RED II)[3,4] of 2018, which again increased the binding, overall target to a 32% share of the EU's gross final energy consumption from renewable sources in 2030. Again, sustainability and GHG emissions savings criteria were included for the use of biomass and biofuels, though again no specific targets were set for bioenergy use. Bioenergy consumption is encouraged by its treatment under the EU Emissions Trading System (EU ETS)[5,6], which provides a direct financial incentive to actors in the Energy Sector to use bioenergy sources. This is a direct result of treating bioenergy consumption as resulting in zero net GHG emissions (see below). Over the period 2010 to 2015, the use of forest biomass in solid form as an energy feedstock in the EU28[7] countries is estimated to have risen from about 90 million oven-dry tonnes (Modt) to 133 Modt[8]. This includes the consumption of wood fuel pellets, estimated at 10 Modt in 2010 and 23 Modt in 2016. The share of wood pellet consumption in the EU28 supplied by imported pellets is estimated to have risen from 2.3 Modt to 7.7 over this period.

Behind the inclusion of bioenergy in these policies is a presumption that, in broad terms, its utilisation can be regarded as 'carbon-neutral' (i.e. growing, harvesting and consuming bioenergy results in more or less zero net GHG emissions). Typically, the possibility that this may *not* be the case (i.e. that using bioenergy sources may lead to increased GHG emissions or alternatively reduced negative GHG emissions) has been assumed to be confined to situations involving land-use change (e.g. deforestation). However, there is growing recognition that, more generally, the production and consumption of bioenergy can have significant impacts on net GHG emissions, potentially involving significant increases. This is particularly the case where there are significant changes in the scale of bioenergy use, and the issue is most pertinent for biomass energy sources derived from forests (referred to here as 'forest bioenergy'). Under RED II, the potential risks of

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3 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.328.01.0082.01.ENG&toc=OJ:L:2018:328:TOC
4 https://ec.europa.eu/energy/topics/renewable-energy/renewable-energy-directive/overview_en
5 https://ec.europa.eu/clima/policies/ets_en
6 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32020D1071&qid=1604511075083
7 EU Member States plus the UK.
8 The quoted estimates are for solid woody biomass consumed for energy purposes, supplied either directly from forests or as solid 'industrial residues' or 'co-products' of the wood processing industries such as sawmills. Contributions to woody biomass consumption from post-consumer waste and in the form of black liquor (a by-product of the paper industry) are excluded. If these contributions are included, the estimated consumption in 2010 and 2015 is equivalent to 150 Modt and 170 Modt, respectively. The estimates presented here are based on an analysis of available data sources carried out by Forest Research. Accurate estimates of the consumption in the EU of woody biomass from forests are difficult to calculate and vary significantly in the literature. Estimates for total use of forest bioenergy in the EU in 2010 (including solid biomass, black liquor and post-consumer waste) vary between 120 Modt and 190 Modt, while those for 2015 vary from around 140 Modt to nearly 200 Modt. Estimates for consumption of individual components are frequently not specifically quoted, but, where they are, can also vary significantly between sources.

bioenergy use leading to GHG emissions increases are addressed indirectly by a requirement that (Article 29, paragraph 7):

"Biofuels, bioliquids and biomass fuels produced from forest biomass […] shall meet the following land-use, land-use change and forestry (LULUCF) criteria:

(a) the country […] of origin of the forest biomass:

> *(i) is a Party to the Paris Agreement;*
>
> *(ii) has submitted a nationally determined contribution (NDC) to the United Nations Framework Convention on Climate Change (UNFCCC), covering emissions and removals from agriculture, forestry and land use which ensures that changes in carbon stock associated with biomass harvest are accounted towards the country's commitment to reduce or limit greenhouse gas emissions as specified in the NDC; or*
>
> *(iii) has national or sub-national laws in place, in accordance with Article 5 of the Paris Agreement, applicable in the area of harvest, to conserve and enhance carbon stocks and sinks, and providing evidence that reported LULUCF-sector emissions do not exceed removals;*

(b) where evidence referred to in point (a) of this paragraph is not available, the biofuels, bioliquids and biomass fuels produced from forest biomass shall be taken into account […] if management systems are in place at forest sourcing area level to ensure that carbon stocks and sinks levels in the forest are maintained, or strengthened over the long term".

The EU and its Member States meet Criteria a(i) and a(ii) as stated above, however this does not apply for all potential sources of biomass fuels (i.e. those imported from non-EU countries).

The basis for this approach is somewhat obscure, but apparently reflects a complication that arises in GHG emissions reporting and accounting for bioenergy, in that the biomass is *produced* in the '*Land Use, Land-Use Change and Forestry' (LULUCF) Sector*, as represented in National GHG Inventories, but is usually *consumed* in the *Energy Sector*. To avoid the double-counting of GHG emissions from bioenergy as a result of reporting them in both the Energy Sector and the LULUCF Sector in National GHG Inventories, the convention is adopted that any CO_2 emissions arising directly from the consumption (burning) of biomass in the Energy Sector are reported as zero. This is on the presumption that the CO_2 emissions are captured by reporting in the LULUCF Sector. However, the consequence of this convention is to mask, at least partially, the impacts on GHG emissions from the consumption of bioenergy. To enable countries to track progress towards emissions reductions targets, accounting rules are applied to the CO_2 emissions (and to carbon sequestration by vegetation) reported for the LULUCF Sector. Generally, the accounting rules for forests (and forest management) are complicated, for reasons discussed later in this report.

For EU Member States from 2021, GHG emissions accounting rules for the LULUCF Sector are the subject of *Regulation (EU) 2018/841 - Inclusion of greenhouse gas emissions and removals from land use, land use change and forestry in the 2030 climate and energy framework, and amending Regulation (EU) No 525/2013 and Decision No 529/2013/EU* (hereafter referred to here as the 'LULUCF Regulation'), which came into force in 2018. Recital (15) of the Regulation states that:

"The internationally agreed IPCC Guidelines state that emissions from the combustion of biomass can be accounted for as zero in the energy sector on condition that such emissions are accounted for in the LULUCF sector. In the Union, emissions from biomass combustion are currently accounted for as zero […], therefore consistency with the IPCC Guidelines would only be ensured if such emissions were reflected accurately in this Regulation."

It follows that the LULUCF Regulation is expected to work synergistically with RED II and the EU ETS as three key building blocks of EU climate and energy policy. In particular, the LULUCF Regulation must work with RED II and the EU ETS, by influencing the national governments of Member States to ensure that the use of biomass for energy (particularly forest bioenergy) helps reduce GHG emissions on a timescale that is relevant for climate change mitigation. (This may be contrasted with the treatment of bioenergy under the EU ETS, which provides a direct financial incentive to actors in the Energy Sector to use bioenergy sources. This is a direct result of treating bioenergy consumption as resulting in zero net GHG emissions.)

1.3 Purpose and structure of report

The European Commission has stated that, "*climate action is at the heart of the recently introduced European Green Deal*[9]", including the aim of "*ambitiously cutting greenhouse gas emissions*" and achieving 'climate-neutrality' by 2050. This has been followed up by the presentation of the EU 2030 Climate Target Plan, which deepens the planned cuts in EU GHG emissions (compared to 1990) to between 50% and 55%, compared with a previous target of 40%. The European Commission's Communication of this Plan raises the prospect of more modest reliance on bioenergy sources, compared with previous ambitions. This appears to be partly in recognition of trade-offs between trying to achieve GHG removals in the LULUCF Sector and trying to achieve GHG emissions reductions in other sectors

[9] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

(notably the Energy Sector)[10]. Given this context, the purpose of this brief is to provide a critical assessment of the fitness for purpose of the EU LULUCF Regulation to meet the climate-action aim of the European Green Deal. The focus is on the effectiveness of the LULUCF Regulation in providing a complementary function to RED II and the EU ETS, to support the use of forest bioenergy in the EU, in ways that will deliver effective GHG emissions reductions.

1.4 Structure of this report

The substantive content of this report is presented as four sequential essays. Firstly, Section 2 provides a concise discussion of the essential science behind forest carbon balances and of the impacts of forest management and biomass utilisation. This is followed by an overview of the historical development of LULUCF accounting approaches (particularly for forests), which is presented in Section 3. In Section 4, an assessment is made of the robustness of the LULUCF Regulation in capturing GHG emissions potentially arising from producing and consuming forest bioenergy, and for promoting the avoidance of such emissions. The implications of this assessment are discussed in Section 5, with particular emphasis on potential issues identified by the assessment.

[10] Specifically, the text of the Communication states that, "*Projected increases in bioenergy use by 2030 are limited compared to today. To ensure the land use sink can continue to strengthen and improve, biomass for energy use in the EU should be produced sustainably, and environmental impacts should be minimised. To limit impact on biodiversity, the use of whole trees … for energy production – produced in the EU or imported – should be minimised. Any unsustainable intensification of forest harvesting for bioenergy purposes should be avoided…*".

2 Status of the science

2.1 How is it possible for forest bioenergy to be carbon-neutral?

The science of forest GHG balances, the impacts of forest management and the role of harvested wood, including bioenergy, has been the subject of intensive research for at least 20 years. Whilst many facts have been established and insights gained, the question of whether the significant extraction and use of forest biomass as an energy source has positive or negative impacts on GHG emissions remains strongly contested. There are a great many scientific and technical papers and reports on the subject, apparently offering contradictory evidence and conflicting conclusions. It is therefore impossible to provide a comprehensive synthesis and assessment of all relevant scientific literature in this report. Reference can be made to several existing published reviews, such as those of Marelli *et al*. (2013) and Matthews *et al*. (2014). Here, the essential facts of relevance to forest carbon or CO_2 balances are presented, with particular relevance to understanding the potential impacts of forest bioenergy supply and consumption. The climate impacts of forests and forest management also involve non-CO_2 GHGs and non-GHG phenomena. These impacts, whilst important in some cases, are secondary to the scope of this report.

Figure 1 illustrates the essential exchanges of carbon involved in the CO_2 balance of forests, obviously in very simplified form. The example is of a forest already under management to produce wood to make a range of products ranging from construction timber to bioenergy.

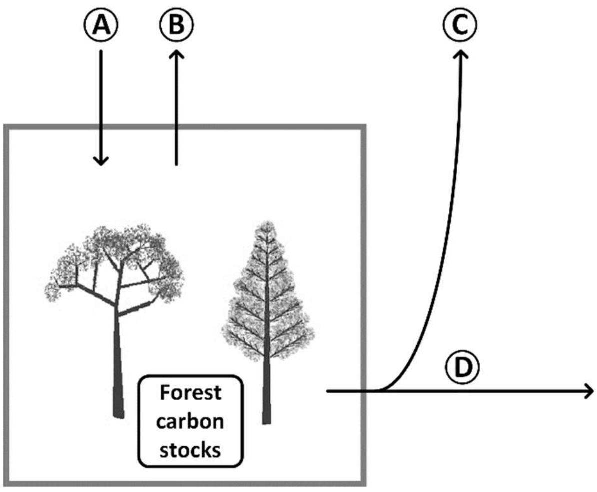

Figure 1. Illustration of the carbon balance of a forest that has been under long-term management for wood production

The box in Figure 1 encloses the forest (trees, deadwood, forest litter and soil). Flows of carbon across the boundaries of the box suggest removal of CO_2 from the atmosphere or losses of carbon from the forest. Much of the debate about the roles of forest management and harvested biomass in GHG balances is confused by differing use (and misuse) of terminology, such as the terms 'carbon sink' and 'carbon sequestration'. Frequently, different definitions are taken for these terms, which can lead to misunderstandings and conflicting conclusions. This point is discussed further in Matthews (2020; see Sections 2.15 and 2.16). It is vital to define clearly the different carbon reservoirs and exchanges of carbon described in Figure 1:

- The net exchange formed by the arrows (A) and (B) represents the capturing of CO_2 from the atmosphere into the forest (as carbon), as a result of the photosynthesis of trees, represented by (A), minus the losses of carbon represented by (B), as a result of respiration and decay processes, and also incidents of natural disturbance (such as fires, storms or attacks by pests and diseases). This net flow of carbon, essentially associated with tree growth and mortality (but also involving deadwood, litter and soil carbon exchanges), is referred to in this report as the '*forest carbon pump*'. Usually, the forest carbon pump removes carbon from the atmosphere and incorporates it into the biomass and organic matter of forests. However, the pump may occasionally be reversed when significant natural disturbance events occur in the forest.
- The arrows (C) and (D) represent the flows of carbon out of the forest resulting from the felling of trees and harvesting of biomass as part of forest management. The arrow (C) represents the loss of carbon to the atmosphere from unutilised parts of trees that are left to decay in the forest (referred to in this report as '*forest residues*'). The arrow (D) represents the flow of carbon out of the forest in the biomass that is harvested and extracted for use as products.
- The '*net forest carbon balance'* is defined in this report as the combined balance formed by (A) – (B) – (C) – (D). This net balance results in the retention of a reservoir of carbon in the tree biomass, deadwood, and litter and soil organic matter of the forest. This reservoir of carbon in the forest may be referred to as a 'carbon pool' and the quantity of carbon in it may be referred to as the 'carbon stock' of the forest.

If the net balance of (A), (B), (C) and (D) is positive (net inflow into the forest), the carbon stock in the forest increases. If the balance is negative, the forest carbon stock gets smaller.

One critical point that can be revealed by the above description is the importance of how the ‘forest carbon sink’ and ‘forest carbon sequestration’ are defined in debates about forest management and the role of harvested wood:

- The forest/forestry sector typically thinks of the ‘forest carbon pump’ as defined above as representing the ’forest carbon sink’
- Environmentalists and most forest carbon researchers typically think of the ‘net forest carbon balance’ as defined above as representing the ‘forest carbon sink’.

The use of the same term to mean different things has led to frequent misunderstandings, confusion and disagreements amongst stakeholders when discussing how forests should be managed and how wood should be used, to achieve reductions in CO_2 emissions.

A further important insight may be gained by considering the carbon flows into and out of the forest illustrated in Figure 1:

If the forest has been under management for wood biomass production for a long time, such that the rate of wood harvesting matches the capacity of the forest to grow more biomass, then (A) – (B) – (C) – (D) = 0. That is, the system is in exact carbon balance. It follows that continuing to harvest biomass from the forest at rates consistent with pre-existing harvesting rates involves zero net CO_2 emissions from the forest.

This observation is the basis for claims that biomass harvested from forests is (or at least sometimes can be) ‘carbon-neutral’. If the historical rate of wood biomass harvesting is lower than the potential of the forest to grow more biomass, then the magnitude of (A) will be bigger than the combined magnitude of (B), (C) and (D). This might lead to the suggestion that the continuation of biomass harvesting at historical rates involves net negative CO_2 emissions. However, there is a serious flaw in drawing the conclusion that biomass harvested from forests can be carbon-neutral, provided simply that the rate of harvesting is within the capacity of the forests involved to grow more biomass. The problem arises when the scale of biomass harvesting is changed, compared with previous levels of harvesting. Before discussing this, attention should be given to the fate of the carbon in the wood products harvested from the forest. This is illustrated, in simplified form, in Figure 2.

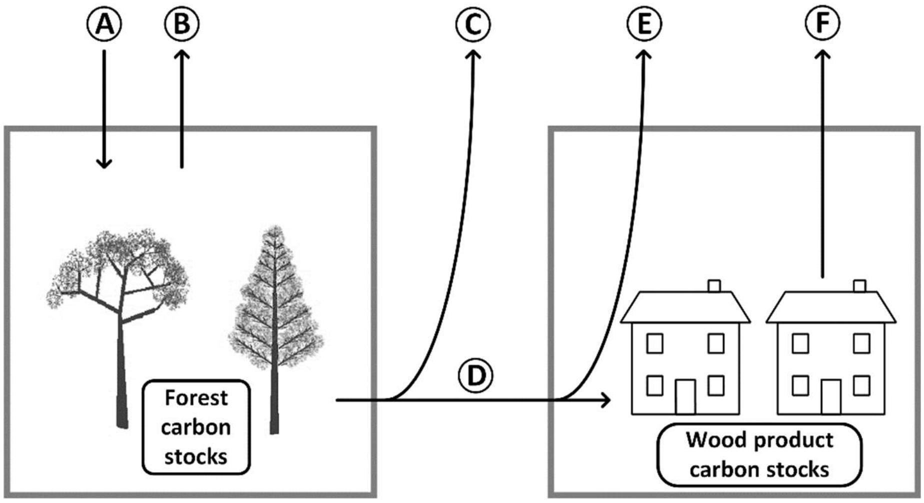

Figure 2. Illustration of the carbon balance of a forest - wood products system that has been under long-term management for wood production

The right-hand box in Figure 2 represents the reservoir of carbon in harvested wood that is extracted from forests and made into useful products (e.g. construction timber, furniture, pallets etc.).

The outflow of harvested wood from the forest, represented by the arrow (D) in Figure 2, goes into the wood products box. However, part of this inflow flows out again, effectively immediately, into the atmosphere as CO_2. This rapid outflow, represented by the arrow (E), represents wood that is burnt during wood product processing (possibly as waste) and the burning of wood fuel, i.e. forest bioenergy in its various forms.

The carbon in the wood making up the various non-energy wood products is not released to the atmosphere immediately. It is retained in the wood whilst the products are in use, are reused or recycled, until the product(s) are disposed of, either by burning (incineration) or decaying in landfill. At this point, the carbon is released to the atmosphere (possibly partly as methane in the case of disposal to a 'wet' landfill; this potential issue is not considered further here). This outflow of carbon from non-energy wood products is represented by the arrow (F) in Figure 2.

The 'net wood products balance' is defined here as the combined balance (D) – (E) – (F). This balance results in the retention of a reservoir of carbon in wood products, referred to as the 'wood-products carbon pool'. The quantity of carbon in this pool is the 'carbon stock' in wood products.

For a given constant inflow of wood into the products box in Figure 2, the size of the wood products carbon stock is determined by the lifespans of the products manufactured from the wood. These lifespans can vary considerably, from very short for bioenergy to multiple decades for construction timber. However, in all cases, these lifespans are taken to be finite (i.e. no wood products last forever). If the flow of carbon in wood into the wood-products box (D) is constant, and the lifespans of wood products are constant, then only a finite carbon stock will accumulate in wood products. The magnitude of this stock is determined by the combination of the inflow and the product lifespans.

A further insight may be gained from the discussion above:

If the supply of wood to make products has remained at the same level for many years, and continues to do so, and if the pattern of wood utilisation (for different products) also stays the same, then (D) – (E) – (F) = 0. That is, the wood products system is in exact carbon balance.

Hence, considering the complete system in Figure 2:

If the forest has been under management for wood biomass production for a long time, such that the rate of wood harvesting matches the capacity of the forest to grow more biomass, and if the supply of wood to make products has remained at the same level for many years, and continues to do so, and if the pattern of wood utilisation (for different products) also stays the same, then (A) – (B) – (C) – (E) – (F) = 0. That is, the system is in exact carbon balance. It follows that continuing to harvest biomass from the forest at rates consistent with pre-existing harvesting rates involves zero net CO_2 emissions from the forest.

(Note the term (D) flows out of the forest system and into the wood-products system, the two flows cancelling each other out, so (D) does not appear in this statement of the carbon balance.)

The management of forests so as to ensure that the rate of wood harvesting matches (or is less than) the capacity of the forest to grow more wood, is consistent with a fundamental principle that is well understood in the forest sector as the 'principle of sustainable-yield management'. A clear understanding of this principle is important for understanding the discussion presented above and below. Sustainable-yield management does not represent a comprehensive approach to sustainable forest management or sustainable wood production, considering all possible criteria and impacts. Such a comprehensive approach would consider impacts on (for example), the stability of forest sites (e.g. with respect to wind risk), the nutrient and water balances of sites, the eutrophication of surrounding watercourses and lakes, the biodiversity of forest stands and the surrounding landscape, and economic and social factors. Rather, sustainable-yield forest management is concerned narrowly, but crucially, with ensuring that levels of wood production from forest areas are actually achievable, given the estimated potential productivity of the forests. In reality, a more comprehensive consideration of the sustainability of specified levels of forest bioenergy production is needed. However, as a minimum fundamental requirement, scenarios for forest bioenergy supply (or wood supply more generally) need to be consistent with the principle of sustainable yield as defined here.

The observations above are the basis for suggesting that the forest and wood sector (i.e. including wood product manufacturing) can be regarded as in carbon balance, when the forests are managed to ensure that harvesting is within the limits of sustainable yield[11].

It may also be observed from the discussion of Figure 2 that the only ways of increasing the size of the carbon stock in wood products are either to increase the magnitude of the inflow (D) (i.e. use more wood products) or to find ways to retain wood in products for longer, or a combination of both. (Note that this assumes that there is sufficient demand from consumers for more and/or longer-lived wood products.)

2.2 Carbon impacts of changes in scale of forest biomass harvesting

From the discussion of Figure 2, it is possible to see how, in principle, the long-term management of forest areas to produce a range of wood products could involve zero net CO_2 emissions to the atmosphere or, under some circumstances, might even be claimed to involve net negative CO_2 emissions. However, it is necessary to consider the consequences of a decision to increase the scale of supply of harvested wood, to produce more bioenergy and/or other products. This is illustrated in Figure 3.

[11] Sometimes, environmentalists and forest carbon researchers may point out that there is an implied 'opportunity cost' here, i.e. associated with continuing to harvest wood at pre-existing rates to make products. Specifically, the decision could be taken instead to stop harvesting wood, or to restrict harvesting to lower rates. In that case, carbon stocks should accumulate in the forests, i.e. CO_2 removals would be increased. The discussion of such options is quite complex and is beyond the scope of this current report. However, the principle raised in this footnote does not contradict the observation that biomass produced by continuing with the harvesting of biomass from forests *can be* regarded as 'carbon-neutral', as long as the rate of harvesting is not increased, compared to historical rates, and the rate is consistent with the principle of sustainable yield.

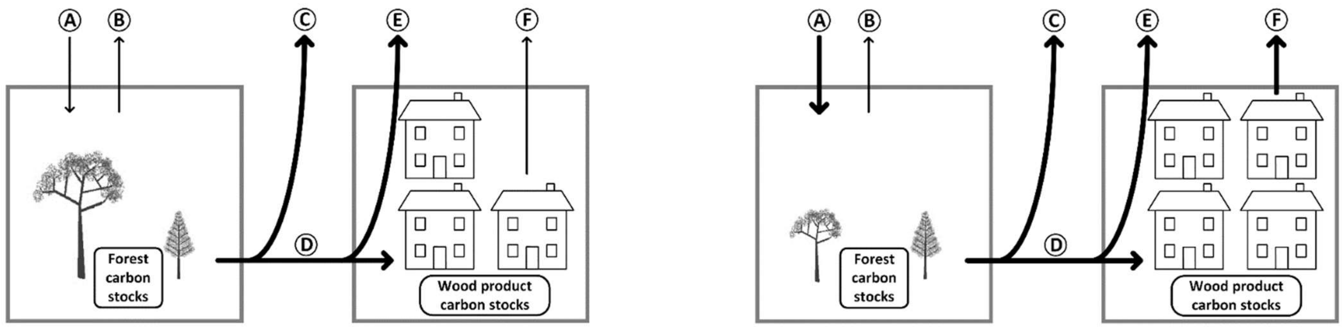

Figure 3. Illustration of the impact on the carbon balance of a forest - wood products system of shortening rotations in a managed forest to produce more wood. Left-hand diagram: following intensification ('short-term'); Right-hand diagram: some time after intensified management ('long-term'). The initial situation is depicted in Figure 2

The illustration is based on an example in which the rotations applied to forest areas (i.e. the time between forest restocking and the final felling of the trees) is shortened. The idea of shortening the forest rotations is to enhance the rate of wood production in forest areas, by harvesting trees at a younger age, whilst they are growing faster, compared to when they are older. This is not necessarily a realistic scenario in many situations, but it is an example that is sometimes presented by the forest sector to illustrate the case for more intensive management of forests for wood production[12].

The changes in carbon flows illustrated by the two diagrams in Figure 3 should be compared with the state of the forest - wood products system before the decision was taken to shorten the forest rotations. This situation has been described already, in the earlier discussion of Figure 1 and 2 (Section 2.1). Hence, before the changed management is introduced, the forest - wood products system is in carbon/CO_2 balance.

The left-hand diagram in Figure 3 illustrates the situation in the years immediately following the decision to increase the wood supply from forests by intensifying management. Compared to the situation in Figure 2:

[12] In many temperate and boreal regions, forest areas are conventionally managed on relatively long rotations (e.g. 50 to 100 years or longer). This is partly to ensure that production includes a high proportion of large-diameter timber of high value, suitable for use in construction, for example. Sometimes, it may be possible to shorten rotations, so that the average rate of wood production over a rotation is increased. However, if rotations are shortened too much, the rate of wood production is depressed, compared to applying longer rotations. These types of situations have been illustrated in Section 3.6.1 and Appendix 2 of Matthews *et al*. (2014). The presumption in the example presented here is that rotations are shortened to increase the average growth rate (and wood production rate) of forest areas and situations in which growth rates are diminished are avoided. This latter situation is unlikely on a large scale in commercially managed forests, because of the implied economic penalty of the 'lost' production (and revenue).

- The outflow of carbon from the forest has increased (thick arrows (C) and (D) in the left-hand diagram in Figure 3), so that the outflow and the net inflow ((A) – (B)) are no longer in balance. Related to this, the forest carbon stock in the forest is diminished. It should be stressed that, *for this example*, this *must* be the case, because the approach to intensifying forest management is predicated on reducing the average age of trees in the forest, to enhance their growth rates. Intrinsically, younger trees are smaller than older trees and carbon stocks are smaller in younger stands of trees, compared with older stands.
- The inflow of carbon to wood products (D) has also increased. For non-energy products, the outflow of carbon (F) is not immediately affected, because the carbon is retained in the additional stock of products. However, for bioenergy products, the outflow of carbon (E) is increased, effectively immediately.

Since the magnitudes of (C), (D) and (E) have been increased, whilst the magnitudes of (A), (B) and (F) are more or less unchanged (initially), it follows that the forest - wood products system is no longer in carbon or CO_2 balance – it is a net emitter of CO_2.

The right-hand diagram in Figure 3 illustrates the situation in the 'longer term', by which point, all of the affected forest areas have undergone the transition to more intensified management, and the system has re-equilibrated:

- The outflow of carbon from the forest (arrows (C) and (D) in the right-hand diagram in Figure 3) is continuing at the enhanced rate.
- However, the net inflow of carbon to the forest has now increased to match the outflow. This occurs because, on average, the younger trees forming the (re-growing) forest areas are growing faster on average over their rotations, compared with the older trees that used to be managed on longer rotations. This strengthens the forest carbon pump (thick arrow (A) in the right-hand diagram in Figure 3). It must be stressed that, *for this example*, this *must* be the case, provided that the forest areas are being managed according to the principle of sustainable yield, i.e. that the rate of wood harvesting does not exceed the capacity of the forest to grow more biomass. This observation is the basis on which some stakeholders sometimes claim that *active forest management strengthens (or maintains) the forest carbon sink*. However, as is clear from the description presented above and below, this is just one consequence of intensifying forest management, in the case of this example.
- The inflow of carbon to wood products (D) is also continuing at the enhanced rate

- The outflow of carbon from bioenergy products (E) is also continuing at the enhanced rate
- The outflow of carbon from non-energy products (F) has now also increased. This is because, by this time, the additional wood products manufactured from the enhanced wood supply are coming to the end of their lifespans (either original or recycled) and are being disposed of.

The consequences of this example of a decision to intensify forest management to produce more woody biomass can now be seen:

- The flows of CO_2 into the forest and out again (either directly from forests or when bioenergy is consumed, or products are disposed of) are in balance before management is intensified (Figure 2).
- Initially, the introduction of the intensified management causes an imbalance in the system, so that there are *net CO_2 emissions* (Figure 3, left-hand diagram).
- Eventually, the system settles down again and flows of CO_2 into and out of the system *come back into balance*. This is the case, even though the rate of wood harvesting, supply and consumption of products is now higher (Figure 3, right-hand diagram).
- Although the system eventually comes back into balance, the magnitude of the forest carbon stocks has been *permanently diminished* (because the average age of trees in the forest is younger than was the case before introducing this example of intensified management). The magnitude of the wood-product carbon stocks has also been *enhanced*. However, this is unlikely to completely offset the reduction in forest carbon stocks. This would only occur if the average lifespan of the combined wood products was very long, e.g. more than 100 years[13].

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[13] This point may warrant further explanation. Consider the following theoretical illustration. The management of a forest is intensified by shortening rotations. The younger trees forming the more intensively managed forest grow faster on average over their rotations than the older trees under the previous management regime. However, the younger trees have carbon stocks over a rotation of (say) 70 tC ha^{-1}, compared with 150 tC ha^{-1} in the older trees, a difference of 80 tC ha^{-1}. Suppose the intensified management of the forests boosts the rate of wood production by 0.8 tC ha^{-1} yr^{-1} – this is roughly equivalent to additional production of 4 m^3 ha^{-1} yr^{-1}. If the additional wood products from this harvested biomass only lasted for one year before they were disposed of, the carbon stock in the additional wood products would be just 0.8 × 1 (year) = 0.8 tC for each hectare of more intensively-managed forest (i.e. 0.8 tC ha^{-1}). If the wood products lasted on average for 50 years, the additional carbon stock would by 0.8 × 50 = 40 tC ha^{-1}, whilst for an average lifespan of 100 years would be 0.8 × 100 = 80 tC ha^{-1}, i.e. just matching the carbon stocks lost from the tree biomass in forests. Hence, for this theoretical example, the lifespans of the wood products need to be at least 100 years on average to compensate for the diminution of the carbon stocks in trees in the forest (note that this analysis does not consider carbon stocks in deadwood discarded in the forest). Whilst this example is theoretical, the numbers are reasonably consistent with estimates based on specific forestry cases studies (see further discussion and supporting references in Section 3.3.3 of Matthews *et al*., 2018).

From the perspective of forest carbon and CO_2 balances[14], the critical questions arising from these observations are:

1. How big is the increase in CO_2 emissions during the transition of the forest areas to more intensive management?
2. How long is the period during which CO_2 emissions are increased?

It should be clear that answers to these questions determine whether forest bioenergy can provide reductions in GHG emissions in policy-relevant timescales, i.e. in respect of recent developments in EU policy frameworks (essentially, cutting GHG emissions in 2030 by at least 50%, compared with emissions in 1990, according to the 2030 Climate Target Plan, meeting a target of 'net zero emissions' by 2050, and restoring degraded ecosystems to good condition by 2050, according to the European Green Deal).

There are other ways in which there could be impacts to CO_2 emissions, involving wood products, with no changes to forest management and without impacts directly on the forest CO_2 balance, as illustrated by the example in Figure 4. Suppose the initial situation is as shown previously in the right-hand diagram of Figure 3, with the flows of carbon and CO_2 in the forest - wood products system in carbon balance. Now suppose that, as a result of incentives to encourage the use of bioenergy, a greater proportion of the supply of wood (D) goes for use as bioenergy, rather than to make non-energy wood products[15]. This situation is illustrated by the left-hand diagram in Figure 4. The immediate result is an increase in the outflow of carbon from the wood products box (E), and a reduced inflow of carbon into non-energy wood products (arrow (f)). As carbon is retained for a finite period in wood products, the outflow of carbon from these products is unaffected initially (thick arrow (F)), because this is related to the disposal of products manufactured some years ago. Hence, the overall forest - wood products system is thrown out of carbon balance for a period, with the duration of this period depending on a number of factors.

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[14] Other questions may also be raised about the potential impacts of intensified forest management, such as wider ecological impacts. Such questions are out of the scope of this discussion.

[15] Probably it should be pointed out that Figures 3 and 4 are stylised depictions of the forest - wood products system and carbon balance. It is very unlikely that wood supply would actually be diverted from use as structural timber to make houses, for use as energy instead, because there is a big difference in the price commanded by the two products. It is more likely that the bioenergy supply might be diverted from making furniture inside the 'houses' in the figures. However, many may argue that even this is an unlikely scenario, and that a more likely scenario would be a general uplift in wood supply from forests, such as illustrated in Figures 2 and 3 (although it must be stressed that this may also be regarded as a theoretical scenario).

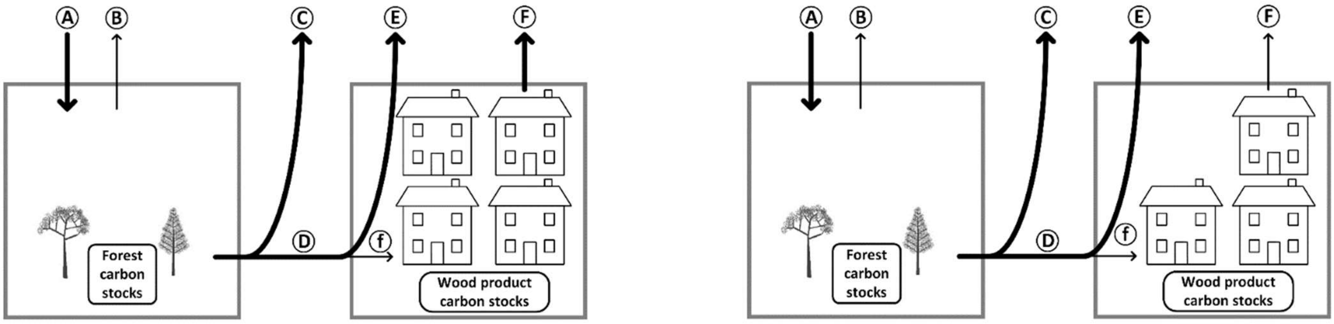

Figure 4. Illustration of the carbon balance of a forest - wood products system and the impact of increasing the proportion of harvested biomass used for energy rather than non-energy products. Left-hand diagram: following change in use ('short-term'); Right-hand diagram: some time after change in use ('long-term'). The initial situation is depicted in the right-hand diagram in Figure 3

The longer-term outcome is illustrated in the right-hand diagram in Figure 4. Here, the increased outflow of CO_2 from the wood products box resulting from increased bioenergy use continues, but the outflow of carbon from non-energy products has diminished, as has the carbon stock in wood products. This is because the lower input of wood supply to make non-energy wood products has 'worked through the system', resulting in a smaller overall stock of wood products, and so fewer wood products are being disposed of. Hence, eventually, the system comes back into carbon balance.

It is important to recall that the examples given above are two specific and theoretical cases amongst many ways in which forest management may be intensified, or wood supply might be changed, to produce more woody biomass for use for energy. Other examples could be given in which increasing wood supply may have a neutral or positive impact on forest carbon stocks and potentially a small or beneficial impact on the overall forest - wood product CO_2 balance, because of the approaches taken to intensifying forest management. Relevant cases can include[16]:

- Introducing new, faster-growing tree species into a forest when areas are restocked
- The planting of additional forest areas (on land previously unused or used for agriculture), encouraged by policy or strong local demand for woody biomass

[16] The example activities listed here are included based on a narrow consideration of the forest - wood products system carbon balance. However, it is naturally assumed that wider sustainability issues should be considered when pursuing these options, e.g. impacts on landscape, biodiversity and local communities.

- The avoidance of the loss of forest areas (deforestation) because of strong local demand for woody biomass (i.e. an economic incentive to maintain forest areas).

However, it should be apparent that increasing the level of wood supply from forests *can* result in a period of increased CO_2 emissions, and that cases that avoid this involve particular circumstances and/or additional actions such as those mentioned immediately above.

Reviews of scientific literature on the full GHG impacts of consuming forest bioenergy (allowing for impacts across all sectors, e.g. LULUCF, Energy, Construction) strongly indicate that the magnitude of increased (or sometimes decreased) CO_2 emissions, and the period over which these occur, can be very variable (Marelli *et al*., 2013; Matthews *et al*.; 2014). In certain situations, the increases or reductions in GHG emissions can continue indefinitely.

Arguments between stakeholders have gone on for at least ten years about how to interpret the very variable results reported in scientific studies. Proponents of forest bioenergy tend to refer to papers reporting net GHG benefits, whilst opponents tend to point to research findings that show net increases in GHG emissions from using forest bioenergy. Varying and often conflicting positions are taken on how forests should be managed (or not be managed), and which parts of trees are acceptable (or otherwise) for utilisation as bioenergy (e.g. branchwood, wood industry residues, stemwood, sawlogs). The debate shows no sign of being settled easily, and this is not always helped by stakeholders sometimes talking at crossed purposes, for example when using different definitions for certain essential terms such as 'carbon sink' (see earlier).

However, the systematic reviews of the literature cited earlier suggest that the variability in results for GHG emissions from forest bioenergy can be understood in terms of different factors related to types of forest management intervention and decisions about how harvested woody biomass is used for different products. This could suggest the possibility of developing a 'decision tree' or a set of criteria for managing risks associated with forest bioenergy sources, to ensure that the GHG emissions of bioenergy are generally low. (Examples of these have been proposed in Matthews *et al*., 2015, Section 2.4 and Matthews *et al*., 2018, Section 6.1). Although there are some relevant criteria included in RED II, these do not cover all the relevant situations (such as the example of intensified forest management discussed above). Instead, as already discussed, RED II mainly relies on the complementary function of the EU LULUCF Regulation to register any GHG emissions arising from bioenergy use in national accounts based on GHG Inventories. The implication is that this approach should provide an incentive (implicitly) at national scale for action to ensure that bioenergy sources are supplied and consumed in ways that do not result in accounted GHG emissions increases (or that any increases are mitigated by other actions). This makes clear the critical role of the LULUCF Regulation in supporting the appropriate use of bioenergy and the need for this to be reflected in the accounting rules for forestry.

3 History of LULUCF accounting

3.1 Why is forest carbon accounting complicated?

In principle, accounting for GHG emissions (or specifically CO_2 emissions), and demonstrating reductions, should be a simple process. Consider, for example, accounting for the consumption of a fossil fuel such as fuel oil, in the Energy Sector. One 'oil barrel' contains about 0.15 tonne of fuel oil. The carbon content of fuel oil is about 0.85 tonne carbon (tC) per tonne oil, whilst 1 tonne of carbon emitted as CO_2 equates to 44/12 tonnes CO_2 (tCO_2)[17]. So, burning 1 barrel of oil emits about $0.15 \times 0.85 \times 44/12 \approx 0.47$ tCO_2.

If a certain nation knows how many barrels of oil it has consumed each year, the CO_2 emissions from one year to the next can be estimated based on simple calculations like those above. The change in CO_2 emissions from one year to the next (increase or decrease) can then be calculated by subtracting the emissions for one year from those for the next year. For example, suppose that a certain nation consumes 400 million barrels of fuel oil in a given year. The CO_2 emissions from burning this fuel oil could be calculated simply as $400 \times 0.47 = 192$ million tonnes CO_2 ($MtCO_2$). If, the following year, the nation consumes 300 million barrels of fuel oil, the CO_2 emissions could be calculated as $300 \times 0.47 = 144$ $MtCO_2$. The emissions reduction in the second year, compared with the first, is $192 - 144 = 48$ $MtCO_2$, or a reduction of 25%.

In practice, calculations can be complicated by variations in the conversion factors, supply chain emissions, including losses of fuel during extraction, transport and processing, and the details of energy conversion processes. However, generally these issues can be allowed for by ensuring that all contributions to emissions are covered and by carefully selecting suitable conversion factors for applying in calculations.

Why is it not possible to use a similar simple approach to accounting in the LULUCF Sector, in particular in the case of forests and forest management? The problem is that land-based vegetation, deadwood, litter and soil are dynamic natural/semi-natural systems. Whilst human interventions (management) can strongly influence the carbon and GHG balances of these systems, they are not completely under human control. This is particularly true for forests. For example, decisions about

[17] A conversion factor of 44/12 is used to calculate the quantity of CO_2 released to the atmosphere, when carbon in a material or fuel is oxidised (burnt) and released entirely as CO_2. The atomic weight of carbon is 12 atomic mass units. The atomic weight of oxygen is 16 atomic mass units. Carbon dioxide is made up of one atom of carbon and two atoms of oxygen, giving an atomic weight of 12 + 16 + 16 = 44. Hence, the ratio between equivalent masses of CO_2 and carbon (converted to CO_2) is 44/12.

when, where and what types of tree to plant are under human control (subject to suitable site and climatic conditions). However, the way in which trees grow and absorb CO_2 over time is the result of biophysical processes and environmental conditions, over which humans have limited control.

Consider the example of the development of the CO_2 balance of a large area of forest (millions of hectares) in a hypothetical nation, as shown in Figure 5. The great majority of these forest areas are under active management for wood production and this has been the case for many decades and possibly centuries. Suppose that the CO_2 balance up to 2020 has been estimated by the country, and the balance beyond 2020 has been projected to 2100, based on available data on the nation's forests. The results for net CO_2 balance have been calculated according to the complete scheme illustrated earlier in Figure 1(a).

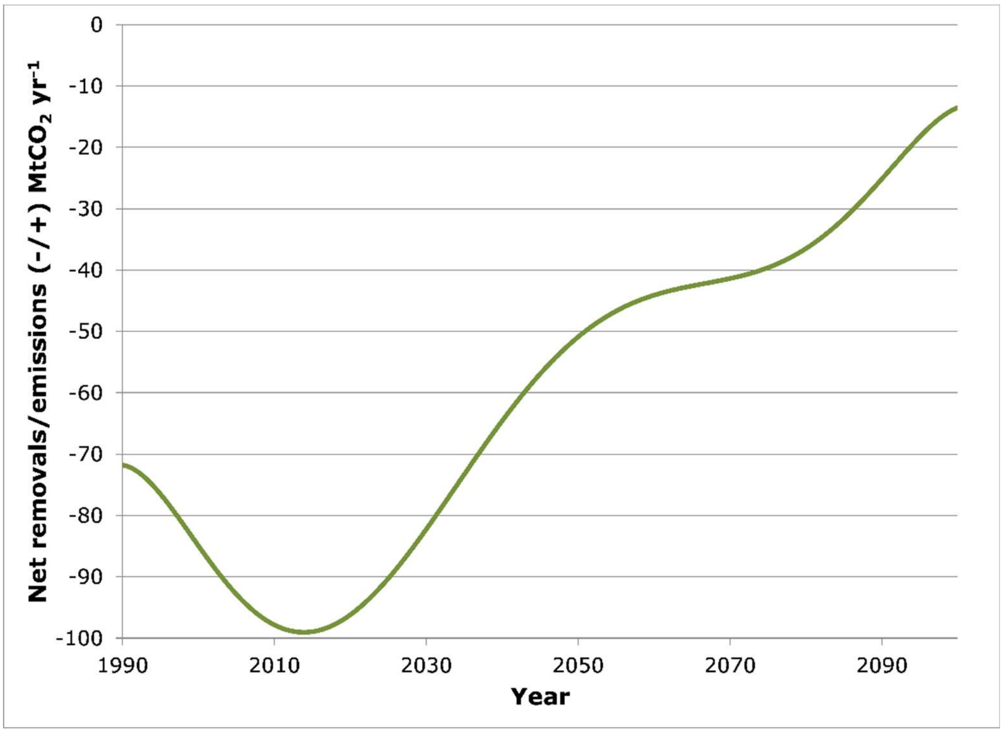

Figure 5. Net CO_2 balance of a large forest area in a hypothetical nation, being managed for wood production

All of the values between 1990 and 2100 in Figure 5 are negative. By convention this means that on balance the nation's forests are 'removing' CO_2 from the atmosphere, rather than emitting CO_2. The rate of removal is changing over time as shown in the figure, and the pattern of 'CO_2 removals' is quite complicated. In 1990 the annual net CO_2 removals by the forest are just over 70 $MtCO_2$, rising to nearly

100 $MtCO_2$ around 2015, but declining to just over 50 $MtCO_2$ by 2050. Part of the observed pattern in Figure 5 is the result of forest management; for example the felling of stands of trees for wood production is one cause of the decline in CO_2 removals after 2015. However, the general pattern, and to some extent the forest management decisions, are being driven by the particular composition and characteristics of the forests. In this example, the forests are contributing significant (and increasing) net removals between 1990 and 2015 mainly because a large proportion of the forest areas are relatively young. This means that the trees are growing relatively fast and are absorbing CO_2 at a relatively high rate. This situation changes in the period after 2015, because the forests are growing older and the net rate of CO_2 absorption is dropping. This is compounded by the felling of forest areas, because they have reached an age where they are suitable (economically) for felling for wood production, leading to more tree harvesting.

A further complication in the example presented here involves the underlying cause of the skewed age distribution of the trees in the forest areas (i.e. proportionally more young forest areas) in the period up to 2015. This leads to the peak in the rate of CO_2 removals around 2015 and is a result of the nation having made efforts to restore and expand national forests (e.g. through afforestation activities) over a number of decades leading up to 1990. It follows that the relatively large magnitude of CO_2 removals around 1990 to 2030 is the direct result of national forestry policies. The decline in the magnitude of CO_2 removals beyond 2030 is equally inevitable, because the trees that were planted in earlier decades must grow older, but the age-related decline in CO_2 removals is beyond human control. (It could be avoided by further efforts to expand the forest area with new forests indefinitely, but this is an unrealistic option.)

What may seem like a somewhat contrived scenario is actually encountered quite commonly in reality. Many nations engaged in significant programmes of afforestation and forest restoration in the second half of the 20th century, and this is the case for a significant number of EU Member States. Attempts to handle the potential issues raised by the pattern of CO_2 removals in forests illustrated above have had a big influence on the historical development of forest carbon accounting approaches, as described below. The following descriptions of accounting approaches are kept simple and so leave out some details actually applied in international climate agreements.

3.2 'Net-net accounting'

Suppose a nation is required to demonstrate reductions in accounted CO_2 emissions, compared with the level of emissions in a '*base year*' of 1990. The simplest way to calculate the change in emissions in a given '*accounting year'*, compared to the base year, is to work out the difference in CO_2 emissions or removals:

Accounted CO_2 emissions/removals	=	Emissions/removals reported in accounting year	–	Emissions/removals reported in base year

This is the '*net-net accounting'* approach and it is equivalent to the simple calculation described for barrels of oil in Section 3.1. In the LULUCF Sector, the calculation above should still work if there are net removals of CO_2 in the base year, or in the accounting year, or both years. By implication, a diminished rate of net CO_2 removals is accounted for as a net increase in CO_2 emissions – this is logically consistent with the overall aims of reducing net CO_2 emissions and/or achieving 'net zero emissions'.

Net-net accounting is applied in most economic sectors and is still applied for the majority of land-use types in the LULUCF Sector (e.g. cropland and grassland). However, difficulties arise when this approach is applied to forest land. Table 1 shows the results obtained if net-net accounting is applied to the sequence of CO_2 removals over time illustrated for the hypothetical nation in Figure 5. The table gives results for accounted net CO_2 emissions or removals for the years 2015 and 2050.

Table 1. Accounted forest CO_2 emissions/removals in 2015 and 2050 for a hypothetical nation based on Figure 5

Year	**1990 (base year)**	**Accounting year**	
		2015	**2050**
CO_2 removals ($MtCO_2$)	−70	−100	−50
Net change (accounted emissions/removals)	-	−30	+20

According to Table 1, the nation would declare net removals of CO_2 (-30 $MtCO_2$) in 2015 but would declare net CO_2 emissions in 2050 (+20 $MtCO_2$). These outcomes, particularly the result for 2050, are likely to cause problems. The relatively high rates of CO_2 removals in forests around 1990 to 2030 are only occurring because of the nation's positive efforts to restore and plant new forest areas in earlier decades. The decline in the rate of removals later on is the result of the trees growing older, over which the nation has limited control. The nation is likely to argue that having to account for net emissions (e.g. in 2050) is penalising the nation for its historical positive actions. This is one reason why net-net accounting has not been applied to forest land in international climate agreements.

3.3 'Gross-net accounting (with cap)'

Difficulties of the kind described above led to the adoption of so-called '*gross-net accounting'* for forests in the first commitment period of the Kyoto Protocol (2008-2012). Under this accounting approach, the hypothetical nation considered above could simply account for the full net CO_2 removals in the forests. For example, this would mean declaring -100 $MtCO_2$ in 2015 and -50 $MtCO_2$ in 2050. However, outcomes of this type are also likely to cause difficulties. The nation is able to account for significant net CO_2 removals in forests despite having made no additional efforts towards climate action under the climate agreement (all the actions were taken in the past). Furthermore, some of the CO_2 removals may be occurring in forest areas by chance (because of the age distribution of the trees), with no relation to any actions taken by the nation with regard to its forests. For these reasons, in the first commitment period of the Kyoto Protocol, the net CO_2 removals that could be accounted for were 'capped' at a relatively small value. For example, suppose a cap of -5 $MtCO_2$ was assigned to the hypothetical nation considered above. In both 2015 and 2050, the rate of removals exceeds this value, so the nation would be limited to accounting for 'capped' removals of -5 $MtCO_2$ in both these accounting years. In the first commitment period of the Kyoto Protocol, an exception was made for forest areas that had been created through afforestation activities since 1990. The full amount of the CO_2 removals in these forests could be accounted for, with removals in the remainder of (pre-1990) forest areas subjected to the cap. This was intended to incentivise afforestation activities. The potential for nations to account for net CO_2 removals for a possibly large area of forest land (even if capped), without needing to take additional mitigation actions, may still be viewed as a problem since it can reduce the incentive for nations to implement measures in existing forests and also means that less efforts need to be made in other sectors.

Gross-net accounting with or without a cap is also problematic when considering the requirement to account for emissions arising from bioenergy use. Specifically, if additional wood were to be harvested from forests to increase the supply of bioenergy, in many situations the accounting approach would not register any changes in CO_2 emissions related to these activities; effectively, any such emissions would not be accounted for.

3.4 'FMRL accounting (with cap)'

In order to address the perceived difficulties in applying net-net accounting or gross-net accounting to forests, a new accounting approach was introduced for forests (existing before 1990) in the second commitment period of the Kyoto Protocol (2013-2020). Gross-net accounting was still applied for forest areas created through afforestation activities since 1990, however, for the remainder of the managed forest area, an approach known as '*Forest Management Reference Level (FMRL) accounting'* has been applied. Essentially, this approach involves carrying out the following procedure, *before the start of the commitment period*:

- It is assumed that the nation has estimated CO_2 emissions/removals for the relevant forest areas up to the current year.
- The nation makes a *projection* of the net CO_2 emissions/removals for the forests into the future, including during the commitment period. This projection is made whilst allowing for the development of the distribution of tree ages in forest areas (i.e. allowing for the consequent changes in tree growth rates and rates of CO_2 removals). Allowance is also made for the impacts arising from the management of forest areas (e.g. future tree harvesting) – future forest management practices are intended to represent '*business as usual management practices*'.
- The projected CO_2 emissions/removals are used as a 'benchmark' or 'reference level'. Specifically, during the actual time of the commitment period, the CO_2 emissions/removals actually reported by the nation for the forest areas are compared with the value indicated by the reference level, to determine the accounted net CO_2 emissions or removals for the forest areas.

The accounted CO_2 emission or removals in a given accounting year are thus calculated as:

Accounted CO_2 emissions/removals	=	Emissions/removals reported in accounting year	–	Projected emissions/removals according to the reference level

For the example of the hypothetical nation discussed earlier, the reference level might be based on a projection similar to the one shown in Figure 5. Hence, for example, suppose that the nation actually reports net CO_2 removals for the forest areas of -40 $MtCO_2$ in 2050. Note that this result is smaller in magnitude than the projected CO_2 removals indicated for 2050 in Figure 5 (-50 $MtCO_2$). The accounted CO_2 emissions/removals would be calculated as:

$$-40\ MtCO_2 - (-50\ MtCO_2) = -40\ MtCO_2 + 50\ MtCO_2 = +10\ MtCO_2.$$

This type of situation might arise if the nation harvested a bigger area of forests during the period up to 2050 than was assumed in constructing the projection to determine the reference level. In other words, the accounted net CO_2 emissions may represent the impacts of intensified management in the forest areas, compared with 'business as usual' forest management practices.

It should be apparent that the assumptions made about forest management practices in making the projection are crucial in determining how much effort a nation needs to make to be able to declare accounted net CO_2 removals (or net CO_2 emissions reductions) for forest land. It is perhaps for this reason that the reference levels defined for application during the second commitment period of the Kyoto Protocol are called '*Forest Management Reference Levels'* or '*FMRLs'*.

The construction of FMRLs requires the application of complex forest models. The inputs to the models include assumptions about the future management of forest areas, notably rates of tree harvesting. In developing these assumptions, nations were allowed to represent *future changes* in forest management, that may take place as a result of the implementation of existing national policies. For example, if a nation had an existing policy setting a target for producing more forest bioenergy, including through intensifying the management of forest areas and increasing rates of tree harvesting, then these intensified management practices could be represented in the model inputs to make the projection. However, this could potentially lead to problems. Two possible perverse outcomes of this approach are:

1. A nation could build into the modelling of future CO_2 emissions/removals the assumption of significantly higher rates of tree harvesting and intensified forest management. These expanded practices are likely to result in significant impacts on net CO_2 emissions from forests (see Section 2.2) which would be included in the projection, and so included in the FMRL, so the nation would not need to account for the (net) increased emissions.
2. Alternatively, if a nation was to build in assumptions about greater harvesting or intensified forest management when projecting the FMRL, but then not actually carry out these practices, then it could improve upon the net CO_2 emissions/removals set by the FMRL, effectively by doing nothing, so generating 'free carbon credits' (sometimes referred to as 'hot air').

To avoid the second kind of outcome, in the second commitment period of the Kyoto Protocol, the net CO_2 removals in pre-1990 forests that a nation can account for (relative to the FMRL) have been 'capped' in a similar way to that described for gross-net accounting (see Section 3.3). It is not clear how it is possible to mitigate for the first kind of outcome, given the specifics of the modelling methods allowed under the FMRL accounting approach.

3.5 'FRL accounting'

Difficulties encountered in credibly implementing the FMRL accounting approach stimulated the development of '*Forest Reference Level (FRL) accounting*'. This approach has been adopted as part of the design of the EU LULUCF Regulation, which applies for internal EU accounting during the period 2021 to 2030.

Essentially, FRL accounting follows a procedure similar to FMRL accounting, except that:

- The accounting applies to the area of 'forest land remaining forest land' (see Section 4.2.2 for further explanation)
- The projection used to construct the reference level (in this case known as a '*Forest Reference Level*' or '*FRL*') is again based on modelling the future development of CO_2 emissions/removals in the relevant forest areas, allowing for the tree age distribution and management of the forests. However, the input assumptions about forest management practices are supposed to represent current, rather than projected, practice, i.e. how forest areas are already being managed (compare this with the discussion of Figure 1(a) in Section 2.1). In other words, possible future changes to forest management practices, even in response to existing national policies, should not be included in the modelling assumptions. To ensure this is the case, FRL accounting requires Member States to characterise how forest areas have actually been managed during a period in the recent past (the '*reference period*', which is set at 2000-2009 in the LULUCF Regulation). It should then be assumed that these practices continue into the future unchanged. Member States are expected to provide documented evidence of the management practices during the reference period.

In principle, this approach should put the forest and wood-products sector on a 'level playing field' with other sectors. This is in the sense that *additional actions* aimed at mitigation need to be taken in the sector *now*, in order for it to be possible to declare net GHG (CO_2) emissions reductions. Equally, if additional activities take place in the sector that lead to increased CO_2 emissions (relative to the FRL), these should also be registered (i.e. accounted for). The consequences of *past* actions (either positive or negative) are not accounted for. This includes any actions to scale up the supply of forest bioenergy – that is, any increases in GHG (CO_2) emissions (or reductions in CO_2 removals) occurring as a result of increased energy supply from forest areas should be registered as accounted emissions, relative to the FRL.

The adoption of FRL accounting as part of the EU LULUCF Regulation should, therefore, be a welcome development, since it is evident from the preceding discussion that the accounting approaches taken in previous climate agreements were likely to leave CO_2 emissions from scaled-up forest bioenergy use unregistered and unaccounted for (gross-net accounting) or might actually conceal the increased emissions (FMRL accounting). At least in principle, such situations could be avoided by adopting FRL accounting. The question remains as to whether there may be 'the devil in the detail' of the specification of FRL accounting or in its implementation. Accordingly, the next section takes a detailed look at the EU LULUCF Regulation, including the specified approach to implementing FRL accounting.

4 The EU LULUCF Regulation: analysis and assessment

4.1 Approach to analysis and assessment

In order to assess the EU LULUCF Regulation, an analysis is made of the main elements of the Regulation. The analysis considers how the elements of the Regulation work together to arrive at accounted GHG emissions for forests and represent the impacts of forest management, including wood harvesting to supply bioenergy. This is accompanied by a commentary on the effectiveness of otherwise of the elements, individually, and also collectively where relevant. This analysis draws on the ideas and understanding presented in Sections 2 and 3. The analysis is presented in Section 4.2. The elements considered consist of:

- The scope of the Regulation
- The representation of forest areas
- Definitions referred to in the Regulation
- Targets set by the Regulation
- The accounting rules
- The flexibilities allowed for in the Regulation.

Several criteria are analysed for each element. For example, for the element, 'Representation of forest areas', criteria of 'afforested land', 'deforested land' and 'managed fore land' are considered.

Based on the analysis, an assessment is made of the effectiveness of the Regulation in terms of the criteria discussed for each element. This assessment is presented in Section 4.3, where some initial observations are also made.

4.2 Analysis of the LULUCF Regulation

4.2.1 Scope of the Regulation

Global coverage?

The EU LULUCF Regulation applies to all 'managed land' in EU Member States. The Regulation does not apply to countries outside the EU. Hence, the Regulation has no relevance for tracking the impacts on forest carbon stocks or forest GHG balances in non-EU countries, that may occur as a result of scaling up the supply of forest bioenergy to the EU from non-EU countries.

Carbon pools and GHGs covered

Within the EU, all relevant forest and wood product carbon pools are included (tree biomass, deadwood, litter, soil and wood products). The three most important GHGs associated with forest GHG balances are also covered, namely carbon dioxide, methane and nitrous oxide. However, this comprehensive representation requires data and modelling methods that can accurately represent the impacts of forest management on all these carbon pools and GHGs, which may not always be available, or there may be issues with quality or completeness. Some such issues have been identified by Böttcher and Reise (2020). The discussion of forest models (see Point 8 under Section 4.2.6) is also relevant here. Improvements to quality and completeness of LULUCF GHG emissions inventories in the EU are actively supported.

Note that some relevant GHG emissions are reported in other sectors. For example, methane emissions from burning bioenergy are reported in the Energy Sector (and as such are covered).

Period covered

Under current arrangements, the LULUCF Regulation only applies for a 10 year accounting period from 2021 to 2030. This is a policy-relevant period for the 2030 EU Climate Target of 2021 to 2030, but is relatively short, particularly with regard to the potential longer-term impacts of management and harvesting on forest carbon stocks and carbon sequestration.

4.2.2 Representation of forest areas

Afforested land and managed forest land

The Regulation allows for the representation of two categories of forest areas, 'afforested land' and 'managed forest land'. These equate to the areas of land defined in National GHG Inventories of the LULUCF Sector (reported under the UNFCCC), referred to as 'land converted to forest land' and 'forest land remaining forest land'.

To count as 'land converted to forest land' in a GHG Inventory, the land must have been converted within 20 years of the inventory year. Any land converted to forest longer ago than this counts as 'forest land remaining forest land'. (This may be referred to as a '20 year transition period'.) This means that the forest areas represented under these two categories 'shifts', or 'migrates', from the first land category to the second in successive GHG Inventories and reporting years. For example, in a GHG Inventory reported in 2021, 'land converted to forest land' would include all such land that was converted (afforested) between 2002 and 2021, whilst for a reporting year of 2022, this would consist of land afforested between 2003 and 2022. The area of 'forest land remaining forest land' for reporting years 2021 and 2022 thus consists of forest areas in existence before 2002 and 2003, respectively.

It may be noted that, with regard to afforested land, the Regulation allows for the option of a Member State applying a 30 year transition period, rather than a 20 year period, in determining the areas of afforested land and managed forest land. However, the conditions attached to being allowed to adopt this option are so strict that it is very unlikely that it will ever be used.

Deforested land

The Regulation also represents the loss of forest areas to other land uses, e.g. to cropland, grassland or settlements. Any emissions arising from such land-use change should be registered under the Regulation, but these will be reported under the relevant new land-use category (e.g. under 'settlements', if the land-use change was to settlements). After 20 years, forest land converted to another land category is transferred to the area of the new land category (e.g. after 20 years, forest land converted to settlements transfers to the area of 'settlements remaining settlements').

The above conventions for the three forest land categories are different to those under the Kyoto Protocol. Under that agreement, afforested land represented all land area afforested since a fixed year of 1990. Deforestation was treated similarly to afforestation. These changes to conventions have the merit of ensuring consistency between accounting and land areas reported in UNFCCC GHG Inventories, but they also have important impacts on the application of accounting rules. This point is discussed in Section 4.2.5.

The implications of excluding land areas not classified as 'managed' are unclear. This may require further consideration, depending on the sense in which it is intended to meet a target of 'net zero emissions' at a global scale (see Section 4.2.3). However, this issue may not be relevant from the perspective of this specific assessment of the EU LULUCF Regulation.

4.2.3 Definitions

The Regulation adopts definitions for certain terms that are consistent with those referred to elsewhere, e.g. under the Kyoto Protocol and in IPCC reports. On the whole these definitions are non-contentious.

'Carbon sink'

It may be noted that the definition of 'carbon sink' is ambiguous. The stated definition is, "*any process, activity or mechanism that removes a greenhouse gas,* *an aerosol, or a precursor to a greenhouse gas from the atmosphere*". For forests, this could be taken to refer to the 'forest carbon pump' as defined in Section 2.1, or to the 'net forest carbon balance', or to the 'forest - wood products system carbon balance', as discussed in Sections 2.1 and 2.2. This has some potential implications for how some other statements in the Regulation may be interpreted, particularly in terms of support for specific forest management activities aimed at climate change mitigation. This point is discussed further in Section 4.2.5.

'Net zero emissions'

It should be noted that this term is not defined in the Regulation. Currently there is no widely agreed definition for this concept. This does not necessarily affect the implementation of the Regulation.

4.2.4 Targets

LULUCF Sector emissions should not exceed removals

The target set in the Regulation is relatively simple: each Member State must ensure that GHG emissions in the LULUCF Sector do not exceed removals in the sector, as calculated according to the accounting rules also specified in the Regulation (see Section 4.2.5). However, no targets are specified for actual quantitative levels for the implied target of net removals in the sector.

Provided that the accounting rules are robust, and particularly noting the application of FRL accounting for managed forest land (see Section 4.2.5), *in principle*, this is a very stringent target for Member States to have to achieve. It is so stringent that the Regulation includes certain flexibilities to allow for difficulties Member States may have in meeting their individual targets (see Section 4.2.7).

At the same time, *again in principle*, the FRL accounting approach should 'factor out' a significant component of the gross CO_2 removals in forest areas, so that these cannot be claimed as part of a Member State's accounts. Effectively, this component serves as a 'buffer' of CO_2 removals, making it more likely that actual (gross) CO_2 removals will exceed GHG emissions in managed forest land, and potentially across all sectors.

4.2.5 Accounting rules

Two 'compliance periods' are defined for the total period covered by the Regulation. The two compliance periods run from 2021 to 2025 and from 2026 to 2030. The target specified under the Regulation must be met during both compliance periods.

Afforested land

Gross-net accounting is applied to the GHG emissions and removals of afforested land. This means that the full amount of the GHG emissions or removals is declared. However, new forest areas are only counted as afforested land for the first 20 years from the date they were created (see Section 4.2.2). After 20 years, the relevant afforested areas 'shift', or 'migrate', from counting as part of 'afforested land', to be included as part of the area of 'managed forest land'. From this point, the CO_2 removals of these forest areas are included within the calculation of the forest reference level. FRL accounting thus applies to this land, so that the (gross) removals are 'factored out' when calculating the accounted removals. Across nearly all of the boreal and temperate regions, carbon stocks in newly-created forests only start to accumulate significantly after 20 years. Hence, the net CO_2 removals that can be declared for afforested land are likely to be modest. This may serve as a disincentive to afforestation activities.

Deforested land

Gross-net accounting is also applied to the GHG emissions and removals of deforested land. After 30 years, deforested land is transferred to be part of the area for the new land-use category. The bulk of the GHG emissions associated with a deforestation event are likely to take place within 20 years of the event occurring. Hence the accounting rules should ensure that GHG emissions resulting from deforestation activities are fully accounted for.

Managed forest land

As discussed in Section 3.5, FRL accounting is applied to the area of managed forest land, where the essential ideas behind FRL accounting are described. However, under the LULUCF Regulation, in addition, a cap is imposed on the quantity of net removals that can be declared (relative to the forest reference level). However, removals related to the accumulation of deadwood and long-lived wood products are not capped.

Detailed specifications for the construction of the forest reference level are given in the Regulation, and include:

- Projecting the future development of forests to construct the forest reference level "*based on the continuation of sustainable forest management practice, as documented in the period from 2000 to 2009 with regard to dynamic, age-related forest characteristics in national forests, using the best available data*"[18].

[18] The Regulation also includes an ambiguously worded paragraph, as follows: "*Forest reference levels […] shall take account of the future impact of dynamic age-related forest characteristics in order not to unduly constrain*

(The period from 2000 to 2009 is the reference period referred to in the Regulation, see Section 3.5.)

- Criteria and elements to cover in constructing the forest reference level, to be documented in a National Forest Accounting Plan (NFAP) to be produced by each Member State.
- Consistency of the projection to construct the forest reference level, as declared in the NFAP, with reported National GHG Inventories.
- A process of external technical review of NFAPs and forest reference levels, with powers for the European Commission to make corrections if needed.

The criteria mentioned above include a requirement to assume "*a constant ratio between solid and energy use of forest biomass as documented in the period from 2000 to 2009*".

Forest reference level construction under the Regulation is further supported by guidance on good practice published by the European Commission[19].

Wood products

The emissions and removals in the carbon reservoir formed by wood products are accounted for under the Regulation using methods consistent with 'Tier 1' (and possibly 'Tier 2') methods defined in IPCC Guidance. In these respects, the methods are non-contentious. A technical annex to the Regulation further clarifies that, "*[…] harvested wood products that were harvested for energy purposes shall be accounted for on the basis of instantaneous oxidation*". This should ensure that emissions from forest bioenergy use are accounted for if the forest reference level for managed forest land is constructed correctly. However, potential issues related to this point are discussed in Section 4.2.6.

The so-called 'production approach' is adopted in accounting for wood products, whereby CO_2 emissions and removals associated with carbon in wood products are attributed to the country were the wood was harvested. This means that a Member State importing significant quantities of forest biomass for consumption as energy does not need to account for the emissions arising from this imported wood fuel. If the wood fuel has been imported from outside the EU, the emissions fall outside the

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forest management intensity as a core element of sustainable forest management practice, with the aim of maintaining or strengthening long-term carbon sinks". This paragraph could be interpreted as reasserting the principles of FMRL accounting (see Section 3.4), and so providing flexibility to expand forest management activities including additional harvesting, without needing to fully account for the consequences in terms of GHG emissions. In the process, the paragraph makes reference to the objective of "strengthening long-term carbon sinks". It should be noted that this is referring to the forest sector's preferred definition of the "forest carbon sink", as discussed in Section 2.1. This does not represent the complete forest - wood products system carbon or CO_2 balance.

[19] https://op.europa.eu/en/publication-detail/-/publication/5ef89b70-8fba-11e8-8bc1-01aa75ed71a1

scope of the EU LULUCF Regulation. As already highlighted in the earlier discussion of the scope of the LULUCF Regulation (Section 4.2.1), it has no relevance for tracking the impacts on forest carbon stocks or forest GHG balances in non-EU countries that may occur as a result of scaling up the supply of forest bioenergy to the EU from non-EU countries. Instead, RED II relies upon the non-EU countries exporting wood fuel to the EU to have committed to the Paris Agreement, including a specified commitment to reduce GHG emissions. It should be conceded that a stronger approach would require international co-operation (not just action by the EU) and an agreement operating at global scale. In this context, some of the stronger aspects of the EU LULUCF Regulation could serve as a possible model.

Natural disturbances

The Regulation includes provisions for emissions arising from significant natural disturbances in forests to be excluded from accounted emissions. The methods for doing this are consistent with relevant IPCC Guidance. The Regulation also stipulates that emissions must be accounted for if wood products (including bioenergy) are harvested from disturbed forest areas ('salvage logging'). Similarly, there is a requirement that forest areas subject to natural disturbance that are subsequently converted to another land use must be accounted for as deforestation.

4.2.6 Commentary on accounting rules

Eight substantive points follow from the analysis of accounting rules presented above.

Point 1: Need for consensus on how to construct a forest reference level

The robust accounting for forest management and biomass use depends crucially on the assumptions made in constructing the forest reference level. Member States need to understand (and be willing to accept) that future intensification of forest management and additional biomass harvesting (already planned or otherwise) must be left out when developing the management assumptions for constructing the forest reference level. There may be some reluctance to do this, possibly particularly amongst Member States with large forest sectors. The effectiveness of the accounting therefore hinges on buy-in from Member States and there being no ambiguity over the basis on which forest reference levels should be, and are, constructed, and on ensuring compliance with the intentions of FRL accounting under the Regulation. This emphasises the critical importance of completeness and transparency in National Forest Accounting Plans.

Point 2: Application of a reference period of 2000 to 2009

The choice of the reference period (2000 to 2009) for characterising "*sustainable forest management practice[s]*" that are to be assumed to be *continued* when constructing the forest reference level could be viewed as problematic. Policy incentives for the increased use of biomass as an energy source were already in place in the EU at the beginning of this period and were further strengthened mid-way through the period (see Section 1.2). Hence, it is likely that forest management practices in EU Member States were already evolving during this period, to increase biomass harvesting. As a consequence, forest reference levels may conceal some GHG emissions increases associated with recent uplifts in rates of forest harvesting in response to EU policies on biomass use (notably related to bioenergy).

The difficulties in selecting a reference period that distributes the burden of achieving net GHG removals in managed forest land evenly (or 'fairly') across all Member States is acknowledged. For example, activities in the forest sectors of a number of Member States were constrained during the late 20th century by adverse socio-political circumstances. The more recent efforts of these Member States to regenerate their forest sectors may incur accounted GHG emissions for managed forest land under FRL accounting if an earlier reference period (prior to the introduction of EU renewable energy policies) were to be adopted. However, whilst recognising the possible need to address such issues, this does not necessarily support the selection of a reference period that may conceal the accounted GHG emissions implied by relatively recent efforts by Member States to 'mobilise wood resources' as part of forest sector regeneration (or modernisation).

Point 3: Reliance on the concept of 'continuation of forest management practices'

There is one critical observation concerning the method specified to construct forest reference levels. This point has been discussed openly by the designers of the forest reference level methodology, but it is unclear if the implications have been widely understood. A forest reference level constructed in compliance with the methods of the Regulation could still give at least some Member States some flexibility to increase rates of wood harvesting, compared with historical rates. In some cases, the potential for increased wood harvesting could be significant. It is important to explain how such a situation could arise. To begin with, it should be observed that the Regulation does not specify 'business as usual forest management' as meaning 'business as usual rates of wood harvesting'. Rather, as already noted, the Regulation specifies that the determination of the forest reference level should be "*based on the continuation of sustainable forest management practice …*", as already described above. The intent of this approach is elaborated in the European Commission guidance supporting the Regulation. In essence, the method is supposed to proceed as follows:

1. Partition the area of managed forest land into uniform components, generally in terms of the tree species composition and growth rate
2. Characterise how each of the components was being managed (or left unmanaged) during the reference period (2000 to 2009). Where clearfelling of components of this type is normally practised, determine the rotation(s). Also characterise any other relevant aspects of management such as thinning practice.
3. For each component, apply the above parameters to the entire forest area represented by the component.

Note that the above procedure has not considered the tree age distribution observed for the forest areas forming different components.

Now, suppose that a particular forest component has been identified, and that this component has an associated characteristic rotation age of 80 years. In the reference period of 2000 to 2009 (for which the management was characterised), suppose that the total area of the component reaching the rotation age, and to be clearfelled, is ten thousand hectares. Now consider a situation in which the age distribution of the forests is very skewed, so that, in the period 2000 to 2009, there is a relatively larger area of trees younger than 65 years, with perhaps ten times as much area (one hundred thousand hectares), compared to the older stands that are being clearfelled. Although only ten thousand hectares of the component was felled in the reference period, the management practice (and the rotation of 80 years) is applied to the whole of the component, including these large areas of younger trees. This means that, during the period 2021 to 2030, the area of the forest component reaching the rotation age of 80 years will be very much bigger than for the reference period (around ten times). As a consequence, when constructing the forest reference level, the area *projected* as being felled in the compliance period will be significantly bigger, and so wood production represented in the reference level will be significantly higher for this component, than was the case during the reference period. This is the case, even though the management of the components is not considered to have changed, but rather is regarded as ‘continuing’, according to the approach specified in the Regulation and the supporting guidance.

Considering the situation described above, it may be argued that this is precisely the point of FRL accounting, i.e. to ensure that countries are not penalised for the age distribution of their forests. Nevertheless, the potential consequence of the particular implementation of FRL accounting in the Regulation is that a country can allow for the harvesting of a very large proportion of a very large forest area during the compliance period, on the basis that very large proportion of a much smaller (older) forest area was harvested during the reference period. The question arises as to whether this kind of outcome is really consistent with the spirit of "the *continuation* of sustainable forest management practice …". This issue is returned to later in this discussion.

(Note that the alternative scenario is also possible, i.e. in which projected wood production represented in the forest reference level drops compared to the level in the reference period, if the age distribution of the forests is skewed towards older stand of trees in the reference period, with relatively smaller areas of younger forests.)

Nabuurs *et al*. (2018) have reported results for a study of the EU forest sector, based on simulations made with the EFISCEN large-scale forest sector scenario simulation model. Simulations were made of the development of the forest growing stock and wood production in 25 EU countries (not including Cyprus and Malta) plus the UK, under a scenario of "*continuation of forest management practices*" as defined in the EU Regulation. The simulations suggested that the harvest (wood removals) for these countries, "*can increase from 420 million m*^{3} *per year in 2000–2009 to 560 million m*^{3} *per year in 2050, due to progressing age classes. This implies there is a possibility to [significantly] increase absolute wood harvests without creating debits compared to the forest reference level*".

Note also, if Member States do not actually increase wood production to a combined level such as suggested by Nabuurs *et al*., this would suggest that the EU should be able to declare net accounted removals relative to forest reference levels, effectively by not taking any active mitigation measures, i.e. the accounting system would generate 'hot air', as discussed in Section 3.4. This may be one reason why a cap is placed on the net accounted CO_2 removals that can be declared for managed forest land by Member States. The application of the cap, whilst counteracting risks of generating 'hot air' in the system, also limits the incentives for taking mitigation measure in managed forest land, aimed at enhancing forest carbon stocks and carbon sequestration rates, where such measures are possible.

As already raised earlier in this discussion, the question arises as to whether an increase in wood production in the future and over the compliance periods is consistent with the ultimate aim of the Regulation of accounting for GHG emissions arising from 'additional' wood production. The immediate impression is that this does not appear to be fully consistent with the circumstances under which forest management and wood production can be considered 'carbon-neutral', as described in the discussion of Figure 1 and 2 in Section 2.1. However, a contradictory view may be taken, in situations where the young forest areas were created through afforestation in recent decades, with the expressed intention of managing them for wood production. This again raises questions over how 'recent' and future afforestation activities are accounted for under the Regulation (see earlier discussion). A balanced solution to these issues is not immediately clear.

The consequences of excluding net CO_2 removals in deadwood and in wood-based and sawnwood products from the application of the cap on removals for managed forest land are unclear. It is also arguable that the method used to reflect this exclusion when calculating accounted emissions and removals is open to interpretation. This point would appear to require further clarification and analysis. This is outside the scope of this assessment.

Point 4: Constant ratio between solid and energy use of forest biomass

The assumption of "*a constant ratio between solid and energy use of forest biomass*" when constructing the forest reference level goes some way towards addressing concerns about the increased use of forest biomass for energy purposes leading to increased GHG emissions. For example, if wood production in a Member State stays around the same rate in future years, but a bigger proportion of the harvested biomass is used for energy, compared to during the reference period, this should register as accounted GHG emissions during the compliance period(s). Equally, if wood production is increased during the compliance period, above the rate assumed in constructing the forest reference level, this approach should ensure that GHG emissions from the additional harvested biomass used for energy are accounted for, at least to a certain extent. However, the approach can still conceal emissions arising from additional forest bioenergy use. Specifically, if the projected forest reference level allows for increased wood production (see Point 3 above), the constant ratio assumed between solid and energy use of forest biomass must mean that some of the additional biomass can be used for energy purposes without needing to declare accounted GHG emissions. (This observation involves the assumption that the Member State does increase wood production in the future to the rates modelled when the reference level was constructed.)

Point 5: Important role of supporting guidance and technical review

Following on from the previous point, the European Commission's guidance on how to construct forest reference levels has a vital role to play in ensuring clarity over what Member States are supposed to do, and how. The guidance, although strictly speaking not compulsory to follow, leaves little room for inappropriate interpretations, such as the need to avoid building in assumptions about how forest management might change or evolve in the future, compared with the reference period. However, this needs to be backed up by a meaningful external technical review process, that tests the validity of assumptions made by Member States about forest management and how the projection is made. It also requires a willingness on the part of Member States to take heed of any feedback received from the technical reviews, and to respond to any requirements for changes in assumptions, where these are needed to ensure compliance with the Regulation. It remains to be seen whether this process will be effective[20].

Point 6: Dependence on availability of reliable forest and forest sector data

The construction of a meaningful forest reference level is entirely reliant on underlying data. The main data required by each Member State are on the composition of the growing stock of the managed forest area (e.g. tree species, growth rates, tree ages). It is equally important to have data on how different types of forest have been managed during the reference period of 2000 to 2009.

Data on the forest growing stock should be available from National Forest Inventories (NFIs) but these are carried out to different standards by individual Member States, and they vary in their level of detail. Some Member States do not have results from NFIs that strictly represent the status of forests during the reference period, or subsequently.

Systematic and detailed quantitative data on forest management practices are not generally collected as part of NFIs. For example, to the author's understanding, information on felling rotations applied to forest stands are not normally included as part of data collected for NFIs. There may also be restrictions on access to management information (e.g. it may be considered to be commercially sensitive). It is also important to recognise that the FRL accounting process requires data on *actual* felling rotations, rather than *planned* rotations. It is possible that rotations could be inferred by analysing felled areas in NFI data – if these were assessed as standing forest in a previous NFI survey, this could indicate how old the trees were when they were felled. NFI data may also include a subjective assessment of whether forest stands have been thinned, but it is unlikely that quantitative data are collected (e.g. on the 'intensity' of thinning) and it may be practically difficult to assess such management parameters. Instead, it is likely that Member States need to rely on other data sources that may have been collected informally, or on information of indirect relevance that requires interpretation (e.g. statistics on national wood production). It is therefore likely that the quality of data underlying the forest reference levels produced by Member States is variable. This may also be

[20] It may be noted that concern about this process have already been expressed in some quarters: https://www.fern.org/publications-insight/european-commission-faces-major-hurdle-to-protect-and-restore-forests-2148/

true for the basic estimates of GHG emissions and removals estimated for managed forest land, as reported in National GHG Inventories.

Point 7: Dependence on availability of reliable wood industry data

The stated expectation in the Regulation that the forest reference level should ensure that, "*emissions resulting from biomass use are properly accounted for*" clearly expresses the intended aim of the Regulation regarding forest biomass used for energy purposes. This is supported by the requirement that the projection made to construct the forest reference level should assume "*a constant ratio between solid and energy use of forest biomass …*", as already noted earlier. The purpose of this criterion is to pick up situations where biomass is being diverted from use for non-energy wood products to use for bioenergy, or where additional wood supply is being used more for bioenergy than for non-energy wood products. The application of the constant ratio in the projection for the forest reference level should mean that at least some of the emissions resulting from the additional bioenergy production should be registered. However, there may be difficulties in calculating this ratio and in checking its validity. For example, the calculation of the ratio could be based on statistics for the direct supply of wood for use as energy (i.e. harvested wood extracted explicitly for us as an energy product), or for all wood consumed as energy (e.g. including that used to generate process heat and power in paper-, panel- and saw-mills, biomass arising as by-products of wood product manufacture, such as wood chips and sawdust, and potentially wood burnt for energy when products come to the end of their lives). In some circumstances, the ambiguity and uncertainty in statistics relevant to forest bioenergy production and use, and the scope for interpretation, could result in projected wood energy use being inflated when a forest reference level is constructed, or in wood energy use being under-reported within a compliance period, relative to the level suggested by the forest reference level. Either of these possibilities could result in the underestimation of GHG emissions from additional bioenergy use. The European Commission guidance suggests that it is "advisable" to refer to the FAO definition for 'wood energy', but this definition is itself not entirely clear. This ambiguity leaves some scope for interpretation by individual Member States and may also make technical review difficult.

The situation is made worse by limitations in the data available on wood production from forests of EU Member States, notably with regard to how harvested wood ultimately gets utilised (in the EU and externally). The FAO publishes statistics on wood production and consumption by individual countries. These statistics cover raw wood production (e.g. as 'industrial roundwood' and 'wood fuel') and also (more recently) more detailed data on quantities of secondary wood products such as 'wood chips and particles' and 'wood residues'. However, the reporting of wood quantities for these sub-categories may be incomplete. There may also be issues with the reporting of the 'informal' harvesting of wood for domestic energy consumption, e.g. a forest owner harvesting trees for fuel for their own use or within their local community – records of such activities may be limited or non-existent. A full understanding of the implications of these issues would require further detailed analysis of the reported wood production data and flows through the wood industry sector. Such analysis is beyond the scope of this report.

Point 8: Dependence on forest models and their correct application

The construction of a reliable forest reference level also requires forest models to be available to Member States that are suitable for application to their forests, and able to represent the kinds of forest management practices that can be taking place, some of which may be quite sophisticated (e.g. complex patterns of thinning, followed by clearfelling on variable rotations, or avoiding clearfelling altogether). Many Member States do not have their own suitable forest models, so they are likely to rely on external support for modelling. The available forest models may also vary in terms of the detail with which processes in different carbon pools are represented. For example, some models may refer to IPCC 'Tier 1' default methods for representing soil carbon stock changes. Forest models may require careful and detailed setting up to ensure the adequate representation of forest areas and forest management practices. Hence, deep knowledge is needed of the status and management of the forest areas, and of the capabilities of the model, and how to make full use of them. This requires close collaboration between forestry experts in Member States and the specialists undertaking the modelling. The reliability of model projections for constructing the forest reference level may be compromised if this is not achieved.

4.2.7 Flexibilities

The LULUCF Regulation allows for certain flexibilities in the 'management' of accounted emissions and removals. Some of these are similar to those included in previous systems such as under the Kyoto Protocol.

Flexibilities between periods

A Member State may 'bank' accounted CO_2 removals for managed forest land in one compliance period (e.g. 2021 to 2025) and use the removals as a contribution towards net CO_2 emissions and removals for a subsequent compliance period (e.g 2026 to 2030).

Flexibilities between Member States

There is also some scope for transferring accounted net CO_2 removals for managed forest land from one Member State to another. The practical details are not defined in the Regulation and realistically the details of such implementation are outside the scope of the Regulation.

Contributions to aid compliance under the Effort Sharing Regulation

The EU Effort Sharing Regulation[21] allows for contributions towards the emissions reductions targets of Member States from net accounted GHG removals in the LULUCF Sector. It is out of the scope of this report to comment on this mechanism and it is not assessed here.

Special flexibilities ('compensation')

There are also some 'special' provisions in the LULUCF Regulation, referring to 'compensation' being possible for Member States that are unable to meet the target of emissions not exceeding removals in the LULUCF Sector over a compliance period. There is a clear indication from the context that the problem is related to having accounted net emissions for managed forest land. The Regulation attaches some conditions to being able to make use of these flexibilities, notably that the LULUCF Sector for the EU as a whole must not register accounted net GHG emissions. The specifics of how these special flexibilities would be implemented (should they be required) are out of the scope of the Regulation and are left undefined.

4.3 Assessment of LULUCF Regulation

The assessment of the EU LULUCF Regulation is presented in Table 2 to 5. It should be stressed that, strictly, this assessment is of the effectiveness of the Regulation in supporting the supply and consumption of forest bioenergy, through working in concert with RED II and the EU ETS, to achieve GHG emissions reductions. Hence the wider effectiveness of the Regulation in facilitating a contribution from the LULUCF Sector towards more general action on climate change (by reducing GHG emissions) is not assessed here. However, some of the observations may be of relevance to this bigger question.

Firstly, Table 2 presents an assessment of the Regulation in terms of the underlying rationale for using it as a complementary instrument to RED II and the EU ETS. This is addressed by considering three high-level criteria:

1. The objective of establishing a 'level playing field' (see Section 3.5) for mitigation actions in the LULUCF Sector and other sectors, including the forest and wood products sectors

[21] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.156.01.0026.01.ENG

2. The capacity of the Regulation to influence the national polices and actions of Member States with regard to forests, forest management and the production and/or consumption of forest bioenergy
3. The capacity of the Regulation to influence actors in relevant sectors (forestry, wood products, construction, energy) in making decisions and choices with regard to supplying forest biomass for use as an energy feedstock, and related forest management and wood harvesting practices, to ensure that these activities support reductions, and avoid increases, in GHG emissions.

These aspects were not considered in Section 4.1 because they are extrinsic to the Regulation itself, but nonetheless highly pertinent to the assessment being made in this report. A brief discussion of issues relevant to these criteria is provided in Section 4.3.1.

Secondly, Table 3 presents an assessment of the design of the LULUCF Regulation, with regard to the elements listed in Section 4.1, drawing on the analysis in Section 4.2 and the background information in Sections 2 and 3.

Thirdly, in Table 4, an assessment is made of the LULUCF Regulation in terms of the capacity and ability of EU Member States to implement the Regulation 'on the ground', consistently with the rationale and the design of the Regulation. This assessment is made by referring to the same elements and criteria as in Table 3.

Finally, a summary assessment is made of the overall effectiveness of the LULUCF Regulation with regard to the aims stated at the outset of this discussion. This is done by combining the assessments for each element and criterion with regard to design and implementation (taken from Table 3 and 4), to arrive at a single assessment for each criterion, and considering these alongside the assessments with regard to rationale, already presented in Table 2.

In all of Table 2 to 5, the assessment of criteria is indicated by a qualitative score with three levels:

1. 'Strong' – The design and/or implementation of the Regulation is assessed as strongly supporting the objective of supporting the effective supply and consumption of forest bioenergy to ensure GHG emissions reductions (and avoid increases)
2. 'Weak' – The design and/or implementation of the Regulation is assessed as weakly supporting the objective of supporting the effective supply and consumption of forest bioenergy to ensure GHG emissions reductions (and avoid increases)

3. 'Poor' – The design and/or implementation of the Regulation falls short of supporting the objective of supporting the effective supply and consumption of forest bioenergy to ensure GHG emissions reductions (and avoid increases).

In some situations, it is not relevant to make an assessment against certain criteria. Where this occurs, this is recorded in the assessments by an entry of 'NR'. One criterion is not assessed and is recorded as 'NA'. In a few cases, it has not been possible to make any assessment, based on information currently available. Where this occurs, this is also recorded by an entry of 'NA' in Table 2 to 5.

4.3.1 Brief discussion of criteria relevant to rationale

Level playing field between LULUCF Sector and other sectors

The rationale behind the Regulation is that additional mitigation actions need to be taken in order to generate accounted net GHG emissions reductions or accounted net GHG removals, regardless of the sector. (Equally, additional actions that worsen the GHG balance should result in accounted GHG emissions, regardless of the sector.) The intention is that this should be the case for the forest sector along with all other sectors. This is a strong principle underlying the Regulation.

Influencing national policies/actions

Forest policy is determined by individual Member States. As noted in Section 1.2, the LULUCF Regulation must work by influencing the national governments of Member States to ensure that the use of biomass for energy (notably forest bioenergy) helps reduce GHG emissions on a timescale that is relevant for climate change mitigation. The rationale behind the Regulation thus appears to be to put in place an accounting framework that 'rewards' national policies or actions that result in additional mitigation in the LULUCF Sector (including the forest sector), and penalises actions that lead to emission increases (or reduced removals) in the sector. However, it is up to Member States to recognise the significance of the LULUCF Regulation, to acknowledge the need for compliance and work out what actions to take as a consequence, and how to implement them. This includes fully understanding the role of forest bioenergy, and the widely varying risks and opportunities presented by encouraging its supply and consumption. This may be regarded as an entirely appropriate approach to sharing responsibility for action between the EU and its Member States. However, the consequence is that the response from Member States may be very variable and not always supportive of the targets set for emissions reductions, whilst there may be limited recognition and/or control of the risks associated with increased forest bioenergy use.

Influencing actors

Ideally, the regulation of forest bioenergy supply and consumption should provide appropriate incentives for using forest bioenergy sources with low associated risks of causing GHG emissions increases, and penalties for using high-risk sources. By nature (and as a consequence of the rationale), the LULUCF Regulation has no direct influence over decisions taken and/or choices made by relevant actors (e.g. forest managers, wood processors and/or power generation utilities). It should be noted that such incentives and penalties are also generally lacking (although not entirely absent) from RED II and the EU ETS. For example, wood biomass produced from managed 'forest land remaining forest land' is typically treated as involving zero GHG emissions from the combustion of the biomass, because there is no land-use change.

Table 2. Assessment of LULUCF Regulation with regard to forest bioenergy supply and consumption: RATIONALE

Criterion	Commentary	Score
Level playing field between LULUCF Sector and other sectors	See discussion in Section 4.3.1. The rationale is to ensure that the forest sector, along with all other sectors, needs to take additional action to generate accounted net GHG emissions reductions or accounted net GHG removals, whilst additional actions that worsen the GHG balance should result in accounted GHG emissions.	Strong
Influencing national policies/actions	See discussion in Section 4.3.1. The rationale is to encourage national policies or actions that result in additional mitigation in the forest sector and discourage actions that lead to emissions increases (or reduced removals). It is up to Member States to understand the implications and work out what actions to take.	Weak
Influencing actors	See discussion in Section 4.3.1. The Regulation has no direct influence over decisions taken and/or choices made by relevant actors (e.g. forest managers, wood processors and/or power generation utilities).	Poor

Table 3. Assessment of LULUCF Regulation with regard to forest bioenergy supply and consumption: DESIGN

Element	Criterion	Commentary	Score
Scope	Global coverage?	The Regulation only covers EU Member States. The Regulation of forest bioenergy imported to the EU from other countries under RED II relies on commitments in those countries to act on climate change, not necessarily involving specific commitments regarding forest bioenergy. (Section 4.2.1.)	Poor
	Carbon pools and GHGs covered	Within the EU, all relevant forest and wood-product carbon pools are included. The three most important GHGs are covered. (Section 4.2.1.)	Strong
	Period covered	The Regulation covers the policy-relevant period of 2021 to 2030, but this is relatively short, particularly with regard to the potential long-term impacts of management and harvesting on forest carbon stocks and carbon sequestration. (Section 4.2.1.)	Weak
Representation of forest land	Afforested land	Afforested land is only recognised as such for 20 years from the time that the forests are created, after which it is classified as managed forest land. Combined with the accounting rules for afforested land and managed forest land, this means that credits for afforestation activities are likely to be limited. The treatment of management assumptions for afforested land when it transfers to managed forest land is not specified. (Section 4.2.2.)	Weak
	Deforested land	Deforested land is recognised as such for 20 years from the time that the deforestation occurs, after which it is classified as the new land use. This should ensure that consequent GHG emissions are captured. (Section 4.2.2.)	Strong
	Managed forest land	All forest land where management is taking place should be covered, with 'unmanaged' forest areas potentially excluded. Earlier commentary on afforested land should be noted. (Section 4.2.2.)	Strong

Element	Criterion	Commentary	Score
Definitions	'Carbon sink'	The definition for 'carbon sink' is consistent with that given in authoritative sources (e.g. IPCC reports). However, this definition is ambiguous (e.g. compare the definition with those suggested in Sections 2.1, 2.2 and 4.2.3).	Poor
	'Carbon source'	The definition for 'carbon source' is consistent with that given in authoritative sources (e.g. IPCC reports). Because the definition of 'carbon source' needs to be consistent with the definition for 'carbon sink', this definition may also be regarded as potentially ambiguous. However, in practice, this term causes less confusion and misunderstandings in discussions of forest management and forest bioenergy use and their potential GHG emissions. (Section 4.2.3.)	Weak
	Other definitions	These are consistent with authoritative sources (e.g. IPCC reports) and appear to be non-contentious. The term, 'net zero emissions' has not been generally defined but this does not appear to affect the implementation of the Regulation. (Section 4.2.3.)	Strong
Targets	LULUCF Sector emissions must not exceed removals	Provided that the accounting rules fulfil their intended aims (notably in the case of FRL accounting for managed forest land), this is a stringent target. In principle, it should not be affected by the lack of a definition for the term 'net zero emissions'. However, see commentary on accounting rules. (Section 4.2.4.)	Strong

Element	Criterion	Commentary	Score
Accounting rules	Reference period 2000 to 2009	EU policies aimed at encouraging the use of renewable energy (including bioenergy) were already in place during the reference period that has been selected for the Regulation. Hence, forest reference levels may conceal some GHG emissions increases associated with recent uplifts in rates of forest harvesting (notably related to bioenergy). (Sections 4.2.5 and 4.2.6, Point 2.)	Weak
	Afforested land	Gross-net accounting should give a strong incentive for afforestation activities. However, see related comments about representation of afforested land.	Strong
	Deforested land	Gross-net accounting and subsequent accounting under the new land use should give a strong penalty for deforestation activities. (Section 4.2.5.)	Strong
	Managed forest land	There are potential problems regarding the reliance of the FRL accounting approach on the concept of "*continuation of forest management practices*" as defined in the Regulation. (Sections 4.2.5 and 4.2.6, Points 1 and 3.)	Weak
	Wood products	Covered under FRL accounting for managed forest land. The 'production approach' should ensure that impacts on GHG balances related to wood harvested from forests in EU Member States are covered. The approach of defining a constant ratio between biomass used for energy and non-energy uses will not always register cases where additional biomass is being supplied for use as bioenergy (see Sections 4.2.5 and 4.2.6, Point 4). Imported wood is not covered by the Regulation (this is covered under the assessment of scope, see Section 4.2.2).	Weak
	Natural disturbances	The approach is reasonably consistent with that specified for the second commitment period of the Kyoto Protocol and allows or some limited flexibility whilst still requiring compliance over the period 2021 to 2030. (Section 4.2.5.)	Strong

Element	Criterion	Commentary	Score
Flexibilities	Between periods	The approach is reasonably consistent with that specified under the second commitment period of the Kyoto Protocol. (Section 4.2.7.)	Strong
	Between Member States	The approach is reasonably consistent with that specified under the second commitment period of the Kyoto Protocol and provides some limited scope for effort sharing amongst Member States. (Section 4.2.7.)	Strong
	Contributions from LULUCF under Effort Sharing Regulation	Not assessed. (Section 4.2.7.)	NA
	'Compensation'	Assessment is not possible because the details are not sufficiently specified in the Regulation. (Section 4.2.7.)	NA

Table 4. Assessment of LULUCF Regulation with regard to forest bioenergy supply and consumption: IMPLEMENTATION

Element	Criterion	Commentary	Score
Scope	Global coverage?	Not relevant.	NR
	Carbon pools and GHGs covered	The quality of the National GHG Inventories of EU Member States is variable, although improvements are actively supported. (Section 4.2.1.)	Weak
	Period covered	Not relevant.	NR
Representation of forest land	Afforested land	The quality and completeness of data on afforestation activities is variable. Often there is no formal monitoring and it is necessary to rely on informal or administrative records. Possible scope for improvement (e.g. through application of remote sensing). (Section 4.2.2.)	Weak
	Deforested land	Same as for afforested land.	Weak
	Managed forest land	Reliant on detailed information on forest growing stock from National Forest Inventories (NFIs). However, the quality and detail of NFI data are variable. NFIs are carried out only infrequently in some Member States. (Section 4.2.2 and Section 4.2.6, Point 6.)	Weak
Definitions	'Carbon sink'	Not relevant.	NR
	'Carbon source'	Not relevant.	NR
	Other definitions	Not relevant.	NR
Targets	LULUCF Sector emissions must not exceed removals	Not relevant	NR

Element	Criterion	Commentary	Score
Accounting rules	Reference period 2000 to 2009	Assessed under 'Managed forest land' below.	NR
	Afforested land	Application of gross-net accounting should be straightforward. (Section 4.2.5.)	Strong
	Deforested land	Application of gross-net accounting, and net-net accounting for the subsequent land use, should be straightforward. (Section 4.2.5.)	Strong
	Managed forest land	Member States may interpret the concept of "*continuation of forest management practices*" very broadly. Very reliant on strong external technical review. NFIs do not always collect systematic and detailed information on forest management practices. Informal and administrative records on forest management practices are usually incomplete, variable in quality and may require analysis and interpretation. (Section 4.2.5 and Section 4.2.6, Points 1, 3, 5, 6 and 8.)	Weak
	Wood products	Wood production statistics can be variable in quality and sometimes incomplete (i.e. there may be under-reporting for total wood production or for some wood product sub-categories such as certain bioenergy feedstocks, see Sections 4.2.5 and 4.2.6, Point 7.).	Weak
	Natural disturbances	Natural disturbances in forests are not always systematically monitored and the completeness and quality of data may be variable. (Section 4.2.5 and Section 4.2.6, Point 5.)	Weak
Flexibilities	Between periods	The details of implementation are not specified in the Regulation.	NA
	Between Member States	The details of implementation are not specified in the Regulation.	NA
	Contributions from LULUCF under Effort Sharing Regulation	Not assessed	NA
	'Compensation'	The details of implementation are not specified in the Regulation.	NA

Table 5. Summary assessment of LULUCF Regulation with regard to forest bioenergy supply and consumption

Element	Criterion	Assessment		
		Design	Implement-ation	Overall
Rationale	Level playing field between sectors	NR	NR	Strong
	Influencing national policies	NR	NR	Weak
	Influencing actors	NR	NR	Poor
Scope	Global coverage?	Poor	NR	Poor
	Carbon pools and GHGs covered	Strong	Weak	Weak
	Period covered	Weak	NR	Weak
Representation of forest land	Afforested land	Weak	Weak	Weak
	Deforested land	Strong	Weak	Weak
	Managed forest land	Strong	Weak	Weak
Definitions	'Carbon sink'	Poor	NR	Poor
	'Carbon source'	Weak	NR	Weak
	Other definitions	Strong	NR	Strong
Targets	LULUCF Sector emissions must not exceed removals	Strong	NR	Strong
Accounting rules	Reference period 2000 to 2009	Weak	NR	Weak
	Afforested land	Strong	Strong	Strong
	Deforested land	Strong	Strong	Strong
	Managed forest land	Weak	Weak	Weak
	Wood products	Weak	Weak	Weak
	Natural disturbances	Strong	Weak	Weak
Flexibilities	Between periods	Strong	NA	Strong
	Between Member States	Strong	NA	Strong
	Contributions from LULUCF under Effort Sharing Regulation	NA	NA	NA
	'Compensation'	NA	NA	NA

Note: The combined score for each criterion is taken as the poorest of the scores for design and implementation. There are only 'overall' scores for criteria relevant to rationale.

The outcome of the assessment presented in Table 2 to 5 is discussed further in Section 5. However, it may be immediately observed that:

- Of the 3 criteria relevant to *rationale*, the LULUCF Regulation scores strongly with respect to 1 criterion, weakly with respect to 1 criterion, and poorly with respect to 1 criterion.
- Of the 20 criteria relevant to *design*, the LULUCF Regulation scores strongly with respect to 10 criteria, weakly with respect to 6 criteria, and poorly with respect to 2 criteria, whilst 2 criteria cannot be assessed.
- Of the 13 criteria relevant to *implementation*, the LULUCF Regulation scores strongly with respect to 2 criteria, and weakly with respect to 7 criteria, whilst 4 criteria cannot be assessed.
- Considering *combined* scores for all 23 criteria relevant for rationale, design or implementation, the Regulation scores strongly with respect to 7 criteria, weakly with respect to 11 criteria, and poorly with respect to 3 criteria, whilst 2 criteria cannot be assessed.
- Setting the assessment of rationale to one side, it follows that there may be more issues with the practical implementation of the Regulation than with its design.
- With regard to the specific aim of this assessment, the weak scores obtained for the assessment of FRL accounting for managed forest land and for wood products accounting are particularly pertinent.

5 Discussion

5.1 General impression of Regulation

Throughout the analysis of the EU LULUCF Regulation, the impression has been gained that it was developed in good conscience by its designers. The Regulation reflects an understanding of the underlying science and potential issues regarding forests, forest management and biomass use, and their potential contributions to mitigating GHG emissions. This is apparent from the strong principles to which the Regulation explicitly or implicitly adheres, as evident from aspects of its design. Specifically:

- As in all other sectors, nations should not be able to declare accounted GHG emissions reductions in the forest sector as a result of 'carrying on with business as usual', without taking additional actions to reduce GHG emissions (or increase removals). Actions that increase GHG emissions (or diminish removals) also need to be accounted for as such. *(FRL accounting rather than gross-net or FMRL accounting for managed forest land.)*
- Accounting in the forest sector should reward or penalise increases or decreases in net GHG emissions in forests that occur over time as a result actions taken now, and not as a result of past actions or autonomous age-related forest growth processes. *(FRL accounting rather than net-net, gross-net or FMRL accounting for managed forest land.)*
- Credits for afforestation activities taken in the past should be limited. *(Representation of afforested land.)*
- Often, the 'mobilisation of wood resources' (e.g. to achieve GHG emissions reductions in the Construction, Wood products or Energy Sectors) is not a 'carbon-neutral' activity. Rather, such activities can have potential counterproductive impacts on GHG emissions and removals in the LULUCF Sector. These impacts need to be accounted for, if they occur. *(FRL accounting for managed forest land.)*
- GHG emissions from increasing biomass use as an energy source need particular attention to ensure they are accounted for. *(Constant ratio assumed between solid and energy use of forest biomass when constructing the FRL.)*

5.2 Key flaws in the Regulation

Whilst the principles clearly underlying the Regulation are strong and valid, from the point of view of the regulation of bioenergy, the assessment of the LULUCF

Regulation has revealed some important weaknesses in design and (likely) implementation. Arguably, there are five major flaws, three flaws that are intrinsic to the Regulation and two extrinsic flaws, as discussed below[22].

5.2.1 Intrinsic flaws

Firstly, FRL accounting is a definite improvement on gross-net accounting and FMRL accounting, as applied in the first and second commitment periods of the Kyoto Protocol. However, for reasons explored in Sections 4.2.5 and 4.2.6, the particular design of the FRL accounting approach in the Regulation can allow rates of forest harvesting (and bioenergy supply) to be significantly increased across the EU region, whilst also being able to account for net GHG removals in managed forest land, or at least avoiding the need to account for net GHG emissions. In other words, there can still be 'hot air' in the FRL accounting approach as defined in the Regulation.

Secondly, the distinction made in the Regulation between woody biomass used for energy purposes and for non-energy ('solid') purposes may be viewed as a positive step. However, partly as result of the specific design of the FRL accounting approach (as discussed above), this can still result in situations where forest bioenergy production can be increased without needing to account for related GHG emissions increases, should they occur. This problem is reinforced by the specification that the forest reference level should be constructed by assuming "*a constant ratio between solid and energy use of forest biomass*". This means that, where the FRL accounting allows for unaccounted increases in wood harvesting, this will include a proportion of increased bioenergy supply that, by the same token, does not get accounted for in terms of GHG emissions. This situation may be exacerbated by the lack of clarity over how to quantify the bioenergy part of the ratio referred to in constructing the FRL (e.g. at what point(s) in wood supply chains does the bioenergy get counted).

Thirdly, the assessment has identified issues with implementation of FRL accounting, particularly with regard to data completeness and quality, although efforts within the EU to address this point should be acknowledged. At present, the major issues are with the lack of systematic, complete data sources on forest management practices in forest areas, and with reporting of wood production statistics, particularly for bioenergy feedstocks. At the very least, this is likely to lead to inconsistent implementation by EU Member States when constructing forest

[22] There are also other issues with the Regulation, as highlighted in the assessment, but a number of these are of less direct concern to the specific question of effective regulation of bioenergy use, or the issue is of wider concern, rather than specific to the Regulation (e.g. how the term "carbon sink" gets defined and used).

reference levels, and the possibility of overestimation or underestimation of projected emissions and removals.

5.2.2 Extrinsic flaws

It should be stressed that the *extrinsic* flaws identified here are strictly nothing to do with the EU LULUCF Regulation, its design or implementation, as such. Rather, these flaws are related to the effectiveness of the LULUCF Regulation and other policy frameworks in working together.

Firstly, the EU LULUCF Regulation can only cover the LULUCF Sectors of EU Member States. As discussed in the assessment (Section 4.2.1 and Section 4.2.5, discussion of 'wood products'), the regulation of imported biomass sources falls back on the relatively weak provisions in RED II, which are unlikely to guarantee that imported wood biomass used for energy will deliver GHG emissions reductions with high certainty. The Regulation could only be extended to non-EU countries if the provisions of the Regulation were to form the basis of a more widely applicable international agreement. Equally, there are potential problems with placing conditions on sources of forest biomass allowable for importation to the EU for energy use, such as because of the implied restrictions on trade with other nations. Whilst these issues cannot be addressed by the EU LULUCF Regulation, it is a gap in the policy framework that is left as a result of relying mainly on the Regulation to account for the impacts on GHG emissions from bioenergy use internally in the EU, and on attaching very limited conditions to biomass sources imported from outside the EU.

Secondly, as highlighted in the assessment, the LULUCF Regulation has no direct influence over decisions taken and/or choices made by relevant actors (e.g. forest managers, wood processors and/or power generation utilities). This is a significant problem because other EU policies continue to work on the assumption that forest biomass (and specifically forest bioenergy) can (nearly) always be treated as being 'carbon-neutral'; this is true of the EU ETS and of RED II, for example. In particular, the EU ETS, with its escalating carbon price, effectively offers increasing financial incentives for using biomass as an energy source with assumed zero GHG emissions. Hence, actors are not receiving the right signals to influence their decisions and choices when supplying or consuming forest bioenergy. Instead, these policies rely upon the LULUCF Regulation sending the relevant signals to the national governments of Member States. Member States then need to register (and ideally foresee) situations where biomass harvesting in EU forests is not consistent with the assumption of carbon-neutrality. The notion appears to be that this will stimulate Member States to ensure that national policies on forests and bioenergy support, rather than undermine, achieving the goal of GHG emissions reductions in policy-relevant timescales. If the Regulation does not fulfil this purpose, the relevant signal doesn't get sent to Member States. It is also possible that some Member States may simply not 'notice' the signal being sent (or not foresee it in sufficient time). Either way, Member States may not recognise where further action is needed on domestic policies supporting forestry and bioenergy. This situation is leaving an important gap in EU policy on bioenergy.

5.3 Concluding observations

The EU LULUCF Regulation is a significant and worthwhile improvement on previous frameworks and it is important to acknowledge the achievement made in bringing it forward, and the efforts of its developers to ensure its integrity. Unfortunately, the introduction of the LULUCF Regulation has not fully resolved the problem of ensuring that the harvesting and use of forest biomass, for energy or for other purposes, is sympathetic to achieving the goal of GHG emissions reductions in policy-relevant timescales.

Essentially, the Regulation still effectively gives a permit to the forest, wood products and bioenergy sectors in the EU to increase wood production, including bioenergy production, potentially without needing to account for all of the consequent GHG emissions increases, should they occur. At the same time, imported biomass is covered poorly, being out of scope of the Regulation and only very weakly covered elsewhere in EU policies.

As a general conclusion, the EU LULUCF Regulation and its approaches to accounting should be viewed as a significant step forward, compared to previous frameworks. Perhaps it is by nature that all policies and instruments will have weaknesses and loopholes, no matter how well they are designed. Nevertheless, the flaws present in the LULUCF Regulation need to be recognised where they could lead to significant problems.

During the development of the assessment presented in this report, possibilities were identified for how the regulation of (forest) biomass for energy purposes in the EU could be improved. Options were considered that involved incremental improvements to the LULUCF Regulation and/or strengthening the provisions of other policies such as RED II. Possible options for future policies are currently the subject if active debate. For this reason, the conclusions of this report do not prejudge what changes would be appropriate to address the issues highlighted by this assessment.

The debate about the role of forest bioenergy in contributing towards achieving GHG emissions reductions, or impeding this goal, has been going on for over a decade now. Stakeholders in the forest and bioenergy industries and in environmental groups can still take polarised positions on the subject. Is there any hope left for reaching a common understanding and consensus, based on the objective and impartial interpretation of the available scientific evidence? Given the urgency with which climate change needs to be addressed, and the need to get responses right first time, scientific researchers and concerned stakeholders have a responsibility to engage constructively in this debate. There have been a number of examples of open letters signed jointly by scientists and concerned individuals, urging the case for deprioritising the use of forest bioenergy or insisting on its benefits. It is suggested here that greater efforts are needed on all sides to establish, not what is disputed, but what can be agreed upon, for example, a core of common scientific principles. If possible, the situation could be improved if a joint statement of such principles, with wide acceptance across stakeholder groups, could be developed, rather than focusing on areas of disagreement.

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