



Improved methods for carbon accounting for bioenergy

Descriptions and evaluations

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List of abbreviations

| | |
|-------------------------------|---|
| ARD | Afforestation, reforestation and deforestation |
| CBA | Consumer-based accounting |
| CO ₂ | Carbon dioxide |
| EPA | Environmental Protection Agency (United States) |
| EU Renewable Energy Directive | Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC |
| EU-ETS | European Union Emissions Trading Scheme |
| GDP | Gross domestic product |
| GHG | Greenhouse gas |
| iLUC | Indirect land use change |
| IPCC | Intergovernmental Panel on Climate Change |
| LCA | Life-cycle assessment |
| LUC | Land use change |
| POUR | Point of uptake and release |
| REDD+ | Reducing emissions from deforestation and forest degradation and enhancing carbon stocks |
| UNFCCC | United Nations Framework Convention on Climate Change |
| US RFS2 | US Renewable Fuels Standard |
| WTO | World Trade Organization |

Executive summary

This report reviews and evaluates bioenergy accounting approaches in the climate context. Consideration of alternative accounting approaches for emissions generated by the use of biomass for energy is very timely. Both the European Union and the United States are engaged in consultation processes to develop regulatory approaches to these emissions. The EU consultations are, to some extent, taking place because the accounting system under the Kyoto Protocol results in use of bioenergy beyond the level justified by the climate mitigation it achieves. The US consultations are in response to the US Environmental Protection Agency's (EPA) recent obligation to regulate carbon dioxide (CO₂) emissions from all sources. This process has openly raised the question of whether CO₂ emissions from use of bioenergy should be treated in the same manner as CO₂ emissions from use of fossil fuels.

Under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, CO₂ emissions from use of bioenergy are counted in the land use sector as carbon stock losses, rather than as emissions in the energy sector, where emissions from fossil fuels are counted. This accounting method, which is also applied under the EU Emissions Trading Scheme (EU-ETS), omits many emissions that result from use of bioenergy in nations with greenhouse gas (GHG) limitation obligations. Consequently, alternative accounting systems are being proposed that would more fully include emissions from bioenergy use in countries with GHG-limitation obligations in the real-world situation that developing countries do not currently, and probably will not in the near future, have GHG limitations.

The report describes and evaluates various bioenergy accounting systems that could be used in nations with GHG-limitation obligations. In this report, the systems are classified into 3 basic approaches:

1. CO₂ emissions are multiplied by '0' at the point of combustion (the current system in which no CO₂ emissions are attributed to bioenergy in the energy sector under the Kyoto Protocol and EU-ETS);
2. CO₂ emissions are multiplied by '1' at the point of combustion (the basic alternative in which the CO₂ emitted when biomass is combusted would be counted in the same way CO₂ released upon combustion of fossil fuels is accounted for under the Kyoto Protocol); and
3. CO₂ emissions along the biomass-energy value chain are the responsibility of end users regardless of where these emissions occur. Value-chain approaches can use calculated amounts of emissions to determine whether bioenergy meets a regulatory requirement or to derive a combustion factor potentially other than '0' or '1' for application to combustion emissions.

This report briefly describes accounting system options and then evaluates them in 2 ways.

First, options are evaluated against 3 criteria:

(1) comprehensiveness over space and time, i.e., the extent to which the system accurately counts all emissions; (2) simplicity, including ease of implementation; and (3) scale independence, or the degree to which the system can be used at the project, entity, national or global level. Second, accounting systems are evaluated with regard to

the degree to which they support 3 key stakeholder goals: (1) stimulation of rural economies and food security; (2) GHG emission reductions; and (3) preservation of forests. From the perspective of GHGs, comprehensiveness over space and time is the most important criterion, but for many stakeholders, support for rural economies or preservation of forests are the most important goals.

A key conclusion is that, generally, '1' multiplier approaches incorporate more emissions than '0' multiplier approaches. Value-chain systems are the most comprehensive with regard to emissions that attend use of bioenergy. POUR (point of uptake and release), one of the 1-multiplier approaches reviewed, is the most comprehensive system as far as forest-related emissions are concerned because it counts all forest atmospheric removals as well as emissions from all uses of biomass, not only those from use of biomass for energy. Furthermore, POUR has the potential to be the most accurate

system in reporting emissions where and when they occur and when the goals of stimulation of rural economies and food security are prioritised, POUR continues to rank at the top of the available options. However, POUR does not rate well in terms of forest preservation.

If carefully constructed, supplemental policies can render a '0' multiplier approach effective in spatial coverage. For example, a '0' multiplier approach can support all 3 goals if sources of biomass for bioenergy are restricted to nations with economy-wide GHG limitations. However, in our opinion, this approach is of limited value because most countries would likely remain outside of the accounting system. Finally, a well-designed value-chain approach could strongly support GHG reductions and preservation of forests, but would be information intensive and depend on associated bioenergy mandates or the structure of a cap-and-trade system to stimulate the rural economy.

1

Introduction

Accounting systems strongly influence decisions, and pressure is increasing to alter the accounting system used to calculate emissions due to bioenergy under the Kyoto Protocol and the EU Emissions Trading Scheme (EU-ETS) (Peters *et al.* 2009, Searchinger *et al.* 2009). The current accounting system does not capture the full extent of greenhouse gas (GHG) emissions caused by bioenergy, and hence encourages nations and energy producers to use more bioenergy than is justified by the amount of GHG emission reductions it achieves.

Under the Kyoto Protocol accounting system, carbon dioxide (CO₂) emissions released from use of biomass are counted not in the energy sector, but rather as changes in levels of carbon stocks in the land use sector. However, carbon stock level changes are not accounted for in nations that do not have GHG obligations under the Kyoto Protocol. Therefore, in the case of biomass sourced from these nations, neither the carbon stock changes nor the emissions at the point of combustion are accounted for—even if the biomass is used in nations that do have obligations under the Kyoto Protocol. This situation has 2 consequences. First, nations with GHG limitations have an incentive to source biomass from nations that do not. Second, since the Kyoto Protocol accounting system relieves energy producers of all responsibility for CO₂ emissions from bioenergy, the system provides a powerful incentive for them to use bioenergy even where its use may lead to increases in CO₂ emissions.

To date, nations with GHG obligations—with the exception of New Zealand—have not imposed

emission limitations, or requirements to hold permits to emit, on entities within the land use sector. Furthermore, the land use sector is not included in the EU-ETS. Therefore, carbon stock losses in the land use sector caused by an increase in bioenergy use are irrelevant both to individual actors in the land use sector in the EU and to energy producers that have obligations under the EU-ETS. These energy producers have a strong incentive to use bioenergy because the EU-ETS does not require them to surrender permits to cover these emissions. However, carbon stock reductions due to use of bioenergy lower a nation's, and the EU's net removals in the land use section, which makes it more difficult for the nation and the EU to meet its GHG emission target. In this case, a likely EU response would be to provide fewer allowances under the EU-ETS. As long as bioenergy emissions continue not to be counted, this action would be likely to stimulate greater use of bioenergy by energy producers with GHG emission limitations, thus creating a vicious circle and exacerbating rather than alleviating the problem.

This situation can be addressed by bringing more land use sector emissions into the accounting system and/or increasing the responsibility of energy sector entities for bioenergy emissions. Approaches that do one or both of these could potentially lead to better alignment of bioenergy use with its GHG consequences. This study focuses on evaluating accounting options that seem to offer this benefit, with the current EU and US consultation processes on how to address bioenergy emissions within regulatory frameworks lending urgency to the task.

1.1 Structure and scope of the report

This report focuses on alternative accounting systems for bioenergy that nations or regions could use in calculating their GHG emissions. We first discuss the three main types of approaches to emissions from bioenergy that can be used in accounting systems (Section 2). In Section 3, we describe alternative accounting systems under each of the main types, noting which of these are in use, which represent modifications of an in-use approach, and which have been suggested but are not yet in use. In Section 4, we propose general criteria (comprehensiveness, simplicity, scale independence) for evaluating bioenergy accounting systems, which we then apply to evaluate the systems. In Section 5, we consider key goals—GHG mitigation, energy and food security, and forest preservation—that diverse stakeholder groups may pursue in connection with use of bioenergy, and discuss the fit between the systems and these goals. In Section 6, we set out our conclusions.

Recent negotiations under the United Nations Framework Convention on Climate Change (UNFCCC) have led to commitments to provide funds to developing countries to reduce emissions

from deforestation and degradation, and for forest conservation (REDD+). Slowing deforestation and forest degradation may reduce the availability of biomass for energy and/or increase its price, thus reducing emissions from this source. However, REDD+ credits may enter accounting systems as offsets,¹ thus lowering entities' costs of meeting their GHG obligations. Given the substantial uncertainties about how the REDD+ system will interact with demand for bioenergy, we do not attempt to envisage interactions between REDD+ and the proposed accounting systems. Furthermore, as the baseline and crediting systems envisaged under REDD+ do not affect how emissions from bioenergy are accounted for, as the term bioenergy accounting is used here, we do not discuss the baseline and crediting concept in this report.

We also recognise that intensity-based targets (e.g. tonnes of GHGs per unit energy, gross domestic product (GDP) or output rather than an absolute number of tonnes) may be incorporated into both developing and developed country climate initiatives, possibly in conjunction with sectoral or bilateral agreements. Although such intensity-based accounting approaches do have attractive features, particularly for the land use sector and bioenergy, analysing them is beyond the scope of this report.

1 Offsets refer to GHG emission credits allocated to entities without GHG obligations under a system in which entities with GHG obligations can use such credits to help them meet their targets.

2

The basic accounting approaches

The basic reason for using bioenergy to help mitigate climate change is that—in contrast to fossil fuel carbon stocks—biomass carbon stocks can be replenished relatively quickly by growing new biomass. However, the emissions from combusting biomass and the replenishment of carbon stocks generally take place in different locations, often in countries far from each other, and in different time periods. This creates challenges for accounting systems if overall emissions are to be accounted for accurately but not all countries account for their emissions.

Each approach to accounting for emissions from use of bioenergy that has been implemented or proposed addresses some or all of these issues, although they do so differently. The following 3 philosophies form the basis of all the approaches to accounting for emissions from use of bioenergy that are discussed in Section 3:

- A. **Combustion factor = 0:** CO₂ emissions produced when biomass is burnt for energy are multiplied by 0 at the point of combustion; the emissions are accounted for in the land use sector as carbon stock losses.
- B. **Combustion factor = 1:** CO₂ emissions produced when biomass is burnt for energy are multiplied by 1 at the point of combustion; emissions are accounted for in the energy sector; uptake of CO₂ from the atmosphere by plants and soils may, or may not, be accounted for.
- C. **Value-chain approaches:** End users are responsible for all, or a specified subset of, emissions that occur along the bioenergy value

chain regardless of where these emissions occur. The calculated emissions can be used either to determine whether bioenergy is eligible to meet a regulatory requirement, or to derive a combustion factor potentially other than 0 or 1 to be applied to combustion emissions.

Throughout this report, accounting systems that use either A or B are assumed to account for emissions attendant on use of bioenergy other than carbon stock gains and losses, e.g. emissions due to transportation of the biomass, in the relevant sector. In contrast, an accounting system that uses C brings all emissions attendant on use of bioenergy into bioenergy accounting. It therefore needs to ensure that any emissions included in the bioenergy accounting system are not also counted elsewhere.

To demonstrate differences between the approaches, we use the simple schematic diagram shown in Figure 1. This diagram shows the flows of GHGs to and from the atmosphere and the trading of biomass (as carbon, C) between the biomass producer and its consumer. The biomass producer has three emission streams: CO₂ absorbed by plants; CO₂ oxidised by plants (both of which are shown as Bio-CO₂); and fossil-CO₂ and non-CO₂ emissions that attend biomass production, conversion and its transportation to a consumer. The biomass consumer has 2 streams: CO₂ from the combustion of biomass (bioenergy CO₂) and fossil-CO₂ and non-CO₂ emissions from combustion and distribution of fuels to end users.

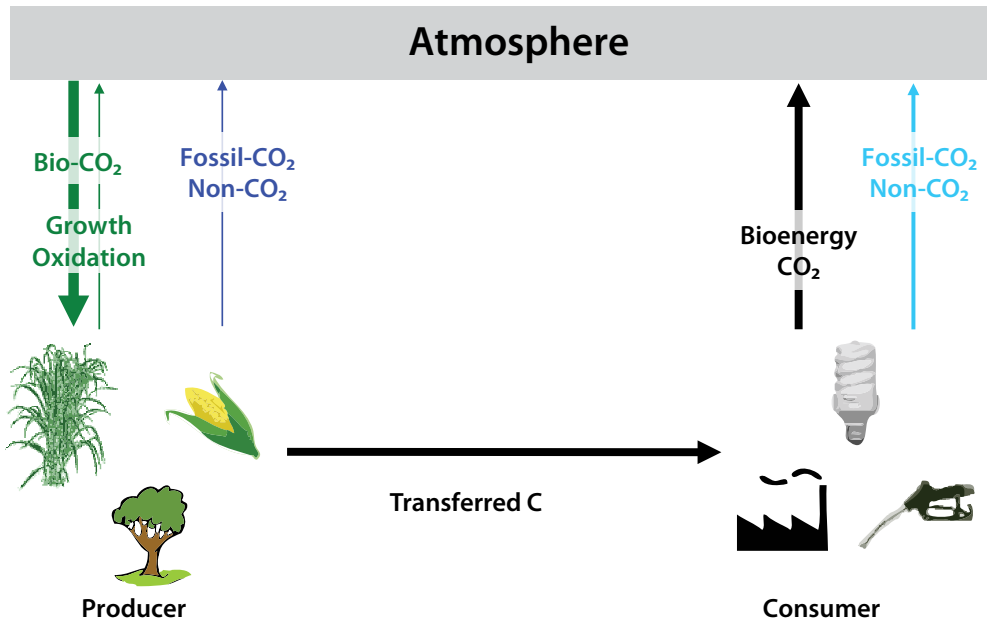


Figure 1. Physical greenhouse gas emissions and flows of carbon in a bioenergy system

As the starting point for the discussion, the diagram shows where the *physical* emissions, carbon uptake and carbon transfer occur in reality. During the discussion and description of ways to account for these emissions, we introduce variations of this diagram to illustrate differences regarding which emission streams are attributed to the biomass producer or the biomass consumer. Subsequent diagrams show the location in which *accounting* of emissions occurs rather than the location of the actual *physical* flows.

2.1 Combustion factor = 0 approaches

This approach multiplies bioenergy emissions by 0 at the point of combustion (combustion factor = 0). Emissions due to combustion of biomass are counted as carbon stock losses in the land use sector (see Figure 2). Under 0-combustion factor approaches, other emissions connected to use of bioenergy, such as those from biomass conversion and transportation (blue arrows), are accounted for in other parts of the accounting system, for example under combustion of fossil fuels. The Intergovernmental Panel on Climate Change

(IPCC) methodology for calculating emissions from bioenergy, which was adopted under the Kyoto Protocol, is an example of a 0-combustion factor approach.

The concept underlying this approach is that as long as sufficient biomass grows to replace the combusted biomass ($\text{Bio-CO}_2 \geq \text{Bioenergy CO}_2$), there are no atmospheric consequences—the atmospheric CO_2 burden will not rise. The atmospheric burden increases only if harvesting exceeds growth.² In this case a reduction in carbon stocks occurs, and the system assumes this reduction will be registered in the land use sector (see Box 1). As long as carbon stock reductions do not occur, or do not appear in the accounting, no emissions are attributed to use of biomass for energy.

In terms of our schematic diagram, under the 0-combustion factor approach, the bioenergy vector shifts from the consumer to the biomass producer (Figure 2).

² Although this is not possible over the long term, it can occur within time frames of concern to many climate-mitigation stakeholders.

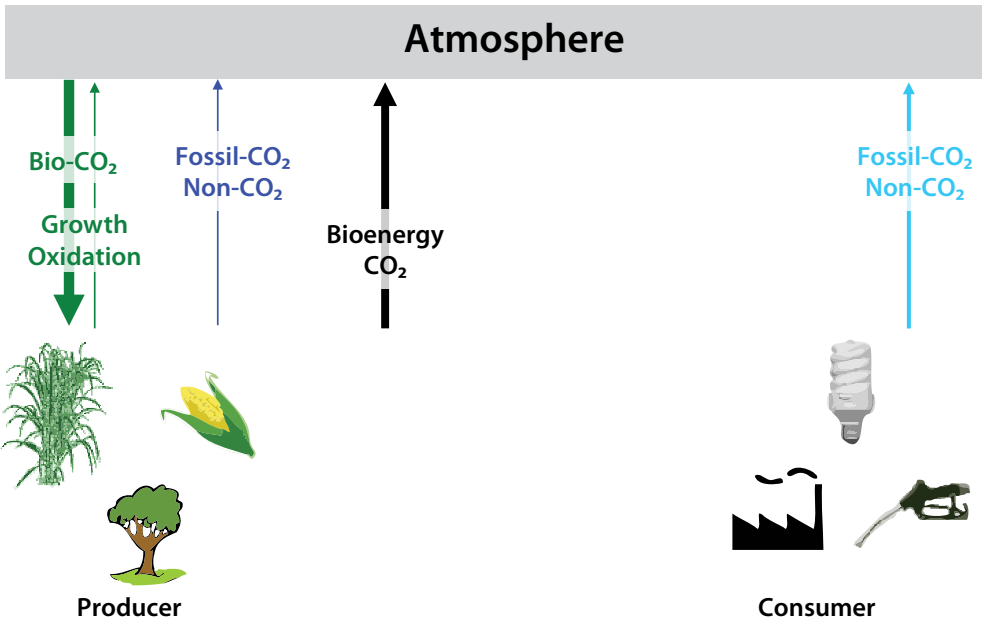


Figure 2. Location of where the physical flows are theoretically accounted for in a 0-combustion factor approach

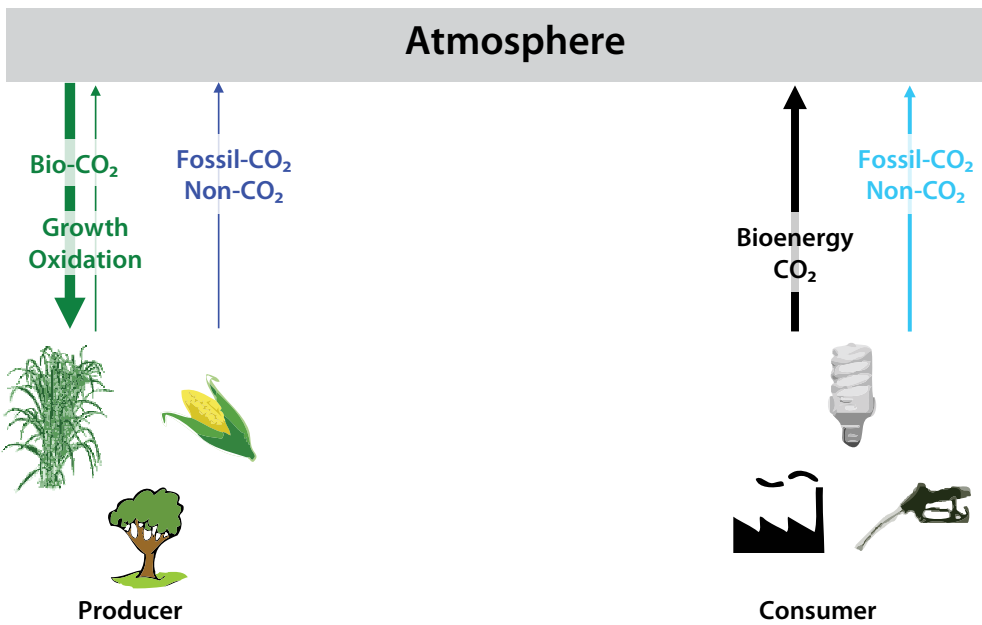


Figure 3. Location of where the physical flows are theoretically accounted for in a 1-combustion factor approach

Box 1. Grounds for attributing zero CO₂ emissions to bioenergy in the energy sector as provided in the IPCC guidelines

The IPCC guidelines set out the following rationales for attributing zero CO₂ emissions to bioenergy in the energy sector.

1. 'They may not be net emissions if the biomass is sustainably produced. If biomass is harvested at an unsustainable rate (that is, faster than annual regrowth), net CO₂ emissions will appear as a loss of biomass stocks in the Land-Use Change and Forestry module. Other greenhouse gases from biomass fuel combustion are considered net emissions and are reported under Energy' (IPCC 1996, Vol. 1, part 1.3).
2. 'Within the energy module biomass consumption is assumed to equal its regrowth. Any departures from this hypothesis are counted within the Land Use Change and Forestry module' (IPCC 1996, Vol. 2, part 1.3).
3. 'If energy use, or any other factor, is causing a long term decline in the total carbon embodied in standing biomass (e.g. forests), this net release of carbon should be evident in the calculation of CO₂ emissions described in the Land Use Change and Forestry chapter' (IPCC 1996, Vol. 3, part 1.10).
4. 'Reporting is generally organised according to the sector actually generating emissions or removals. There are some exceptions to this practice, such as CO₂ emissions from biomass combustion for energy, which are reported in AFOLU Sector as part of net changes in carbon stocks' (IPCC 2006, Vol. 1, part 1.6).
5. 'Biomass data are generally more uncertain than other data in national energy statistics. A large fraction of the biomass, used for energy, may be part of the informal economy, and the trade in these type[s] of fuel (fuel wood, agricultural residues, dung cakes, etc.) is frequently not registered in the national energy statistics and balances' (IPCC 2006, Vol. 2, p. 1.19).
6. 'Net emissions or removals of CO₂ are estimated in the AFOLU sector and take account of these emissions' (IPCC 2006, Vol. 2, part 1.20).

2.2 Combustion factor = 1 approaches

The basic alternative to using a 0-combustion factor is to treat CO₂ emissions from biomass in the same way as emissions from fossil fuels (Figure 3). Emissions at the point of combustion are multiplied by '1', that is, they are given their full value.³ As can be seen, Figure 3 is identical to Figure 1. Thus the 1-combustion approach accounts for emissions as they occur in reality. As in the case of the 0-combustion factor approach, emissions other than carbon stock losses are accounted for elsewhere in the accounting system, for example, in the sector in which they occur. Although proposed, 1-combustion systems are not yet in use.

2.3 Value-chain approaches

The EU Renewable Energy Directive and the US Renewable Fuel Standard are examples of value-chain approaches applied to biofuels. However,

value-chain approaches have not yet been applied to biomass used for heat and power. These, approaches consider both negative and positive GHG consequences along the entire bioenergy value chain—from biomass cultivation through to consumption—and transfer these consequences to end users (see Figure 4). Under this approach, all emissions attendant on use of bioenergy (green, black and blue arrows) become part of the bioenergy account within the overall accounting system. This approach enables 'fine tuning' of the combustion factor. That is, it allows a combustion factor other than 0 or 1 to be calculated and applied to emissions. This is accomplished by aggregating into a single number the atmospheric removals and emissions over the full production-through-use cycle. For example, if throughout the full production-through-use cycle 50 tC is sequestered whilst 100 tC is emitted, a factor of 0.5 could be applied at the point of combustion.

A value-chain approach can encompass emissions and removals (i.e. uptake of CO₂ from the atmosphere) occurring at the biomass cultivation and harvesting stages, as well as those due to transportation (including to processing facilities and to end users or fuel distributors), those due

³ CO₂ emissions are used as the basis for assigning values to other gases. Emissions of other GHGs are assigned values determined by their global warming impacts relative to the impact of a tonne of CO₂.

to conversion processes, and those due to final combustion. Value-chain systems vary in the extent to which they bring these emissions and atmospheric removals into the accounts of the end users of bioenergy. In general, however, benefits and liabilities are included regardless of where in the world they occur.

Value-chain approaches alter a fundamental principle of current instruments used to address climate change—that nations are responsible only for emissions occurring within their national borders. Under value-chain approaches, users tend to be held responsible for emissions that occur along a product's value chain—the emissions 'embodied' in the product—regardless of where these emissions occur (Figure 4).

Unlike the basic 0- or 1-combustion factor approaches, because they generally attempt to track all GHG emissions attributable to a specific lot of biomass, value-chain approaches encounter, and attempt to deal with, the problem of how to include emissions from indirect land use change (iLUC). Production of a specific lot of biomass can

lead to land use changes—and accompanying GHG emissions—outside of the production area itself (i.e. iLUC), because of market forces. Use of land to produce biomass for energy rather than another product generally results in unmet demand, or higher prices for food, feed, pulp and paper or roundwood. To take advantage of the attendant market opportunities, land conversion may take place elsewhere or forest harvesting may intensify.

As many food, feed and fibre markets are global, iLUC can occur anywhere in the world. For example, conversion of forest and grasslands to cropland is occurring in much of Africa and Latin America both independently of, and in response to, demand for bioenergy within and outside these regions. Land conversion can also occur in developed nations. In the United States, for example, some analysts suggest that land is being withdrawn from the Conservation Reserve Program in response to higher prices for corn driven by biofuel mandates (Fykse 2007). Determining how much land use change is properly associated with production of biomass for energy represents a significant challenge.

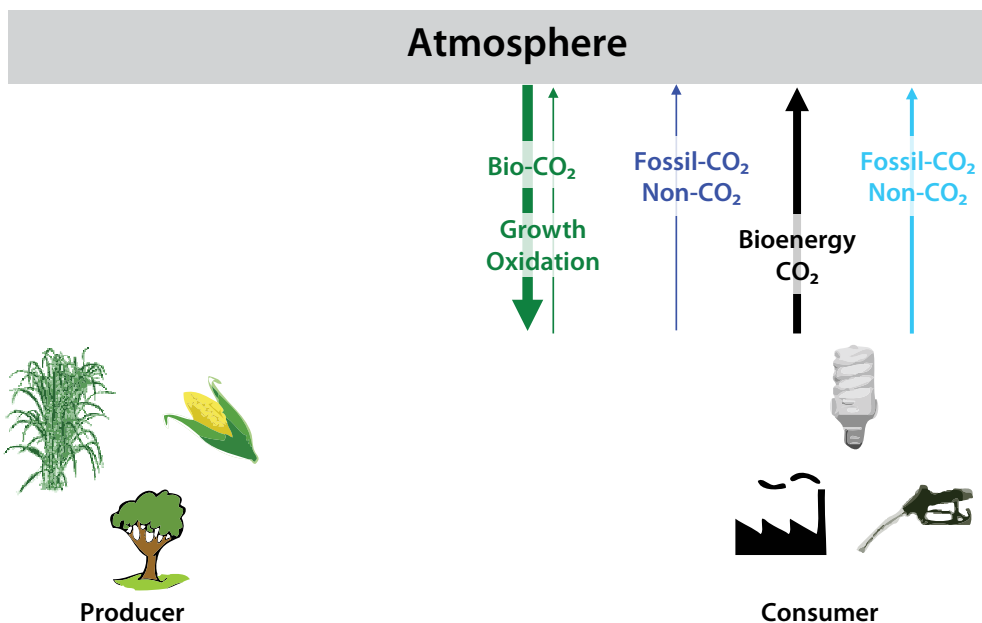


Figure 4. Location of where the physical flows are theoretically accounted for in a value-chain approach

3

Alternative accounting systems

The 0-combustion factor approach was designed for, and works well under, full reporting of GHG emissions by all nations. This condition, namely, global reporting of emissions of all greenhouse gases and changes in terrestrial carbon stocks, is largely satisfied under UNFCCC reporting. However, under the Kyoto Protocol, only a limited number of nations have obligations to account for emissions. The analyses in this report assume that this situation—non-global accounting of emissions—will continue in the near future.

Alternative bioenergy accounting approaches, proposed to better align bioenergy use with its GHG consequences, have been largely developed in response to the fact that not all nations must account for their GHG emissions. Some approaches modify the current system—which assigns no emissions at the point of combustion of biomass—whereas others seek to replace it. The approaches that we review in this report fall under one of three basic ways to address the limited global scope of accounting obligations, as follows.

1. Continue with the current 0-combustion factor approach but:
 - a. impose an emission correction factor or tax; or
 - b. restrict sources of biomass.
2. Change to assignment of full value to combustion emissions (1-combustion factor approach).
3. Make users responsible for all bioenergy value-chain emissions.

0-Combustion factor systems are described in Section 3.1. These include the current accounting system under the UNFCCC and Kyoto Protocol (Section 3.1.1) and 2 options that modify the current system to address the incomplete coverage of land use sector emissions within accounting systems (Section 3.1.2). Two 1-combustion factor approaches are then described (Sections 3.2.1 and 3.2.2), followed by descriptions of value-chain accounting approaches, including 2 that are in use (Section 3.3.1) and another that has been proposed (Section 3.3.2). A summary and a numerical example demonstrate how the systems function in Section 3.4.

3.1 Combustion factor = 0 approaches

3.1.1 The current approach

The reporting system used under the UNFCCC, and subsequently adopted for accounting under the Kyoto Protocol, in essence multiplies the CO₂ emissions that occur when biomass is combusted for energy by 0, relying on counting changes in carbon stock levels in the land use sector to measure the atmospheric impact of use of biomass.

As pointed out by Searchinger *et al.* (2009) and Pingoud *et al.* (2010), this system does not work well under the Kyoto Protocol, because it fails to account for many land use sector emissions. Land use sector emissions are not counted in:

1. non-Annex I countries, because they do not have accounting obligations;
2. Annex I countries that have not ratified the Kyoto Protocol (e.g. the United States); and
3. Annex I countries that have ratified the Kyoto Protocol but where emissions occur:
 - a. due to management changes in nations electing not to report emissions from management of, for example, forests, grassland and agricultural lands;⁴ and
 - b. due to deforestation in nations experiencing stable or net gains in forest land area. Emissions due to deforestation tend not to be reported in this situation because most forest inventories only report net changes in forest area; reforestation and deforestation are not reported separately.

The analyses in this report assume that, in particular, many non-Annex I countries will not commit to full accounting of carbon stock changes in the near future. Although REDD+ can be expected to move non-Annex I countries towards such accounting, particularly given the current status of international climate negotiations, it is not possible to estimate the number of countries that will participate, the extent of accounting that will be undertaken, or when such accounting will reach standards prevalent in Annex I nations.

3.1.2 Modifications to the current approach

Emissions correction charge

One way to continue with the existing system (0-combustion factor) while addressing the incomplete accounting that results from the lack of accounting obligations in many countries is to impose a tax or other correction factor. The tax or correction factor would be designed to compensate for emissions due to carbon stock reductions in such countries, and possibly also for GHG emissions caused by biomass conversion in them, or transportation from them. A land use change (LUC) carbon tax or correction factor could be global or nation-specific. For example, a country-based correction factor could be applied to

⁴ The Kyoto Protocol only requires reporting of emissions and removals due to afforestation, reforestation and deforestation.

biomass originating from a nation to compensate for the level of deforestation or loss of carbon in agriculture and grassland soils caused by producing the biomass that is exported from that country for energy.

Including a policy overlay

Another option is to correct flaws as they appear using policies that restrict the entrance of some types of biomass into the system. For example, policies could be adopted that would restrict biomass sources to be:

- a. 'acceptable' lands, land use change or biomass types; and
- b. 'acceptable' trading partners.

The policies would then have to define what constituted 'acceptable'. Policies could be used to restrict the source and type of biomass so that eligible biomass would have no CO₂ emissions at the production stage. For example, a policy could stipulate that the biomass must be produced on dedicated plantations or from waste materials that met conditions ensuring zero emissions. For instance, acceptable plantations might have to be established on degraded or agriculturally non-productive land and only agricultural residues that would otherwise be burnt could be used.⁵

Alternatively, a user (consumer) of biomass for energy could adopt a policy requiring that the biomass be produced in a nation that has accepted economy-wide GHG emission restrictions. A view emerging in the wake of the United Nations Climate Change Conference in Copenhagen is that bilateral or multilateral climate change agreements may be more realistic and easier to negotiate than a climate change agreement with worldwide, or even developed-country-wide, commitments. In this scenario, a 0-combustion factor accounting approach with an 'acceptable' trading partner policy overlay would fit well. This more open, flexible architecture may even provide incentives

⁵ Not all waste biomass can be considered to have zero emissions. For example, biomass in landfills can remain there for decades, so its use for bioenergy causes near-term emissions. Similarly, agricultural residues that would remain on the land can increase soil organic carbon stocks rather than releasing carbon as CO₂ through oxidation.

for more parties to undertake post-2012 climate agreement commitments.

3.2 Combustion factor = 1 approaches

This section examines the ‘Tailpipe’ and ‘POUR’ accounting options, which use a 1-combustion factor approach. Neither of these approaches has been used to date.

3.2.1 Tailpipe

We use the term ‘tailpipe’ to refer to a system in which only the flows to the atmosphere are considered; changes in carbon stocks are not included in the accounting. Under this approach, emissions from bioenergy are treated in the same way as emissions from fossil fuels; that is, the biomass consumer uses an emission factor of 1 for CO₂ emissions when the biomass is combusted. Carbon stock changes are not measured in determining the impact of use of biomass for energy.

In our schematic diagram, only the flows to the atmosphere from bioenergy combustion appear (Figure 5). If the system were to account for carbon stock reductions, it would need to include

a mechanism to avoid double counting of the emissions due to use of biomass for energy.

3.2.2 Point of uptake and release (POUR)

POUR differs from 0-combustion systems and the tailpipe method in its approach to accounting for land use sector removals. Unlike these systems, it accounts for total net CO₂ uptake by plants from the atmosphere. While 0-combustion systems only account for atmospheric removals reflected in carbon stock changes, POUR accounts for these plus carbon removed from the landscape for all purposes. Carbon embodied in biomass removed from the landscape represents carbon removed by plants from the atmosphere. Therefore, like positive carbon stock changes, it constitutes a ‘negative’ emission. By including the carbon embedded in wood removed from the landscape as part of the negative emissions, double counting is avoided when this biomass is combusted because the negative and positive emissions cancel each other out.

Under POUR, the biomass producer accounts for total net carbon taken up through plant growth, and the consumer accounts for emissions from combustion of the biomass (Figure 6). Figure 6 is identical to Figure 1 because emissions and

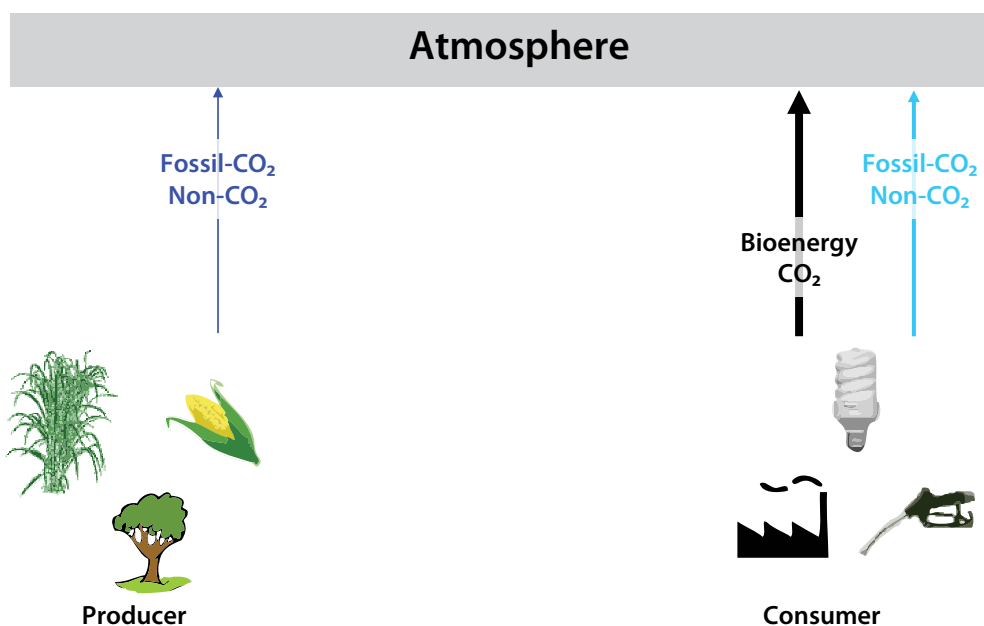


Figure 5. Location of where the physical flows are theoretically accounted for in a tailpipe approach

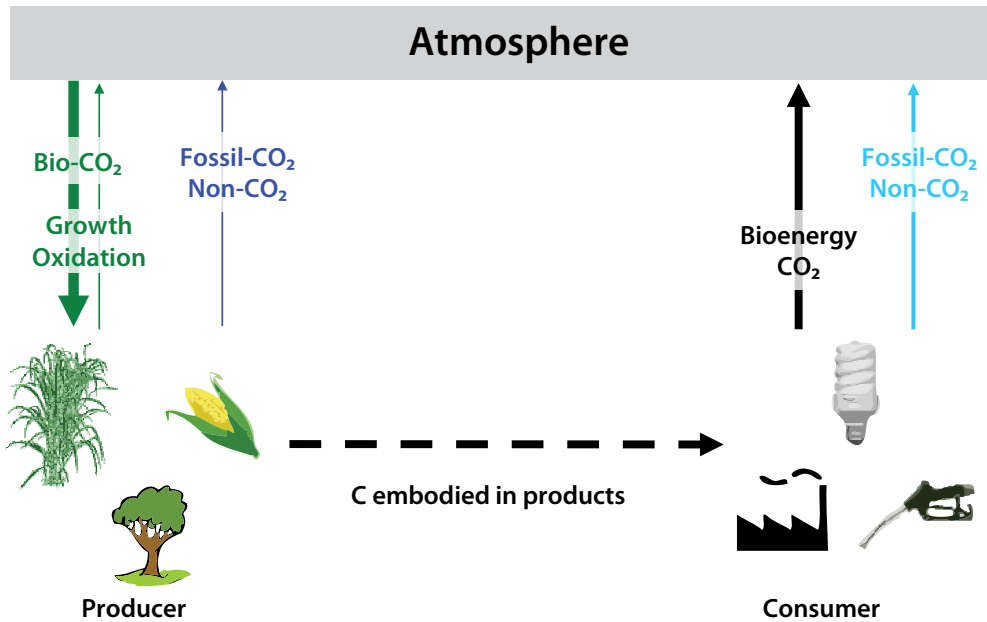


Figure 6. Location of where the physical flows are theoretically accounted for in a point of uptake and release (POUR) approach (combustion factor = 1)

removals are accounted for when and where they occur.

Contrary to common belief, in this accounting system it is not necessary to measure fluxes to and from the atmosphere. Total net CO₂ removals from the atmosphere at the biomass production point can be estimated by adding the carbon stock change between years t_0 and t_1 to the total amount of biomass embodied in products of all types, including annual crops and wood removed for energy and long- and short-lived wood products over the same period. Since the POUR method accounts for the total net CO₂ removed from the atmosphere, it is appropriate to account for all returns of carbon to the atmosphere—both from combustion and decay of biomass products—when they occur.

3.3 Value-chain approaches

In value-chain systems, CO₂ emissions and removals that occur throughout all production, conversion, transportation and consumption processes are considered the responsibility of the consumer (Figure 7).

A value-chain approach is similar, but not identical, to a life cycle assessment (LCA). An LCA considers

not only GHG emissions but also, for example, details of production or conversion processes, energy balances, inflows and outflows of materials, and environmental impacts of waste disposal. Value-chain approaches in the climate context consider only GHG emissions and removals, and do not need to consider either conversion process details or material inflows and outflows.

Value-chain approaches may estimate or measure the following: net increases or decreases in carbon stocks due to land use or management changes; emissions due to cultivation, including from use of fertilisers, liming and tillage; emissions due to harvesting operations and transportation to a conversion facility; conversion process emissions, including from fossil fuels and fermentation; emissions due to transportation to distributors or end users of fuels; and emissions due to combustion.

If a value-chain approach is instituted for bioenergy in nations that address emissions more generally through a domestic GHG cap, the overall accounting system is prone to double counting. For example, harvesting, processing and domestic transportation emissions may be counted in the transportation sector or by processing entities. If these emissions are also included in value-chain

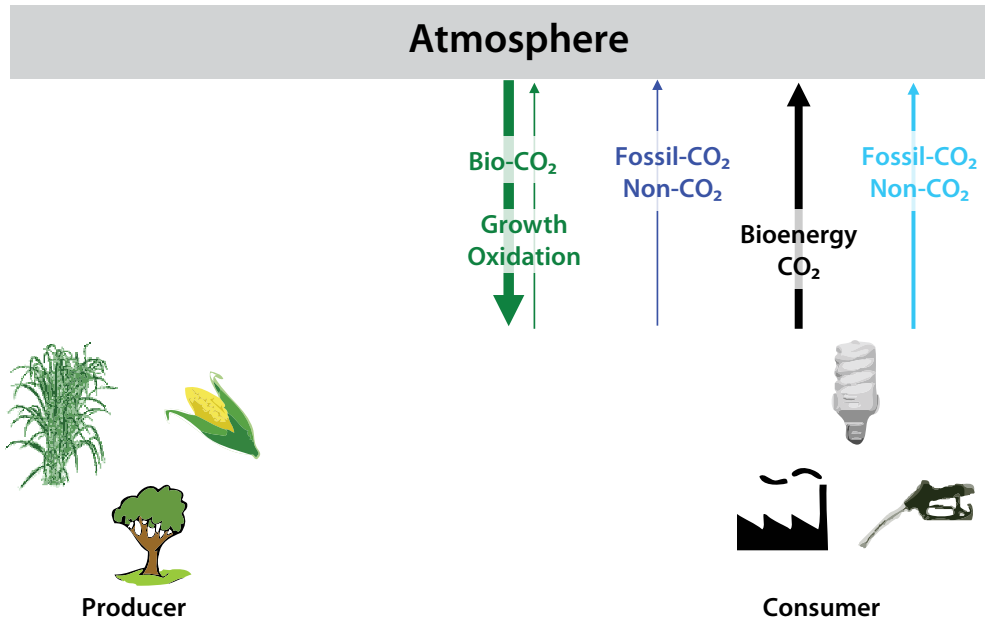


Figure 7. Location of where the physical flows are theoretically accounted for in a value-chain approach

accounts of entities using bioenergy, they would be counted twice. Thus in such situations value-chain approaches designed to avoid this problem, such as described in Section 3.3.2, should be used.

The value-chain systems described in this report focus on biofuels rather than bioenergy more generally. To the extent that biofuels are currently made from annual crops, only annual growth is harvested and used. Therefore the systems do not need to address, or include provisions to address, a problem that is likely to arise when woody biomass is used for heat or power: the time required for trees to remove from the atmosphere an amount of CO₂ equal to that emitted when woody biomass is combusted.⁶

3.3.1 The EU Renewable Energy Directive and US Renewable Fuels Standard

The EU Renewable Energy Directive and US Renewable Fuels Standard (RFS2) are attempts to ensure that biofuel use is in line with its GHG consequences (EU 2009, Federal Register 2010).

⁶ The US EPA Renewable Fuels Standard allows use of woody biomass for biofuels but limits sources in a way likely to limit timing problems. Wood must come from plantations established as of 2007 or residues, pre-commercial thinnings or wildfire areas (see Section 3.3.1).

Both of these systems include emissions due to production of biomass regardless of where in the world this occurs (see Section 3.1.1).

The EU Renewable Energy Directive can be classified either as an 'Existing + policy overlay' system or as a 'Value chain' system. We include it here with other value-chain approaches to avoid two separate discussions.

The EU Renewable Energy Directive contains provisions that prohibit the use of certain types of biomass in meeting the Directive's renewable energy goals. Although the Directive does not directly alter Kyoto Protocol or EU-ETS rules, it is clearly an attempt to use policy to address problems arising from the insufficient accounting of carbon stock changes under the Kyoto Protocol. The Directive uses both restrictions on the biomass source and a value-chain approach to address this problem. Provisions include:

1. Definitions of lands which are not 'acceptable' as sources of biomass. The Directive does not accept biomass from land that had 'high carbon stocks' as of 2008 but no longer qualifies as land with high carbon stocks. Separate definitions are provided for forests, wetlands and land with potential tree cover (see Article 17 for the

complete list of criteria determining lands from which biomass can not be sourced).

2. A value-chain approach to calculating emissions along a biofuel's value chain. These calculations are used to determine whether the level of emissions from a particular 'batch' of biofuel is under a given threshold. The Directive requires that the value-chain GHG emissions of biofuels be 35% lower than those of the fossil fuels they replace. Emissions due to cultivation and harvesting of biomass, transportation of biomass or fuel to distributors, and conversion processes are included in the calculation.

The US EPA RFS2 also restricts which biofuels can be used to meet the US biofuel mandate⁷. It:

1. Provides a 'positive' list of biomass types and lands from which biomass can be used. This can be contrasted with the approach in the EU Renewable Energy Directive which seeks to define lands from which biomass cannot be used. Five categories of biomass are eligible: crops and crop residue, planted trees and tree residues, slash and pre-commercial thinnings, biomass from specified areas at risk of wildfire, and algae. Croplands, tree plantations and forests must have been actively managed since December 2007 for biomass from them to be eligible.
2. Applies a value-chain approach. Although more restrictive with regard to the origin of biomass, the US EPA RFS2 is less demanding than the EU Renewable Energy Directive in the calculation of emissions in some ways. First, the US EPA RFS2 does not require fuel distributors, or those offering fuels to distributors, to calculate GHG profiles. The US EPA has used models to calculate which fuels and biomass source combinations (e.g. corn ethanol, sugarcane ethanol, biodiesel from soybeans) meet the requirement that a biofuel's emissions be 20% lower than the fossil fuel it replaces. Thus, biofuel providers or distributors are relieved of the burden of calculating emissions along a value chain and the emission reduction that

must be met is less stringent than in the EU regulations. Further, biofuels produced in US conversion facilities built prior to 2007 are deemed eligible regardless of their actual GHG profiles. On the other hand, the US programme is more inclusive of value-chain emissions than the EU programme. The models used to calculate eligibility include emissions due to iLUC (ICCT 2010), a source of emissions not yet included in the EU Renewable Energy Directive. This inclusion may mean that the EU and US thresholds are closer to each other than the difference between 20% and 35% suggests.

3.3.2 Consumer-based: Combustion factor between 0 and 1

Both the EU and US value chain approaches are used only to determine whether a biofuel can or can not be used to comply with a mandate. DeCicco (2009) has proposed a system in which GHG emissions calculated along the value chain would be used to compute a combustion factor other than 0 or 1 that would be applied to emissions.

The DeCicco system starts by allocating credits (negative emissions) to producers for the net GHG emissions embodied in the biomass sold to a consumer. These credits are reduced by emissions due to cultivation (e.g. from fertilisers and liming). Remaining credits are then transferred to the processor. Further deductions may be made at the processing step (e.g. for emissions due to use of fossil fuels). Remaining credits are further transferred to the consumer, in this case represented by a fuel distributor. The remaining credits are then used to reduce the fuel distributor's obligations under a GHG limitation system. A default factor of 1 is used for all fuels sold, including biofuels. Thus biofuels, unless accompanied by credits, are subjected to a 1-combustion factor at point of combustion. A lower factor as justified by the net credits from the value-chain GHG emission calculation can be used for biofuels.

Fuel distributors are designated as the consumers because, in practice, GHG obligations are more likely to fall on distributors than on individual consumers. Fuel distributors meet their obligations by submitting allowances to cover the CO₂

⁷ The US Energy Independence and Security Act of 2007 requires that 36 billion gallons of biofuels be blended into US transportation fuels by 2022 (<http://www.epa.gov/otaq/fuels/renewablefuels/index.htm>).

emissions of fuels sold. To the extent that biofuels are part of a distributor's fuel mix, the distributor's obligation per gallon of fuel sold can be reduced. The reduction corresponds to the net amount of CO₂ removed from the atmosphere after emissions along the biofuel value chain have been deducted from credits. Any emissions along the value chain that are covered by another party (e.g. emissions from electricity plants that also have emission obligations) are excluded from DeCicco's system to avoid double counting.

3.4 Summary and numerical examples

The preceding discussions have considered alternative approaches to determining a factor to be applied to emissions at the point of combustion. A summary of the factors used by different approaches from bioenergy in accounting systems, based on the combustion factor used, is given in Table 1.

Table 1. Summary of accounting systems

| Accounting system | combustion factor = 0 | 0 < combustion factor < 1 | combustion factor = 1 |
|---------------------------------------|-----------------------|---------------------------|-----------------------|
| Existing + emission correction charge | ✓ | | |
| Existing + policy overlay | ✓ | | |
| Tailpipe | | | ✓ |
| Point of uptake and release (POUR) | | | ✓ |
| Value Chain | | ✓ | |
| Value Chain-DeCicco | | ✓ | |

Table 2. Numerical example demonstrating differences between the accounting systems

| Producer component | Actual | Kyoto Protocol | Tailpipe | POUR | Value-chain | DeCicco |
|--|-----------------|----------------|----------------|-----------------------------|---------------------------|---------------|
| Net photosynthesis | -148 139 | | | <i>-148 139^a</i> | in cons. | in cons. |
| Stock change | na | 12 345 | na | na | na | na |
| Harvesting and processing | | | | | | |
| Collection and processing | 22 540 | 22 540 | 22 540 | 22 540 | in cons. | 22 540 |
| Process waste (burnt) | 8 024 | | 8 024 | 8 024 | in cons. | 8 024 |
| Subtotal | 30 564 | 22 540 | 30 564 | 30 564 | in cons. | 30 564 |
| Transportation emissions | | | | | | |
| Transportation | 2 473 | 2 473 | 2 473 | 2 473 | in cons. | 2 473 |
| Producer total | -115 103 | 37 357 | 33 037 | -115 103 | 0 | 33 037 |
| Consumer component | | | | | | |
| Wood consumption | 152 460 | 0 | 152 460 | 152 460 | 72 488 | |
| Consumer total | 152 460 | 0 | 152 460 | 152 460 | 72 488 | 39 452 |
| Other components | | | | | | |
| International transportation | 35 131 | na | na | na | in cons. | in cons. |
| Global total | 72 488 | 37 357 | 185 497 | 37 357 | 72 488^b | 72 488 |
| Global total if producer does not participate | | 0 | 152 460 | 152 460 | 72 488 | 72 488 |

a Value in italics is an estimate and is not measured.

b 105,525 if the producer also accounts for emissions

na = not applicable

in cons. = in consumer total

3.4.1 Numerical example

In Table 2, we use a hypothetical numerical example to illustrate (1) the range of emissions and removals (uptake of CO₂ by plants and soils) potentially included in the accounting systems and (2) where—in the producer or consumer account—these emissions and removals are accounted for in the different systems.

Description

In the example, a producer (nation, region or individual) produces 83 200 t of wood pellets that are shipped to the consumer, who uses them to produce 1.0 PJ of electricity. There are emissions along the entire value chain because the wood must be harvested, dried, pelletised and transported to the consumer before combustion. In the example, it is assumed that the pellets are shipped from the producer to the consumer by sea and that the consumer's facility is on the coast. Values for harvesting, processing and transportation emissions are based on values for pellets produced in Canada and shipped to Sweden (Magelli *et al.* 2009). As the consumer's facility is on the coast, no transportation emissions are allotted to the consumer.

The biomass is assumed to come from a forest that has been sustainably managed for multiple decades (the average harvest level is less than the net annual increment). To meet increased demand for bioenergy, the rotation length is shortened (frequency of harvest increases), which results in a period of time when the harvest exceeds the net annual increment. After this time, the management returns to a sustainable management regime although with a shorter harvest rotation. In the example, the amount harvested (87 539 Mg—the amount of biomass required to make the wood pellets) exceeds forest growth (i.e. 80 803 Mg). In addition, 5% of the harvested biomass (e.g. harvesting residue left in the forest) is not shipped to the consumer. For simplicity in accounting for GHG emissions, we assume that this residue is burnt, for example by the local population for heating and cooking.

The distribution of these emissions between the producer and consumer under the various

accounting systems is shown in the 5 right-hand columns in Table 2. Where the magnitude of net uptake of CO₂ by the forest (net photosynthesis) is needed for an accounting system, it is assumed that this is not measured directly but is estimated as the stock change plus the amount of biomass shipped.

Throughout Table 2, it is assumed that the consumer of the biomass operates in a nation with GHG accounting obligations. The row 'Producer' total indicates the total GHG emissions that are accounted for in the Producer nation if that nation has an accounting obligation. 'Consumer total' indicates the total GHG emissions that will be covered by the system if only the consumer is in a nation with GHG obligations. The row 'Global Total' indicates the GHG emissions that will be accounted for if both consumer and producer are in nations with GHG obligations. The final row indicates emissions accounted for if the biomass producer is not in a nation with GHG accounting obligations.

Combustion factor = 0 approaches

In general, under the Kyoto Protocol, net photosynthesis, decay of biomass and emissions from biofuel combustion are ignored. The stock change is recorded as an emission if there is a carbon stock loss or as an atmospheric removal (reduction in emissions) if there is a stock gain. As a result, in this example, the producer accounts for the stock loss, harvesting emissions and emissions due to transportation of biomass to the coast. However, if the producer is in a developing country (i.e. a nation without accounting obligations under the Kyoto Protocol) none of these emissions will be accounted for as shown in the final row in Table 2. The consumer has no emissions, regardless of whether the consumer is in a developing country or country with Kyoto Protocol accounting obligations, because neither international shipping emissions nor emissions at the point of combustion are accounted for under the Kyoto Protocol. Thus, in this example, under the Kyoto Protocol only 37 357 out of 72 488 Mg CO₂-eq are accounted for even if the biomass producer is located in a nation with GHG obligations.

Combustion factor = 1 approaches

In the tailpipe approach, by definition, only emissions from combustion activities (including the burning of residue) are included. As shown in Table 2, the producer's 33 037 Mg CO₂-eq of emissions will be accounted for if the producer is in a nation with GHG obligations. The consumer will report the actual amount due to combustion of the biomass (152 460 Mg CO₂-eq) but is not given any credit for plant growth that removes CO₂ from the atmosphere. Consequently, the Global Total calculated using a tailpipe approach is more than two and a half times actual total global emissions.

In the POUR method, the producer records an *estimate* of the net photosynthesis. If the producer is in a nation with GHG obligations, emissions due to harvesting and processing and domestic transportation will be accounted for. When added to the estimated net photosynthesis, the producer's total emissions become -115 103 Mg CO₂-eq. The consumer records the emissions from the combustion of the biomass.

If the producer is not in a nation with GHG accounting obligations and only the consumer's emissions are reported, then POUR accounting reaches the same numbers as the tailpipe approach. However, a primary motivation for POUR is to ensure that carbon stock losses turn up in the accounts of entities combusting biomass for energy whilst avoiding an accounting system that discourages bioenergy where this is not the case. To accomplish this, POUR would need to include a mechanism that transfers credits from net photosynthesis to consumers. If such a mechanism is included, POUR would record the same amount as if both Consumer and Producer nation had obligations, i.e., 37 357 Mg CO₂-eq. Emissions from international transportation would not be included in the POUR part of the accounting system as POUR only addresses emissions due to use of biomass.

The possibility of credits equal to net removals, i.e., the -115 103 Mg CO₂-eq that would be recorded in the Producer nation in this example may entice producers to participate in a POUR approach.

Value-chain approaches

As explained above, a value-chain approach transfers responsibility for all emissions along the value chain to the consumer. By including emissions that occur in nations without GHG obligations as well as those due to international transport, value-chain approaches can report actual global emissions (72 488 Mg CO₂-eq) regardless of whether a producing nation has a GHG obligation. However, as mentioned, this approach is prone to double counting. For example, even if harvesting, processing and domestic transportation emissions are counted in the producer nation they could also be included in value-chain accounts of entities using bioenergy. If this were to happen, they would be counted twice. Under such circumstances, the total emissions under 'Value chain' would increase to 105 525 Mg CO₂-eq (72 488 + 30 564 + 2473).

DeCicco's approach addresses this problem by specifically omitting from the bioenergy value chain any emissions that would be reported elsewhere in a GHG accounting system. In our example, if the producer nation reports emissions due to harvesting, processing and domestic transportation (i.e. 30 564 + 2473 = 33 037 Mg CO₂-eq) these emissions would not enter into consumer totals. All the remaining emissions, including the net removals, would be the responsibility of the consumer (-148 139 + 152 460 + 35 131). As the harvesting, process and domestic transportation emissions are reported either within the value chain (producer does not report any GHGs) or outside of it (producer does report some GHG emissions) the accounting system will report 72 488 Mg CO₂-eq. regardless of the participation of the producer nation.

4

Evaluation of accounting systems

One of the most problematic aspects in selecting or reaching agreement on an internationally applicable accounting system for bioenergy and related land-use sector emissions stems from the fact that the condition of forests and croplands varies greatly from nation to nation. In most developed countries, a significant proportion of forest land was converted to croplands during past centuries. These nations therefore have ample land on which to produce biomass for biofuels without causing extensive emissions from deforestation in current time periods. In many developing countries, however, significant conversion of forests to croplands is still, or only now, underway. This conversion serves both to increase the amount of land available for meeting food demand and to provide land for biomass for bioenergy. The result is that if emissions due to deforestation in developing countries are attributed to biofuels—as occurs under the EU Renewable Energy Directive and the US RFS2—these countries may be treated unfairly compared with developed countries.

Furthermore, forest area in many developed nations is stable or growing because of factors unrelated to production of biomass for energy. Causes include abandonment of farmland, afforestation drives and changing market conditions which may preserve domestic carbon stocks at the expense of carbon stocks elsewhere. As a result, under a non-modified, Kyoto Protocol 0-combustion factor approach, developed nations may be in a position to increase harvests, including clear-cutting that does not result in land use change, to obtain woody biomass for energy without any emissions showing up in

either their energy or land use sector accounts. This contrasts with the situation in nations with largely intact forests that are at earlier stages of conversion of forest to agricultural lands. If faced with a GHG obligation in the land use sector, these nations would incur emissions due to carbon stock losses, possibly for many decades, for any increases in harvests.

Current REDD+ discussions include proposals to use forward-looking baselines to accommodate such differences. However, establishing substantiating credible forward-looking baselines faces significant hurdles because future forest cover and condition cannot be predicted with any confidence. Consequently any emission reductions measured in relation to such baselines can not have the certitude of emission accounts. Since the design of an accounting system that could satisfactorily accommodate national differences is an issue requiring considerable research, the following evaluation does not try to assess the cross-national equity of the accounting systems.

General criteria

A seminal paper on the accounting of GHG emissions from bioenergy was written by a group of experts meeting in Edmonton, Canada, in 1997 (Apps *et al.* 1997). In 'A statement from Edmonton', the authors identified the following 5 principles for an accounting system: accuracy, simplicity, scale independence, precedence and incentives. In the context of accounting systems, as distinguished from measurement contexts, accuracy refers to

accounting all emissions without double counting; it can therefore be considered within the more general concept of comprehensiveness over space and time. In the Edmonton article, precedence is used to refer to practices that are already in use and thus can be considered an aspect of simplicity. Noting that a system should 'be as simple as possible, but not simpler' (in the words of Albert Einstein), we therefore propose that a GHG accounting system should be evaluated against the following criteria:

- comprehensiveness over space and time;
- simplicity; and
- scale independence.

As pointed out in Section 3, we believe that many countries are unlikely to adopt either economy-wide or land-use sector-wide GHG emission limitation obligations in the near future. Consequently, all the following evaluations assume this as a reality.

4.1 Comprehensiveness over space and time

Since it is assumed that none of the accounting options covers emissions from use of bioenergy in developing countries because these countries will not take on GHG-limitation obligations, the maximum spatial coverage assumed to be achievable is complete coverage of emissions from use of bioenergy in developed countries that have economy-wide GHG limitations, including as may occur in the United States under the Clean Air Act, forms of economy-wide GHG regulations other than caps on tons of emissions (Federal Register 2009).

4.1.1 Current approach

Given the maximum spatial coverage as defined above, the 0-combustion factor approach has substantial weaknesses in terms of comprehensiveness over space. Under the current approach, emissions at the point of combustion of biomass are not counted anywhere in the world, and emissions due to carbon stock reductions are counted only in nations that have accepted GHG

limitations under the Kyoto Protocol. Even in these countries, current Kyoto Protocol rules only require accounting of emissions due to deforestation, with accounting of forest and other land management voluntary. Furthermore, since deforestation appears only if there is net loss of forest area or if inventories report areas of deforestation and afforestation independently rather than on a net basis (UNFCCC 1998), the result is a significant lack of spatial coverage and thus significant inaccuracy with respect to both space and time.

4.1.2 Modifications to the current approach

Modified 0-combustion factor approaches attempt to compensate for the incomplete spatial coverage of the current approach by applying a correction factor or policies that place restrictions on the origin of biomass. In the correction factor approach, an emissions correction charge is added (e.g. via a LUC tax or iLUC factor) based on global estimates of emissions related to carbon stock reductions in non-capped countries. Factors or taxes could also be used to address emissions due to conversion and transportation in these nations. However, to date, most factors proposed have focused only on incorporating emissions due to carbon stock losses⁸.

In effect, taxes or factors compensate for the incompleteness of spatial coverage of emissions due to carbon stock losses globally by increasing the stated amount of emissions from bioenergy in, or the costs of biomass from, the countries where the tax or factor applies. In this way, taxes or factors counteract both the tendency to use bioenergy beyond the GHG emission reductions it achieves and the incentive to use bioenergy as an inexpensive way to meet GHG obligations. These approaches would result in accurate accounting of timing only to the extent that use of biomass from forest land converted to other land uses and increased harvests from forests, as well as iLUC, is discouraged.

⁸ In cases where emission factors are calculated for specific biofuel chains, they constitute part of a value chain approach.

Under an ‘acceptable trading partner’ approach, spatial coverage gaps would be partially or completely closed for participating nations if all ‘acceptable partners’ took on economy-wide GHG limitation obligations. However, unless a large number of nations accept such obligations, this approach will simply leave most biomass use outside of the system, and therefore unaccounted for. Even in the case of nations with GHG obligations, the degree of closure of spatial gaps and accuracy of timing would depend on the rules governing which carbon stock reductions are included in land use sector accounting.

In approaches based on defining ‘acceptable lands or biomass sources’, effectiveness of spatial completeness is highly dependent on how the lands or acceptable sources are defined. It is likely that the ‘ruling out’ approach of the EU Renewable Energy Directive would be less effective in achieving spatial completeness than a ‘positive list’ such as that of the US RFS2. Nevertheless, even policies of this type may not be able to cover all possibilities because of the number of possibilities that may be involved (Pena *et al.* 2010).

The time accuracy of ‘acceptable lands or biomass sources’ approaches can only be judged in cases where they have been relatively fully developed. To date, these policy approaches have only been applied to biofuels. The timing issue is generally substantially less complex for biofuels than in the case of use of woody biomass, as annual crops are currently the primary source of biomass for biofuels. Therefore, the time accuracy of an ‘acceptable lands’ or biomass sources approach if applied more generally to bioenergy cannot be evaluated at this time.

4.1.3 Combustion factor = 1 approaches

1-Combustion factor approaches, that is, fully counting emissions from biomass combustion, significantly increase spatial coverage of bioenergy emissions. All carbon stock reductions represented by the biomass combusted in nations with GHG limitations would be counted regardless of where the biomass originated. In this way, a 1-combustion factor approach comes quite close to achieving ‘maximum’ coverage of carbon

stock losses due to use of bioenergy in nations with GHG limitations. Of the emissions due to carbon-stock level changes that are attendant on this use, the approach only fails to account for emissions from oxidation of biomass left in forests, soil-carbon losses that may accompany harvests, and decay of biomass that was harvested but not converted for use for bioenergy. The magnitude of these emissions is significantly lower than the carbon losses unaccounted for by the 0-combustion factor system.

The tailpipe method is not accurate with respect to timing, in that it ignores the atmospheric removals of CO₂ that result when forest recovers from the biomass harvest. As this omission concerns removals, that is, negative emissions, the tailpipe method can be considered quite conservative. It generally results in overestimating the environmental damage and underestimating the benefits from bioenergy if regrowth of the harvested biomass occurs.

However, if major emissions occur in addition to those caused by combusting harvested biomass—as happens, for example, in the case of drainage of peatland—even full accounting of emissions from biomass combustion will result in underestimation of the overall GHG emissions.

The POUR method attempts to improve accuracy across space and time by including all uptake and release of CO₂, both that which appears as stock changes and that which is embodied in removed wood products. All uptake as well as any land-sector emissions, are recorded in the producer country’s account and all releases due to combustion in the consumer country’s account. POUR provides the most complete coverage and accurate timing if producer countries either have a GHG obligation or are entitled to receive credits for sequestered carbon. Where producer countries neither have GHG obligations nor are eligible for credits, POUR reverts to the tailpipe method. We see this as an advantage of POUR—it is conservative under a system that does not provide credits for uptake to nations without GHG obligations but does provide a spatially and temporally accurate account when both producer and consumer participate.

4.1.4 Value-chain approaches

All value-chain approaches include emissions that neither the 0- nor 1-combustion factor approaches cover. This is because they include some or all emissions due to cultivation, conversion and transportation of biomass to end users, regardless of where in the world they occur. However, value-chain approaches tend to be spatially incomplete primarily because they attempt to link emissions along the production chain to specific 'lots' or batches of biomass rather than being designed to account for emissions across the landscape, e.g., at a national scale.

Since a given lot of biomass comes from a specified, restricted land area, only emissions incurred during management of, and use changes on, this land can be 'directly' associated with the batch. As iLUC can occur anywhere in the world, there is no way to determine how much of this is due to a specific lot of biomass. Failure to include emissions due to iLUC is a primary source of incomplete spatial coverage.

Both the EU Renewable Energy Directive and the DeCicco system attempt to avoid the iLUC problem through financial mechanisms designed to discourage iLUC. However, the effectiveness of the EU approach has been evaluated as very poor (Lange 2011), and it is unlikely that the DeCicco approach would fare better. As the US RFS2 includes iLUC in its modelling of emissions—even though this modelling is open to many questions—it could be assumed that its spatial coverage of iLUC is more complete than that of the other systems.

The spatial coverage of the EU Renewable Energy Directive is also less complete than that of the US RFS2 with regard to emissions from land use change directly involved in production of biomass. The exclusion approach—as distinct from the US RFS2 positive list—fails to pick up some potentially significant sources of carbon stock reductions. Carbon stock losses on land that does not undergo a land category change are not counted. A great deal of biomass, for example, can be removed from some forests without changing their category. In some countries, land with 10% or 30% crown cover qualifies as a forest. In these countries, substantial

biomass could be removed from forests with crown cover of 80% without the forest falling beneath the 30% crown cover stipulated as constituting a category change.

In addition to spatial problems, value-chain approaches face timing issues if they are applied to woody biomass rather than to annual crops. Removal of any amount of woody biomass from a forest for delivery to a user entails a carbon stock reduction on the parcel of land harvested. Under the limited spatial perspective of a 'lot' or 'batch'-based approach, the recovery of carbon stocks is limited to this location. Hence, in the case of woody biomass, relatively long time periods—ranging from several years in the case of fast-growing, short-rotation plantations to decades for long-rotation forests managed primarily for lumber—are required for the regrowth, and it is likely to prove challenging to include this regrowth in a value-chain calculation.

The alternative is to try to link regrowth across an entire forest to a biofuel 'batch.' However, unless there is a contract or legal connection between an entire forest and a particular bioenergy producer, it is hard to see how forest regrowth across a particular forest holding—much less across an entire nation—could be attributed to any lot of bioenergy. Any attempt to establish such a link faces additional objections because forest regrowth in managed forests is generally undertaken for high-value wood products, not for biomass for energy.

Consequently, value-chain approaches involving use of woody biomass require a mechanism to accurately reflect the time difference between emissions and removals, that is, the reality that bioenergy emissions occur immediately whilst compensating recovery of carbon stocks can take years, decades or longer. Designing such a mechanism that would be acceptable among all stakeholders is likely to be challenging.

The EU Renewable Energy Directive and DeCicco's system avoid the timing issue because they focus on annual crops as the source of biomass for biofuels. However, these approaches would have to address the timing issue if they were extended to heat and power or if biofuels from woody biomass became

a commercial option. The US RFS2 value-chain system does allow use of woody biomass to produce eligible biofuels. The restrictions on the types of woody biomass that can be used under the USRFS2 restrictions on eligible woody biomass may serve to keep the lag between emissions and regrowth within acceptable bounds from the point of view of climate mitigation and stakeholders. However, until significant amounts of woody biomass are used for biofuels, it is not possible to establish the rotation lengths and constancy of plantation carbon stocks. Therefore, it is not yet possible to assess the length of time imbalances that may occur between GHG emissions and recovery of stocks under the US RFS2. Some other options for dealing with this problem in value-chain approaches are suggested in Box 2.

4.2 Simplicity

4.2.1 Current approach

The unmodified 0-combustion factor approach may be the simplest of the approaches that include emissions from land use change; certainly, its simplicity was one of the reasons that it was selected under the UNFCCC and Kyoto Protocol. It requires only the measurement of carbon stock changes, for which there is considerable experience due to forest inventories. However, the question arises whether, under real-world conditions, this approach is

‘simpler than possible’ given that the accounting system should achieve reasonable coverage.

4.2.2 Modifications to the current approach

Correction factors and policy overlays, and restricted trading partners

In principle, use of a correction factor is relatively simple; however, in practice, it may be quite complicated to estimate and agree on such factors. Whilst policy overlays that define acceptable partners or sources of biomass add complexity, the degree of complexity depends on the policy. To date, biofuel consumers have designed policy overlays that rely on definitions, particularly definitions of ‘acceptable’ sources of biomass. Care is needed in formulating such definitions to ensure that they cannot be interpreted differently in different countries or by different participants in the system. In this regard, the US RFS2, whose definitions were refined through an extensive stakeholder process, seems to have been more successful in achieving simplicity than the EU Renewable Energy Directive. However, consumer nations’ different objectives and situations may make it significantly more difficult to design definitions or other policy overlays that would be accepted among several trading partners, much less worldwide.

Box 2. Timing in value-chain systems: Possible options

One option for dealing with timing in value-chain systems is based on the fact that it is not possible to combust biomass that has not already removed CO₂ from the atmosphere. This option adopts the perspective that using biomass for energy does not add to the atmospheric burden because the CO₂ being returned to the atmosphere had previously been removed from it within the time frame of human-induced climate change. Under this approach, there would be no need to measure carbon stock levels between 2 points of time, as is done under the 0-combustion factor and POUR approaches.

A less radical option might come from new research that is exploring the possibility of introducing information on expected biomass recovery time into an emission factor (Walker *et al.* 2010, Zanchi *et al.* 2010a, 2010b). This requires the use of forward baselines that indicate carbon stock levels over time with and without removal of the biomass. By comparing these 2 levels, it is possible to determine the percentage of emissions that would be compensated for by forest growth at any particular point of time. This approach poses several challenges. First, as is generally the case, reaching agreement on future baselines across a range of stakeholders is difficult. Second, incorporating the results into an emission factor would require agreement on the appropriate point of time at which to make the assessment. Possibly more problematic is the fact that whilst comparison of carbon stock levels with and without harvests is clearly a useful tool for selection of energy options, accounting systems are intended to provide information about results of actions, not comparative results.

Finally, factor approaches and policy overlays, including restrictions on trading partners, must be designed in such a way that they cannot be perceived as constituting an unfair trade practice. This in itself may prove a complex undertaking, particularly in the case of restricting trading partners. All of these approaches are likely to be subject to scrutiny by the World Trade Organization (WTO), an exceedingly complex process in itself.

4.2.3 Combustion factor = 1 approaches

1-Combustion factor approaches may constitute the 'simplest possible' approaches under real-world circumstances.

Tailpipe method

A tailpipe accounting system may be the simplest of all approaches. It requires only that bioenergy emissions be measured or the amount of biomass consumed for bioenergy be measured and then converted to CO₂. There is no need to measure carbon stock levels, use of fertilisers during cultivation or fossil fuels used in cultivation, conversion and transportation of biomass.

Point of uptake and release (POUR)

The POUR approach is less simple than the tailpipe and 0-combustion factor approaches, because it requires measuring carbon stock changes, information on the total amount of biomass sold by producers, as well as measurements of bioenergy emissions in the consumer nation. Although this may be relatively straightforward for some biomass uses and commodities, it will become more complicated where biomass can be used for multiple purposes. In particular, it would most likely be necessary to separate biomass used for food from other biomass. Consequently, it would be necessary to separate:

- a. oils used for food and feed from those used for energy; and
- b. grains used for food and feed from those used for energy.

Assuming reporting of GHGs for foodstuffs were not part of the accounting system, statistics on the oils and grains used for energy in nations with GHG obligations would be needed, along with an

algorithm to relate the carbon in these oils and grains to net CO₂ removed during the growth of the related plants. Developing these may be quite complicated because of the need to determine how to handle both in-field and field-to-end-user losses.

4.2.4 Value-chain approaches

Value-chain approaches are inherently more complicated than 0- and 1-combustion factor approaches. In addition to estimating carbon stock changes and emissions, these approaches require that emissions from direct and indirect land use, management changes, cultivation, conversion processes and transportation be tracked and associated with a particular lot of bioenergy. Further, as illustrated by the EU Renewable Energy Directive and US RFS2, value-chain approaches may need to be supported by restrictions on sources of biomass, default factors and modelling. Finally, if the value-chain approach is designed to cover use of woody biomass, a mechanism will be needed to address the time delay between the immediate release of CO₂ during combustion and the longer period required for uptake of CO₂ through growth on the lands from which the biomass originated.

A particular complication that arises with the approach in the EU Renewable Energy Directive is related to enforcement difficulties connected to the definitions used. For example, the EU Renewable Energy Directive states that biomass must not originate from lands that are:

... primary forest and other wooded land, that is to say forest and other wooded land of native species, where there is no clearly visible indications of human activity and the ecological processes are not significantly disturbed (Art. 17, 3.a).

Determining when these criteria are met is difficult, as would be enforcement. A producer in a developing country could probably easily show that there is human activity in virtually any forest, whereas EU stakeholders are likely to hold the view that significant forests show no such activity. In contrast, the US RFS2 definitions of eligible biomass and the lands from which it can be taken are sufficiently clear that determining

whether biomass source qualifies is relatively straightforward.

A development that could simplify use of value-chain approaches for bioenergy would be to institute agreements to use value-chain approaches across a wide range of goods beyond bioenergy, a development that the more open, flexible climate negotiations that may evolve from the COP 15 and COP 16 meetings may facilitate. Supporting the incorporation of value-chain approaches into international climate agreements is the recognition of the limits of the current national boundary approach to goods. In the context of a broad range of goods, value-chain approaches are referred to as consumer-based accounting (CBA) (see Box 3). If CBA is adopted in climate agreements for a wide range of biomass-based goods, the simplicity of a value-chain approach to bioenergy will increase substantially for two reasons. First, familiarity with value-chain approaches in general will increase. Second, if all biomass sold to nations with GHG obligations is subject to value-chain accounting, attribution of land use change to 'lots' of bioenergy will be easier because under these circumstances indirect LUC would resolve into direct LUC. What constitutes indirect LUC for production of biofuels will be direct LUC for some other product.

Box 3. Value-chain accounting in international agreements

Consumer-based accounting for a wide range of products is under consideration in the context of climate change mitigation for several reasons. First, international trade is escalating and is the fastest growing macro-economic driver of global GHG emissions (Peters *et al.* 2009). Second, most developed countries are net importers of embodied emissions. This means that climate instruments confined to regulating emissions occurring within national borders understate the emissions generated by most developed countries. In a world in which primarily developed countries assume GHG-limitation obligations, the combination of these two facts means that GHG obligations will cover an increasingly small percentage of global emissions if they continue to be restricted to emissions occurring within national boundaries.

4.3 Scale independence

4.3.1 Current approach

The 0-combustion factor approach was designed, conceived and originally analysed in the context of national reporting under the UNFCCC. However, carbon stock level accounting, upon which it is based, can take place at any scale from the stand level up to the national or even multinational level—a significant advantage from the perspective of many stakeholders.

However, measurements of forest-carbon stock changes give very different results depending on the scale at which they are taken. Whereas, for example, annual forest regrowth can exceed or fully compensate for removals at the national or landscape level, this is not true at the stand level. Further defining the relevant boundaries of a forest for the purpose of assessing carbon stock changes at a smaller than national or even global scale is challenging.

4.3.2 Modifications to the current approach

Modified versions of the current approach will all inherently have the same scalability issues as the current approach. In addition, factors, taxes or policy overlays are all designed to operate at the national level. They can be prorated (factors and taxes) or applied (policy overlays) at the local or regional level but have the problem that local or regional conditions may not be the same as the national average.

4.3.3 Combustion factor = 1 approaches

1-Combustion factor approaches can have greater scale independence than 0-combustion factor approaches. The tailpipe method is fully scale independent because it only accounts for emissions, thus avoiding the scale problems of selecting an appropriate boundary to undertake carbon stock level measurements. In contrast, POUR suffers from the same scale problems as in 0-combustion factor approaches because it relies on measurements of carbon stock changes where results can vary depending on the scale at which the measurements are made.

Table 3. Subjective evaluation of accounting approaches according to criteria

| Accounting system | Comprehensiveness | Simplicity | Scale independence | Rank (even weight) | Rank (comprehensiveness more important) |
|---|-------------------------------|----------------------------|------------------------|--------------------|---|
| Combustion factor = 0 approaches | | | | | |
| Unmodified | Low (6) | High (1) | Yes with drawbacks (1) | 3 | 4 |
| Existing + emissions correction | Acceptable (4) | Low (5) | Yes (1) | 4 | 5 |
| Existing + policy overlay | Depends on policy details (5) | Depends: medium to low (4) | Yes (1) | 4 | 6 |
| Combustion factor = 1 approaches | | | | | |
| Tailpipe | Medium (3) | High (1) | Yes (1) | 1 | 1 |
| Point of uptake and release (POUR) | High (2) | Medium (3) | Yes (1) | 2 | 1 |
| Value-chain approaches | | | | | |
| All | Very high (1) | Low (5) | In some versions (6) | 6 | 3 |

Note: The values in parentheses are the rank of each approach for each criterion. For example, under scale independence, we evaluated all accounting systems except value chain as having the same rank. As there are 6 accounting systems, value chain was given a rank of 6.

4.3.4 Value-chain approaches

Just as 0-combustion factor approaches were originally conceived of as national-level approaches, value-chain approaches were conceived of as batch- or lot-level approaches. However, scaling-up is possible through use of national-level estimates of GHG emissions at each step along the value chain. For example, all sugar-based ethanol from a given country could be assigned a GHG value representing, say, average emissions due to cultivation, iLUC and LUC due to production of sugar cane for ethanol, biomass conversion and its domestic transportation. In essence, the US RFS2 used modelling to estimate such average GHG emissions of distinct biomass type–conversion process combinations.

Although this suggests that it should be possible to bring scaled-up GHG implications of value chains into a national GHG account, currently results of value-chain calculations do not enter into any national GHG accounting system. Under both the EU Renewable Energy Directive and the US RFS2, a fuel distributor or supplier is only responsible for establishing, for each lot of biofuel used, that it meets acceptability criteria. Only under DeCicco's

proposed system would value-chain calculation results play a role in achieving a GHG obligation.

4.4 Summary

The results of the foregoing analysis are summarised in Table 3. The second, third and fourth columns show how each accounting system ranks against the three criteria discussed above. The final 2 columns show (a) the ranking for each system if the separate criteria are given equal weight, and (b) the ranking if comprehensiveness is considered more important than other criteria.

We find that the tailpipe accounting approach performs relatively well against all criteria: it is relatively comprehensive, is reasonably simple to implement, and is scale independent.⁹ However, POUR also rates well. If comprehensiveness is considered twice as important as simplicity, POUR ranks better than tailpipe. Value-chain approaches generally receive a lower ranking because of their complexity.

⁹ At least conservatively, given the likelihood that there will continue to be countries (producers) that will not accept GHG emission restrictions.

5

Impacts of accounting systems on stakeholder goals

In this section, we consider the implications of different bioenergy accounting systems for stakeholder goals because of the prominence of these goals in bioenergy discussions and policy. Accounting systems support or hinder goals because they tend to provide incentives or disincentives for specific actions. As suggested in Section 1, the unmodified 0-combustion factor system provides strong incentives for both nations and energy producers to use bioenergy to meet GHG obligations, particularly if related carbon stock losses occur in another entity's account.

This system supports goals such as energy independence, energy diversity and rural economic development, so long as the biomass is produced domestically. However, the system works against other stakeholder goals, such as global reductions in GHG emissions or preservation of forests in developing countries. Indeed, a major motivation behind suggestions for changing the current accounting system is its effects on the goal of preserving forests in developing countries.

A potential REDD+ instrument can be viewed as a 'policy addition' to address the weakness of the current Kyoto Protocol accounting system in relation to the goal of preservation of forests in developing countries. However, REDD+ is not itself an accounting system, and it is not yet apparent how effective a future REDD+ instrument will be, how it will interact with the accounting systems explored in this report, or how it will affect the ranking of accounting systems in terms of the goals discussed below. Therefore, as in the rest of

the report, REDD+ is not considered here. The remainder of Section 5 is devoted to examining stakeholder goals and their relationship with the accounting systems and their inherent incentives.

5.1 Stakeholder goals: Biomass for energy

We begin by discussing why interest in use of biomass for energy has emerged, as the reasons translate into goals. Bioenergy stakeholders, whether they are bioenergy producers or consumers in developing or developed countries, face a set of problems that use of bioenergy may help solve or may aggravate. In the economy as a whole these problems include:

- energy security—limited access to primary energy carriers, particularly petroleum, and projected energy price increases;
- food security—including both domestic supply and higher food prices;
- loss of environmental services through the depletion of natural resources (i.e. deforestation);
- vulnerability to climate change; and
- the need to reduce GHG emissions.

There are also problems that are specific to the rural economy such as:

- low timber and agricultural commodity prices; and
- limited employment and income opportunities.

To tackle these problems, nations or stakeholders within nations promote use of bioenergy to achieve goals such as:

- increasing energy security;
- stimulating the rural economy (both agricultural and forest-based); and
- reducing GHG emissions.

At the same time, the stakeholders may promote preservation of forests to:

- reduce GHG emissions;
- maintain or enhance livelihoods based on forest products (including bioenergy); and
- maintain habitat and other environmental services.

Goals such as these can be mutually supportive or competitive. For example, use of bioenergy to enhance energy security or to stimulate the rural economy automatically fosters the other goal if biomass is produced and used domestically. However, tensions may emerge between these 2 goals and preservation of forests. The following discussion looks at the extent to which each accounting approach supports or impedes achievement of key goals.

5.2 Evaluations against goals: Looking at incentives

Accounting systems foster goals to the extent that they provide incentives to take actions that support the goals. For example, any accounting system that provides an incentive to use bioenergy tends to have the effect of stimulating the rural economy because it causes actors to increase demand for biomass. This demand supports or increases biomass production and prices. Support of prices and demand for agricultural products is a major reason why nations find it easy to pass legislation (or adopt policies) that promotes biofuels as these are currently produced almost exclusively from agricultural products.

The 0-combustion factor approaches promote use of bioenergy from agricultural products because no carbon stock losses are attributed to annual crops, no emissions are counted when the biomass is combusted, and emissions due to

resulting land use change, particularly if it occurs in developing countries, will also not be counted. The 0-combustion approach promotes use of woody biomass to the extent that carbon stock losses are not reported or are not the responsibility of the entity using the biomass. Thus, 0-combustion factor approaches stimulate the rural economy and will enhance energy security if the biomass is produced and used domestically. In contrast, 1-combustion factor approaches tend to discourage use of bioenergy under GHG limitations because the user (i.e. consumer) is responsible for the emissions from biomass combustion. In principle, value-chain approaches are neutral between use of bioenergy and other fuels from a GHG point of view. However, to date, value-chain approaches have been used in combination with mandates (e.g. requiring a specific share of biofuels for transport), with the mandate driving increased use of bioenergy. Thus, it is the mandate rather than the value-chain accounting system that provides the incentive to use bioenergy, at least as these systems have operated to date.

In the following, we assess the relationships between the basic approaches and stakeholder goals in more detail by considering impacts on 2 goals that can be served by bioenergy—stimulation of rural economies and GHG reductions—and 2 goals that stakeholders may see as threatened by bioenergy—preservation of forests and food security. Food security is discussed in conjunction with stimulation of rural economies. We do not provide a separate evaluation category for energy security because, in the bioenergy context, energy security tends to be fostered or hindered under the same circumstances that support domestic rural economies. Similarly, maintenance or enhancement of forest-based livelihoods and environmental services is fostered or hindered under the same conditions as preservation of forests and so is not discussed separately.

5.2.1 Combustion factor = 0 approaches

Stimulation of rural economies and food security

An unmodified 0-combustion factor approach under the real-world conditions assumed throughout this report, including the lack of GHG-

emission limitations on land-sector entities in almost all nations, provides a strong stimulus to use bioenergy, and hence stimulates production of both agricultural and forest biomass (Cortez *et al.* 2010). However, this stimulus may result in price increases for food, replacement of food and feed crops with energy-oriented crop production and an increase in the need for food imports in nations where agricultural supply is not sufficient to meet both demands (Pimental *et al.* 2009). Price increases tend to benefit farmers but can burden the general population, particularly its poorer segments, with the relative importance of these benefits and drawbacks varying from nation to nation.

Modifications that use factors or taxes increase the costs of using bioenergy and thus weaken the biomass stimulus. The extent of the stimulus reduction will depend largely on the magnitude of the correction factor or tax. Most likely, the correction would have different implications for different types of biomass because of underlying differences in costs both in the biomass itself and in the alternatives available to energy suppliers to meet GHG obligations. Policy overlays that use an ‘acceptable lands’ approach reduce the stimulus for selected sources of biomass. However, it is unlikely these approaches would counteract food price rises because land use is highly interchangeable and both food and energy markets are global. Therefore, restricting the use of certain lands for biomass for energy will most likely result in lands elsewhere being dedicated to that purpose.

GHG reductions

The unmodified 0-combustion factor approach fails to systematically encourage GHG emission reductions under the current—and most likely ongoing—system of incomplete national participation in binding GHG targets. To the extent that the 0-combustion factor approach encourages bioenergy—thereby leading to uncounted emissions due to LUC, including deforestation; iLUC; forest degradation; or other uncounted stock reductions in forests—it may actually result in more emissions than the continued use of fossil fuels. In addition to problems connected to lack of reporting of carbon stock losses, combustion of biomass generally generates more CO₂ emissions per unit of energy produced than the combustion of fossil fuels,

with the difference being largest in the case of petroleum-based fuels or natural gas. This increases the difficulty of achieving near-term GHG emission reductions if woody biomass is used to produce energy (Walker *et al.* 2010, Zanchi *et al.* 2010a, McKechnie *et al.* 2011, Repo *et al.* 2011).

Modifications of the 0-combustion factor approach try to correct this failure and ensure reductions in GHG emissions. However, the effectiveness or significance of any GHG emission reductions achieved through most of the modifications examined is questionable. It is not clear whether a correction factor or tax would effectively reduce emissions or simply add to the cost of bioenergy, particularly because bioenergy use is most often driven by mandates that require the incorporation of a specified amount or percentage of bioenergy or biofuels.

‘Acceptable biomass sources’ approaches can support the goal of reducing GHG emissions, although their effectiveness depends on programme design. For example, the EU Renewable Energy Directive’s use of acceptable lands provisions is likely to be less successful in preventing GHG emissions due to use of biomass for energy than the US RFS2 because of the deficiencies discussed in Sections 4.1.4 and 4.2.4.

Restriction of trading partners to nations that have economy-wide GHG emissions targets would guarantee GHG emission reductions by the parties that agree to the restriction, as both partners would need to meet their targets. However, to ensure that actual GHG reductions are in line with those stated in targets, it would be necessary for all stock losses to be accounted for, including, for example, those not currently mandatory or reported under the Kyoto Protocol, e.g., losses due to management changes in forests remaining forests or to deforestation in situations of net forest area stability or increase. However, a restricted trading-partner approach has no effect on GHG emissions in other nations. Consequently, the extent of the improvement in achieving global GHG reductions compared with the unmodified 0-combustion factor approach would be highly correlated to the number of GHG-obligation nations that engage in such restrictive trade agreements.

Preservation of forests

The extent to which an accounting approach preserves forests is closely related to its ability to reduce GHG emissions. The unmodified approach, for example, does neither very successfully. Similarly, just as it is not clear whether a correction factor would reduce emissions, it is not clear whether it would preserve forests.

Analysis of the approaches that currently define ‘acceptable lands’ reveals significant weaknesses in the EU Renewable Energy Directive in terms of preserving forests. These weaknesses result from use of crown-cover criteria in combination with accounting for carbon stock changes only if land use change occurs. This system allows both significant degradation of natural forests and even replacement of natural forests with plantations as long as they meet the crown-cover criteria. The US RFS2, by restricting use to woody biomass from forests planted by hand or machine on land cleared prior to 2007, is very likely to avoid interference with forest preservation goals.

5.2.2 Combustion factor = 1 approaches

Stimulation of rural economies and food security

Multiplying CO₂ emissions by 1 (giving them their full value) at the point of combustion provides a disincentive for nations and energy producers that are under GHG limitations to use bioenergy because, in the vast majority of applications, biomass results in more CO₂ emitted per unit of energy produced than other options. Thus under 1-combustion factor approaches use of bioenergy increases rather than alleviates difficulties in meeting GHG obligations and demand for biomass is dampened. Consequently these approaches, fail to stimulate rural economies or the agriculture and forestry sectors, and have no negative impacts on food security. Whilst the tailpipe approach strongly discourages the use of bioenergy, a POUR approach may overcome this disincentive if it includes a mechanism that transfers atmospheric removals (sequestration) from the biomass producer to the biomass consumer.

POUR provisions that allocate CO₂ removal credit for biomass grown to producers can provide an

incentive to grow biomass. However, the strength of this incentive will depend crucially on the rules governing transfer of such credits to biomass consumers as well as on market conditions. One issue would be whether the mechanism restricts transfers and use of credits to purchasers of biomass to cover emissions, or whether the credits could be sold openly on a GHG market. These options are quite different and would have significant implications for how the POUR approach would function.

If POUR credits were sold on the general GHG market, the POUR mechanism would be confronted with the complexities of these markets. Market conditions—particularly demand from non-biomass users—would determine the impacts on bioenergy and energy security. However, this option could make it possible for POUR to support rural economies without supporting energy security. The economic analysis and modelling that would be required to determine whether, and under what market conditions, POUR-based credits would support rural economies or energy security and the extent of such impacts are well beyond the scope of this study.

If POUR-generated ‘CO₂ uptake’ credits were sold only to bioenergy producers, the negative impact of a 1-combustion factor approach on use of bioenergy would be ameliorated to a greater or lesser extent depending on credit prices. The impact on rural economies would depend on prices paid for such credits. Impacts on energy security would depend largely on whether domestic or non-domestic biomass was used to produce the energy.

Finally, although POUR was designed with woody biomass in mind, it could also be applied to annual crops used for energy. In this case, POUR might promote the transfer of agricultural biomass to energy sector entities, potentially exacerbating food security concerns.

GHG reductions

The 1-combustion factor approaches can be effective ways to control GHG emissions. The tailpipe approach requires bioenergy producers to count their emissions and offers no relief from the extra emissions per unit of energy generated

by biomass compared with fossil fuels. POUR would offer relief to bioenergy consumers insofar as credits for removals embodied in the biomass combusted are available and transferred to them at low cost. As costs of credits increase, use of bioenergy is increasingly discouraged, thus increasingly contributing to GHG emission control.

If offers of credits for net removals can induce nations without GHG obligations to track total net atmospheric removals, POUR would serve as a route to more inclusive accounting without imposing GHG obligations.

If countries without GHG-limitation obligations can receive credits with value on an open GHG market for removals embodied in harvested wood, they will have a strong incentive to harvest. However, since credits are granted only for carbon in wood sold minus carbon stock losses, a strong incentive to shift to sustainable forest management is also provided.

Preservation of forests

As the tailpipe approach discourages the use of bioenergy, it can be considered as supporting preservation of forests, in the same way that it supports reductions in GHG emissions from biomass. In contrast, as discussed above in connection with stimulation of rural economies and energy security, the impact of POUR on forest preservation could only be determined through knowledge of program details and economic analyses beyond the scope of this study.

5.2.3 Value-chain approaches

Stimulation of rural economies and food security

As mentioned above, current value-chain approaches have been implemented in conjunction with mandates, with the mandates not the accounting system driving increased use of bioenergy and thus stimulating rural economies. In the absence of experience and sophisticated modelling, it is impossible to evaluate the impact of value-chain approaches themselves on rural economies other than to note that, insofar as their goal is to align use of bioenergy with its emissions, value-chain approaches are more likely to

resemble 1-combustion factor than 0-combustion factor approaches.

GHG reductions

Making users responsible for value-chain GHGs can translate into incentives to produce and to purchase biomass with the lowest GHG profiles. To the degree that this occurs, value-chain approaches may be amongst the most effective ways of reducing GHG emissions associated with the use of bioenergy when not all countries have GHG limitations. However, for value-chain approaches to function effectively in this manner, the level of GHGs emitted along the value chain must be correlated with bioenergy users' costs in meeting their obligations. Of the approaches reviewed in this report, only the DeCicco system would achieve this; neither the EU Renewable Energy Directive nor the US RFS2 functions in this manner.

In the DeCicco approach, the fuel consumer's cost of meeting its obligation varies according to the level of value-chain emissions. Lower levels of value-chain emissions translate into lower consumer costs because the distributor will need fewer allowances to emit to meet its obligations. Consequently, consumers have an incentive to offer higher prices for lower GHG-emission pathways, which in turn provides incentives for biomass producers, converters and transporters to seek ways to lower their GHG emissions.

Preservation of forests

The impact of a value-chain approach on forests will depend greatly on the specifics of its design, as suggested by the previous discussions of differences between the EU Renewable Energy Directive and the US RFS2. As long as bioenergy mandates are driving biomass use, the level and specifics of the mandates also play a role in the impact on forest preservation.

Without mandates, and assuming a value-chain approach in which energy users are responsible for the GHG emissions of the fuels they use, particularly given the difficulties of attributing forest growth to specific batches of biofuels, it is unlikely that forest biomass would be used for energy because of its higher emissions per unit of energy than other options. Under these

conditions, a value-chain approach would tend to preserve forests.

5.3 Summary

Table 4 summarizes the preceding discussions and ranks the various approaches against each goal. The final column provides an overall ranking with ‘stimulation’ of rural economies given twice the weight of other goals as it may be the most important goal for many countries. In summary, we find that an enhanced version of the current Kyoto Protocol accounting system in which all carbon stock losses in nations with GHG obligations are accounted for and acceptable trading partners are limited to those that have economy-wide GHG limitations is the only option that receives a rating of ‘high’ across all goals (see Table 4). Essentially, this recreates the situation considered when the existing accounting system was conceived. However, most countries and forests—and a corresponding proportion of bioenergy-related GHG emissions—would fall

outside of the system, as with the Kyoto Protocol. Furthermore, significant issues arise in relation to the feasibility of implementing such a system, given the complexity of the WTO process likely to be triggered. Assuming that achieving GHG emission reductions globally is an important goal, 1-combustion factor and value-chain approaches tend to provide better support of policy goals.

Table 5 brings together the results of ranking the various approaches against criteria and against goals. When comparing the benefits of the various accounting systems, decision makers are likely to assign different weights both to the various criteria and the various goals. In Table 5, we set out the results when (a) comprehensiveness and (b) stimulation of rural economies are given twice the weight of the other criteria and goals. What we find is that a POUR approach has the highest combined ranking. This is closely followed by two of the value-chain approaches and the existing approach limited to acceptable trading partners.

Table 4. Subjective evaluation of accounting approaches' support of goals

| Accounting system | Stimulate rural economies | Rank | Protect food security | Rank | Reduce GHG emissions | Rank | Preserve forests | Rank | Rank (even weight) | Rank (stimulation more important) |
|---|---------------------------------------|------|---------------------------------------|------|------------------------------|------|------------------------------|------|--------------------|-----------------------------------|
| Combustion factor = 0 approaches | | | | | | | | | | |
| Unmodified | High | 1 | Low | 8 | Low | 9 | Low | 8 | 9 | 7 |
| Existing + emissions correction | Lower than unmodified | 4 | Higher than unmodified | 7 | Depends on mandates | 7 | Depends on mandates | 6 | 8 | 8 |
| Existing + acceptable lands | Selective | 5 | Uncertain | 3 | Depends on programme details | 7 | Depends on programme details | 6 | 7 | 6 |
| Existing + acceptable trading partners | High | 1 | High | 1 | High | 1 | High | 1 | 1 | 1 |
| Combustion factor = 1 approaches | | | | | | | | | | |
| Tailpipe | Low | 9 | High | 1 | High | 1 | Low | 8 | 6 | 8 |
| POUR ^a | High | 1 | Low | 8 | High | 1 | Low in the short term | 5 | 4 | 3 |
| Value-chain approaches | | | | | | | | | | |
| EU Renewable Energy Directive | Depends on mandates | 5 | Depends on mandates | 3 | Medium | 6 | Medium | 4 | 5 | 5 |
| US RFS2 | Depends on mandates | 5 | Depends on mandates | 3 | High | 1 | High | 1 | 2 | 2 |
| DeCicco-type | Depends on structure of cap-and-trade | 5 | Depends on structure of cap-and-trade | 3 | High | 1 | Likely high | 3 | 3 | 4 |

Values in brackets refer to the rank of each approach for each criterion.

^a Credit market or transfer system assumed

Table 5. Combined subjective evaluation of accounting approaches

| Accounting system | Rank (comprehensive more important) | Rank (stimulation more important) | Combined rank |
|--|-------------------------------------|-----------------------------------|---------------|
| 0-combustion factor approaches | | | |
| Unmodified | 4 | 7 | 7 |
| Existing + emissions correction | 5 | 8 | 9 |
| Existing + acceptable biomass types and sources | 6 | 6 | 8 |
| Existing + acceptable trading partners | 6 | 1 | 3 |
| 1-combustion factor approaches | | | |
| Tailpipe | 1 | 8 | 6 |
| POUR | 1 | 3 | 1 |
| Value-chain and consumer-based approaches | | | |
| EU Renewable Energy Directive | 3 | 5 | 5 |
| US RFS2 | 3 | 2 | 2 |
| DeCicco type | 3 | 4 | 3 |

6

Summary and conclusions

The way in which the Kyoto Protocol and EU-ETS accounting systems address bioenergy emissions gives entities with GHG obligations an incentive to use bioenergy at the expense of maintenance of carbon stocks. The purpose of this report was to examine alternative approaches to accounting for bioenergy emissions that could potentially redress this system weakness.

The weakness occurs because the Kyoto Protocol's accounting system counts emissions due to bioenergy use as carbon stock losses in the land use sector, rather than as combustion in the energy sector. However, many nations do not submit accounts under the Kyoto Protocol, and so carbon stock losses in these nations escape Kyoto Protocol accounting. The EU-ETS, following the Kyoto Protocol accounting approach, also does not include emissions from bioenergy in the energy sector. Since the land use sector has no part at all in the EU-ETS, neither bioenergy emissions nor carbon stock reductions play a role in the choices of entities with EU-ETS obligations. Thus the Kyoto Protocol provides an incentive for Kyoto Protocol-compliant nations to obtain biomass for energy from nations without Kyoto Protocol obligations, whilst the EU-ETS provides energy producers with a powerful incentive to use bioenergy regardless of its carbon stock implications.

The report reviewed approaches to accounting for bioenergy emissions that fall into one of the following basic categories: (1) application of a 0-combustion factor to bioenergy emissions, that is, the current approach; (2) assignment of the

full GHG value to the emissions as done for fossil fuels, that is, multiplying CO₂ emissions by 1, i.e., 1-combustion factor approach; and (3) holding consumers, that is, users of bioenergy, responsible for net GHG emissions generated along the bioenergy value chain. This latter approach can result in combustion factors between 0 and 1.

The report examined several options within each of these categories. Flaws in the current 0-combustion factor approach could potentially be redressed by imposing a carbon tax or fee on biomass used for energy or by restricting biomass to specified types and sources. Carbon taxes or fees could counteract the incentive to use more bioenergy than warranted by its GHG emission profile. However, achieving this goal would clearly depend on the levels of such charges and the costs of alternative supply energy options. Specifying types and sources, including restricting sources to nations with GHG caps, could make it possible to avoid the problem of uncounted carbon stock losses. However, the acceptability and feasibility of implementing sufficiently tight restrictions in order to achieve this goal are unknown. Further such an approach is likely to leave significant bioenergy-related emissions outside of the system just as the current system does.

Applying a combustion factor of 1 significantly increases the fraction of emissions due to bioenergy captured in the accounting system compared with the use of a 0-combustion factor. All emissions due to combustion of biomass for energy by nations with GHG obligations would fall within the accounting system, regardless of where the biomass

came from. Emissions that would not be included would be those due to land use change, soil and litter pool losses, as well as ongoing emissions generated by drainage of wetlands in nations without GHG obligations. Two 1-combustion approach options were reviewed in this report: (1) the tailpipe approach, in which only combustion emissions are counted; and (2) the point of uptake and release (POUR) approach, in which both atmospheric uptake of carbon by plants and emissions from combustion are counted. Tailpipe is likely to discourage use of bioenergy whilst POUR can potentially overcome this drawback by implementing a mechanism to transfer credits from producers of biomass to users. However, designing mechanisms to transfer credits and to distinguish between biomass used for food and biomass used for energy (particularly where the same biomass can be used for either food or energy) poses significant challenges.

The report reviewed two value-chain approaches that are currently in use for biofuels: that specified in the EU Renewable Energy Directive and that in the US Renewable Fuels Standard 2 (RFS2). It also reviewed a proposed system that is not in use (DeCicco 2009). Value-chain approaches differ from the above approaches in two significant ways. First, they encompass not only emissions from combustion of biomass and carbon stock losses but also emissions from cultivation of biomass and its conversion and transportation. Second, unlike any of the 0- or 1-combustion factor approaches, they hold a consuming nation responsible for emissions that occur outside of its national borders. Concerns with value-chain approaches include their high information requirements, including information from countries all over the world, and their 'lot' orientation. To date, value-chain approaches have been designed to assign emissions to specific lots of biofuels, rather than to estimate national-level impacts. This lot-based orientation creates a need to estimate emissions from indirect land use change (iLUC), which is challenging.

Finally, the report evaluated the options reviewed against a set of general criteria and selected stakeholder goals. The general criteria were comprehensiveness (i.e. accuracy) over space and time, simplicity and scale independence. The key

goals considered are those that stakeholders often pursue in conjunction with bioenergy: stimulation of rural economies and food security, GHG reductions and preservation of forests.

With regard to comprehensiveness or accuracy over space and time, the POUR and value-chain approaches seem to be the most promising. To achieve high levels of comprehensiveness, POUR would need to include a mechanism to transfer credits from biomass producers to users, including from producers in nations without GHG limitations. The mechanism would have to be sufficiently attractive to induce at least key nations providing biomass for energy to participate in the system. For application to woody biomass, value-chain approaches would need to develop a mechanism to address the time lag between the generation of emissions and the compensating removal of carbon from the atmosphere by trees. It is important to note the significant differences in the system boundaries of spatial comprehensiveness of these approaches. POUR is comprehensive across changes in carbon stocks, bioenergy emissions and emissions due to decay of biomass in all uses. Value-chain approaches only address biomass used for bioenergy but, unlike POUR, include emissions generated through cultivation, conversion and transportation of biomass as well as its combustion.

Tailpipe is the simplest approach, and the current, unmodified 0-combustion factor approach is also relatively simple. All other approaches are more complicated. Tailpipe is also the only approach that is completely scale independent. However, it gains both its simplicity and its scale independence by completely ignoring carbon stock increases. Therefore, in line with the principle that a system should 'be as simple as possible, but not simpler', some degree of complexity may be necessary to achieve a system with appropriate comprehensiveness.

Although all 0-combustion factor approaches and POUR can be applied at any scale, they were designed for application at the national level and give quite different, and possibly problematic, results when applied at the project level. In contrast, value-chain approaches were developed for project-

level application, and application at national levels requires adaptation, possibly through modelling.

The relationships between the accounting systems and stakeholder goals are considered in this report for several reasons. Whilst reducing GHG emissions is clearly the most important goal for climate change mitigation, it must be recognised that various stakeholders are interested in bioenergy use for other reasons, some of which are politically more potent than climate change mitigation. Stimulation of rural economies, food security and forest preservation are amongst such goals. Accounting systems foster or hinder such goals because they tend to provide incentives to undertake, or refrain from undertaking, specific activities. Importantly, an accounting approach may promote some goals whilst impeding others.

In general, 0-combustion factor approaches, by encouraging use of bioenergy, tend to stimulate rural economies, but modifications are needed to ensure that GHG emission reductions are achieved and that forests are protected. Modifications may also be necessary to protect or enhance food security. The 1-combustion factor options have the opposite tendencies: they tend to discourage use of bioenergy and fail to stimulate rural economies. Implementing a credit transfer mechanism under POUR could counteract these tendencies. With a credit transfer mechanism available to all nations,

POUR could be effective in controlling GHG emissions because it could induce nations without GHG obligations to participate in reporting net atmospheric removals and provide them with an incentive to move to sustainable forest and agricultural practices. Value-chain approaches are theoretically neutral between use of bioenergy and continued use of fossil fuels. However, to date, they have been used in conjunction with mandates that drive use of bioenergy, and the specifics of the mandates have determined the outcomes for stakeholder goals.

The report suggests that several alternative approaches to accounting for emissions due to bioenergy can potentially meet both general criteria and stakeholders' goals more satisfactorily than the current system does. However, none of the available options emerges as a clear winner. POUR is of interest because of its potential to provide comprehensive and accurate reporting over space and time, and a well-designed value-chain approach integrated into a cap-and-trade system is of interest because of its capability to drive continued efficiency improvements and GHG reductions along entire value chains. POUR, well-designed value-chain approaches or even modifications of the current approach with careful designation of permitted types and sources of biomass hence hold sufficient promise to warrant further investigation.

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Under the United Nations Framework Convention on Climate Change, carbon dioxide emissions from bioenergy are counted as carbon stock losses in the land use sector rather than in the energy sector. This method omits many emissions since many nations that source biomass for bioenergy do not have greenhouse gas obligations. Accounting systems have been proposed to address this omission. This working paper describes and classifies these accounting systems into three basic types. Type 1 counts carbon dioxide emissions from bioenergy combustion unaccounted for in the energy sector. Type 2 counts bioenergy combustion emission accounted for in the energy sector. Type 3 counts all other emissions along the supply chain, which are the responsibility of end users. The accounting systems are evaluated against three criteria: comprehensiveness, simplicity and scale independence. They are also evaluated against three key stakeholder goals: stimulation of rural economies and food security, greenhouse gas emission reductions and preservation of forests. The paper describes four key conclusions. First, Type 2 approaches incorporate more emissions than Type 1 in the real-world situation. Second, a Type 2 system that includes carbon dioxide uptake by vegetation in the land use sector ranks highly if stimulation of rural economies and food security is a priority. However, it may not preserve forests or stimulate bioenergy development. Third, policies can make Type 1 approaches effective. However, this may be of limited value if many countries remain outside the accounting system. Fourth, a Type 3 approach supports greenhouse gas emission reductions and preservation of forests but is less simple, and stimulation of the rural economy depends on the structure of the cap-and-trade system.

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