Briefing Paper

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

Robert Matthews

1 Introduction

Historical context and rationale for policy on bioenergy

Biomass has been increasingly recognised as a potential renewable energy source. That this could involve low or zero net emissions of greenhouse gases (GHGs) was based on the assumed closed cycle exchange of carbon between the atmosphere and plant biomass.

Since 2001, targets relating to the percentage of energy from renewable sources have been set by the Renewable Electricity (RES) Directive, the Renewable Energy Directive (RED) and the recast Renewable Energy Directive (RED II), with increasing, mandatory targets with each directive. Although biomass was not explicitly promoted it was included as one renewable energy source. The EU Emissions Trading System (ETS) also incentivises the use of bioenergy, by rating GHG emissions from biomass consumption as zero. Over the period 2010 to 2015, the use of forest biomass in solid form as an energy feedstock in the EU 28 countries is estimated to have risen from about 90 million oven-dry tonnes (Modt) to 133 Modt. This includes the consumption of wood fuel pellets, estimated at 10 Modt in 2010 and 23 Modt in 2016, including 7.7 Modt imported in 2016.

There is growing recognition that bioenergy can have significant impacts on net GHG emissions where there are changes in the scale of the use of biomass from forests ("forest bioenergy") as a result of changes in carbon stocks and impacts on rates of carbon sequestration. Under RED II, these potential risks of bioenergy use leading to increased GHG emissions are addressed in Article 29, which requires that countries supplying forest biomass must have mechanisms to conserve and report changes in carbon stocks.

Biomass is produced in the LULUCF (Land Use and Land Use Change) Sector but usually consumed in the Energy Sector. To avoid double counting of GHG emissions in both sectors, the convention is that CO_2 emissions from burning it in the Energy Sector are reported as zero but are captured by reporting in the LULUCF Sector. However, this can potentially mask the impacts on GHG emissions from bioenergy.

In the EU, GHG emissions accounting rules for the LULUCF sector, for application from 2021, are the subject of the LULUCF Regulation which came into force in 2018. However, this must work synergistically with RED II and the EU ETS, by influencing national governments of Member States, as key building blocks of EU climate and energy policy, to ensure that the use of biomass for energy helps reduce GHG emissions on a timescale that is relevant for climate change mitigation. There are, however, limits on the control the EU can exert on fuel imported from non-EU countries.

Purpose and structure of briefing

The EU Green Deal aims to cut GHG emissions ambitiously and achieve climate-neutrality by 2050, whilst the EU 2030 Climate Target Plan specifies cuts in EU GHG emissions by between 50% and 55% by 2030 compared to 1990, although less reliance on bioenergy is implied.

The purpose of this brief is to provide a critical assessment of the efficacy of the EU LULUCF Regulation to meet the EU's climate action aims, and its effectiveness in providing a complementary function to RED II and the ETS to support the use of forest bioenergy in the EU to deliver GHG emissions reductions. This briefing paper provides a summary of an accompanying technical report, where a more thorough analysis and assessment may be found.

Section 2 discusses the science behind forest carbon balances and of the impacts of forest management. Section 3 presents an overview of the historical development of LULUCF accounting approaches. In Section 4 an assessment is made of the robustness of the LULUCF Regulation in capturing GHG emissions arising from producing and consuming forest bioenergy, and for promoting their avoidance. Section 5 discusses the implications, with emphasis on potential issues identified by the assessment and presents some conclusions.

2 Status of the science

The science of forest GHG balances, the impacts of forest management and the role of harvested wood, including bioenergy, have been the subject of intensive research for at least 20 years. Whether the significant extraction and use of forest biomass for energy has positive or negative impacts on GHG emissions remains strongly contested. Scientific and technical papers and reports on the subject apparently offer contradictory evidence and conflicting conclusions.

Looking more closely at this research, subtle, but key, differences in approach can be seen, including in the use and definition of common terminology. For example: the forestry sector typically thinks of the 'forest carbon sink' as the 'forest carbon pump', that is, the net flow of carbon between the forest and atmosphere from tree growth and mortality, respiration and decay, whereas environmentalists and most forest carbon researchers typically think of the 'forest carbon sink' as the 'net forest carbon balance' which also includes the flow of carbon out of the forest in the biomass that is harvested and extracted for products. LULUCF reporting for forest land in the EU reflects the 'net forest carbon balance' for forest land categories.

Differences such as this have led to misunderstandings and disagreements when discussing how best to manage forests and utilize wood to achieve reductions in CO_2 emissions.

There are situations in which wood harvested for products (including bioenergy) can be regarded as "carbon neutral". One example is when biomass is produced from forests under certain conditions:

- The forest areas producing the biomass are being managed sustainably (that is, according to the principles of strong sustainable forest management standards that include criteria covering the maintenance of soil and water quality, conservation of biodiversity, protection of habitats, respect for local/indigenous communities and so on, as well as sustainable-yield harvesting)
- Wood harvesting is within the limits of 'sustainable yield', i.e., the level of biomass harvesting does not exceed the capacity of the forests to grow more biomass to replace the losses

- The 'intensity' of harvesting has been practiced for many decades, i.e., the annual level of harvesting has been roughly constant, and neither increasing nor decreasing significantly over time.

However, it is flawed thinking to assume that harvested biomass is always 'carbon neutral', if the only first two conditions above are met. This is particularly the case if the level of biomass harvesting is escalated over time.

Generally, if the level of wood harvesting in forests is increased to meet additional requirements for biomass, this can perturb the carbon balance of forestry systems, generally leading to a period during which emissions are increased. (This point is explained more thoroughly in the accompanying technical report.) Essentially, the duration of the period of increased emissions depends on how long it takes for the forests to recover from being perturbed by the additional harvesting, which may be within one year or may involve centuries. Alternatively, even if forest management remains unchanged, if the proportion of wood for energy is increased, this can result in a more rapid outflow of carbon to the atmosphere from wood products, which may diminish, but only after some time.

Conversely, an increased demand for biomass from forests can provide incentives to maintain existing forests (rather than changing to another land use) and potentially to expand forest areas, providing additional carbon sequestration as well as additional biomass. However, the consequent response of the sector (e.g. to retain existing forests or possibly expand them) and the resulting potential positive carbon uptake and avoidance of carbon losses are uncertain. Where they do occur, this is likely to involve some time lag.

Faced with what sometimes appear to be contradictory conclusions in scientific studies, conflicting positions are taken by stakeholders on how forests should be managed, how wood should be utilised for products, and which parts of trees are acceptable (or otherwise) for energy. However, there have already been several reviews of relevant research and findings. These reviews have concluded that the magnitude and duration of the period of increased emissions arising from increased biomass harvesting from forests depend on numerous factors. These factors can be understood and actions that increase bioenergy supply in ways that are likely to lead to long-term increases in emissions can be identified. For example, it may be possible to develop a "decision tree" or a set of criteria for managing risks associated with forest bioenergy to ensure that the GHG emissions of bioenergy are generally low.

3 History of LULUCF accounting

Why is forest carbon accounting complex?

Accounting for changes in GHG emissions in the LULUCF sector is complex, particularly in the case of forests and forest management, especially as many factors are not under direct human control. While the choice of tree planting stock can be chosen (within the constraints of the site and climate), the way the trees grow and absorb (and emit) CO_2 over time is the result of biophysical processes and environmental conditions over which

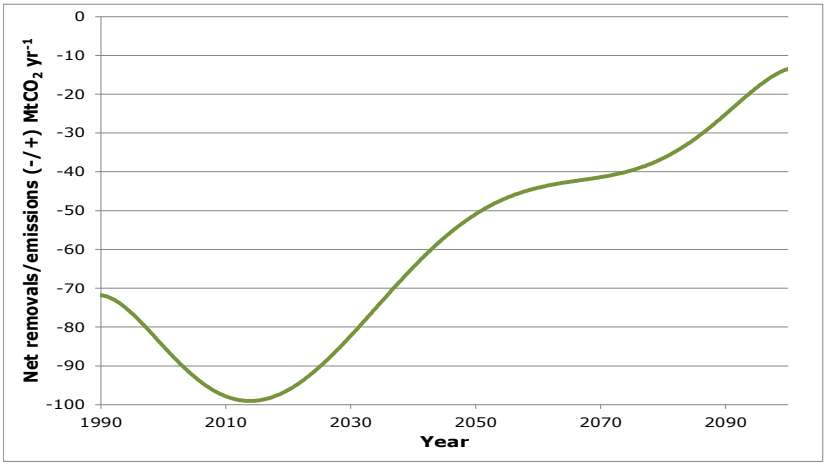

Figure 1 Net CO_2 balance of the forests of a hypothetical nation

humans have little control. There are also time lags of years or decades between planting, the accumulation of carbon, and harvesting.

Figure 1 illustrates the net CO_2 balance over time for the forests of a hypothetical nation, expressed in units of millions of tonnes of CO_2 per year ($MtCO_2$). The great majority of the nation's forests have been under active management for many decades or centuries. Negative numbers indicate net absorption (or 'removal') of CO_2. In 1990, a significant proportion of the forest area is formed of relatively young trees, which are the result of afforestation activities before 1990. These contribute towards increasing absorption CO_2 up to 2015. However, as these trees age, the rate of net forest carbon sequestration (i.e. the rate of net accumulation of carbon stocks) declines. However, the accumulation of carbon in forest stands can continue for a significant period beyond the time when forest stands are typically harvested. Hence, harvesting for wood production also contributes to the subsequent fall.

Table 1 gives the net rate of net CO_2 removals for the nation's forests for three example years of 1990, 2015 and 2050, and also compares the rates in 2015 and 2050 with that in 1990. The values have been rounded to make them easier to interpret.

The changes in the rate of net CO_2 removals are an inevitable consequence of a (laudable) historical afforestation programme. (The only way to avoid the decline would be to continue the afforestation activities indefinitely, which is unrealistic.) When allowing for past forestry practices, these characteristics make it difficult to apply relatively simple accounting approaches to forest land, such as 'net-net accounting' and 'gross-net accounting', as explained below.

Table 1 Net CO_2 removals in a nation's forests in three example years

Year	Net CO_2 removals/emissions ($MtCO_2\ yr^{-1}$) (rounded to assist interpretation)	Change compared to 1990
1990	-70	-
2015	-100	-30
2050	-50	+20

'Net-net accounting'

The *'net-net accounting'* approach is applied for most land uses (e.g. cropland and grassland). The approach involves subtracting the net CO_2 emissions or removals, estimated to have occurred in forest land in a 'base year', from the net CO_2 emissions or removals for an 'accounting year' or 'accounting period'. Taking the example illustrated in Figure 1 and Table 1, for a base year of 1990, the *accounted* net CO_2 removals in 2015 would be -30 $MtCO_2$ (the difference in net removals for the two years). However, for an accounting year of 2050, net emissions of +20 $MtCO_2$ would be accounted, effectively penalizing the nation for its efforts towards afforestation before 1990.

'Gross-net accounting (with cap)'

Under the *'gross-net accounting'* approach, the total CO_2 removals (or emissions) are accounted, rather than the change from a base year. For example, based on Figure 1 and Table 1, the full net removals of -100 $MtCO_2$ would be accounted in 2015, with net removals of 50 $MtCO_2$ accounted in 2050. However, this would mean that the nation would be able to declare significant accounted net CO_2 removals, without having taken any additional mitigation activities during the accounting years (or even since 1990). The net removals in forest land are the result of actions taken in previous decades, or in some situations may simply reflect the current structure of forest areas, which may not be the result of any specific actions taken by the nation. For this reason, net removals that can be accounted may be 'capped' at a maximum removal (e.g. perhaps -5 $MtCO_2$ for this example nation). It remains the case that this accounting approach could allow nations to claim net CO_2 removals for forest land,

without taking any mitigation actions (sometimes referred to as accounted 'hot air'), and that potential CO_2 emissions from additional harvesting (or bioenergy or other wood products) would not be accounted for.

'FMRL accounting (with cap)'

To address the difficulties with the accounting approaches discussed above, *'Forest Management Reference Level (FMRL) accounting'* was developed. Under this system each nation makes a projection of net CO_2 emissions/removals from forests, based on the assumption of *"business as usual forest management practices"*. The projected level of CO_2 emissions or removals is known as the 'Forest Management Reference Level' or 'FMRL'. In each accounting year, this *projected level* is subtracted from the actual emissions/removals, so that performance relative to the FMRL benchmark is assessed.

The construction of FMRLs requires sophisticated forest models, and these are sensitive to assumptions about potential future changes in forest management.

Under the FRML accounting approach, nations can allow for the impacts of existing policies when making assumptions about future forest management. For example, an existing policy to increase the supply of bioenergy from forests can be allowed for, so that its impacts are then included in the calculation of the FMRL. Consequently, the potential impacts of the policy on net CO_2 emissions/removals would not be included in accounted emissions/removals. Conversely, if the assumed future changes in forest management do not actually occur, but had been built into the FMRL, this could lead to the nation being able to account for 'hot air'. As a guard against this possibility, the accounted net CO_2 removals under FMRL accounting may be capped, as under gross-net accounting.

'FRL accounting'

'Forest Reference Level (FRL) accounting' attempts to address the difficulties with FMRL accounting by basing the construction of the projection for the 'Forest Reference Level' or 'FRL' on the *observed recent management of forest areas*, without allowing for the possible future evolution of forest management practices in response to policies. A 'reference period' is set (such as 2000 to 2009) and (documented) forest management over this period is assumed to represent future practice when projecting CO_2 emissions and removals. This should mean that the impacts of changes to forest management including in response to policies (positive or negative), should be accounted for, whilst the impacts of past actions, and of changes in the development of forests unrelated to management, are not accounted for. This principle of FRL accounting is laudable but the effectiveness of the approach relies on the details of its design and implementation, as discussed below.

4 EU LULUCF Regulation: analysis and assessment

The technical report accompanying this brief presents a detailed analysis and assessment of the EU LULUCF Regulation. The focus is on the effectiveness of the regulation in supporting the appropriate consumption (and supply) of (forest) bioenergy, by ensuring bioenergy use contributes towards achieving reductions in GHG emissions in policy relevant timescales. The full assessment has identified elements of the Regulation that are strong in supporting this goal. However, there are also elements that only weakly support the effective use of bioenergy, whilst there are some elements that are assessed as poor, i.e., seriously falling short of supporting the desired outcomes.

This brief can only present a summary of the most important findings of the full assessment. Given the purpose of this brief, the emphasis below is on the key findings regarding the most important poor and weak aspects of the Regulation.

4.1 Key flaws and weaknesses in the Regulation

4.1.1 Flaws and weaknesses in rationale

Lack of direct influence over 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, 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.

Influencing national policies/actions

Largely, forest policy in EU Member States is not determined by the EU but by individual Member States. Hence, as noted in the introduction to this brief, 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 penalizes actions that lead to emissions 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, 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.

4.1.2 Flaws and weaknesses in design

No coverage of non-EU countries supplying biomass to the EU

The EU LULUCF Regulation applies to all EU Member States but 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. 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.

Definitions of 'carbon sink' and 'carbon source'

The definitions for 'carbon sink' and 'carbon source' are consistent with those given in authoritative sources (e.g. IPCC reports). However, these definitions are ambiguous in some

respects (particularly in the case of 'carbon sink'), which can lead to confusion and misunderstandings in discussions of forest management and forest bioenergy use and their potential GHG emissions.

Representation of afforested land

Because of the way afforested land is defined under the Regulation, when this is combined with the Regulation's accounting rules, credits for afforestation activities are likely to be very limited. This is a weak incentive for Member States to carry out afforestation activities, which are one way in which additional biomass resources could be created in conjunction with additional forest carbon sequestration.

Accounting rules: Reference period 2000 to 2009

The Regulation refers to a reference period of 2000 to 2009 for characterising "sustainable forest management practice[s]" that are to be assumed to be continued when constructing the forest reference level. However, 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 during the period. 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).

Accounting rules for 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. Most importantly, among these, 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.

Alternatively, if the FRL for a Member State allows for some increased wood harvesting, but wood harvesting is not actually increased, this would suggest that the Member State 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.

Accounting rules for wood products

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 scope of the EU LULUCF Regulation and may not be accounted.

For EU Member States, when the forest reference level is constructed, an assumption is made regarding future wood production of "a constant ratio between solid and energy use of forest biomass". The purpose of this accounting rule 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. This approach goes some way towards addressing concerns about the increased use of forest biomass for energy purposes leading to increased GHG emissions. However, the approach can still conceal emissions arising from additional forest bioenergy use. Specifically, if the

projected forest reference level allows for some increased wood production, 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.

4.1.3 Weaknesses in implementation

Representation of forest land

The representation and modelling of forest land is reliant on detailed information on the growing stock of managed forest land areas (e.g. tree species, growth rates, tree ages), generally obtained 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. The quality and completeness of data on afforestation and deforestation activities is variable. Often there is no formal monitoring and it is necessary to rely on informal or administrative records. It is equally important to have data on how different types of forest have been managed during the reference period of 2000 to 2009. However, systematic and detailed quantitative data on forest management practices are not generally collected as part of NFIs. 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).

Accounting rules applied to managed forest land

When constructing the forest reference level for managed forest land, Member States may interpret the concept of "continuation of forest management practices" very broadly. The effectiveness of the approach is thus very reliant on strong external technical review. Furthermore, as highlighted above, 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.

Accounting rules applied to wood products

As discussed earlier, the LULUCF Regulation requires that the construction of the forest reference level should apply "a constant ratio between solid and energy use of forest biomass …", when projecting future wood production. However, there may be difficulties in calculating this ratio and in checking its validity. The situation is made worse by limitations in the data available on wood production from forests of EU Member States. The reporting of wood production (e.g. in FAO statistics) according to important categories and sub-categories (such as 'wood fuel', 'wood chips and particles' and 'wood residues') 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.

Accounting rules applied in the event of natural disturbances

The Regulation includes provisions for emissions arising from significant natural disturbances in forests to be excluded from accounted emissions. 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. However, natural disturbances in forests are not always systematically monitored and the completeness and quality of data may be variable. This presents an obstacle to the effective application of the natural disturbance provision and may mean that in practice it cannot be used, or that it cannot be used effectively.

5 Discussion and conclusions

5.1 General impression of Regulation

The EU LULUCF Regulation was developed in good conscience and 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.

5.2 Key flaws in the Regulation

Whilst the principles underlying the LULUCF Regulation are strong and valid, this assessment has revealed some important weaknesses in design and implementation. **Five major flaws** – three flaws intrinsic to the Regulation and two extrinsic flaws – are discussed below.

5.2.1 Intrinsic flaws

The **first flaw** concerns the design of FRL accounting. FRL accounting offers a definite improvement on accounting rules in previous climate agreements. However, 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 still accounting for net GHG removals in managed forest land, or at least avoiding the need to account for net GHG emissions.

The potential for unaccounted GHG emissions resulting from the first flaw is exacerbated by the **second flaw**, which arises from the specification that the forest reference level should be constructed by assuming "*a constant ratio between solid and energy use of forest biomass*". If this ratio allows for a generous amount of bioenergy and the level of harvesting is projected to increase as part of modelling the FRL, then this could accommodate a significant increase in bioenergy use in the future without accounting for any consequent GHG emissions.

The **third flaw** arises from the major issues 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. This is likely to lead to inconsistent construction of FRLs.

5.2.2 Extrinsic flaws

It should be stressed that the *extrinsic* flaws identified here are related to the effectiveness of the LULUCF Regulation and other policy frameworks in working together.

The **fourth flaw** arises from the fact that the EU LULUCF Regulation can, of course, only address the LULUCF Sectors of EU Member States. The regulation of imported biomass sources falls to relatively weak provisions in RED II, which are unlikely to guarantee that imported wood biomass used for energy will deliver GHG emissions reductions. These issues cannot be addressed by the EU LULUCF Regulation, requiring broader, international agreement.

The **fifth flaw** arises because the LULUCF Regulation cannot directly influence the decisions of relevant actors. However other EU policies intended to influence actors continue to work on the assumption that forest biomass can (nearly) always be treated as being 'carbon-neutral', e.g. in the EU ETS and RED II. In particular, the escalating carbon price in the EU ETS 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 when supplying or consuming forest bioenergy.

5.3 Concluding observations

The EU LULUCF Regulation and its approaches are a significant step forward, e.g. compared to previous accounting under the Kyoto Protocol. This is a major achievement on the part of those involved in its development and agreement. Nevertheless, the flaws present in the LULUCF Regulation need to be recognised where they could lead to significant problems.

Whilst the full assessment presented in the accompanying technical report was being carried out, 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 of 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.

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 with this debate. 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.

This work was commissioned by Fern and Birdlife Europe, with funding from the European Climate Foundation, the David and Lucile Packard Foundation and the European Union. The contents of the report are the sole responsibility of the authors and can in no way be taken to reflect the opinions of any of the donors.

Alice Holt Lodge
Farnham
Surrey, GU10 4LH, UK
Tel: **0300 067 5600**

Northern Research Station
Roslin
Midlothian, EH25 9SY, UK
Tel: **0300 067 5900**

Forest Research in Wales
Environment Centre Wales
Deiniol Road, Bangor
Gwynedd, LL57 2UW, UK
Tel: **0300 067 5774**

info@forestresearch.gov.uk
www.forestresearch.gov.uk