ALTERNATIVE GREENHOUSE GAS ACCOUNTING SYSTEMS FOR BIOENERGY: DESCRIPTIONS AND EVALUATIONS

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ABSTRACT: Pressure is rising to alter the accounting system used to calculate emissions due to bioenergy under the Kyoto Protocol and the EU Emissions Trading Scheme because it does not capture the full extent of greenhouse gas (GHG) emissions from bioenergy use. Both the European Union (EU) and United States (U.S.) are engaged in consultation processes targeted on how to treat emissions connected with use of biomass for energy within regulatory systems hence this discussion of accounting options is timely. The paper first classifies alternative accounting systems into the following three basic approaches: 1) CO_2 emissions produced when biomass is burnt for energy are not counted at the point of combustion but are accounted for in the land use sector as carbon stock losses (a combustion factor = 0 approach);. 2) CO_2 emissions produced when biomass is burnt for energy are accounted for in the energy sector; uptake of CO_2 from the atmosphere by plants and soils may, or may not, be accounted for (a combustion factor = 1 approach); 3) 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 (a value chain approach). The paper then evaluates these approaches against general criteria, and assesses their impacts on a selected set of stakeholder goals. The general criteria are: (a) comprehensiveness; (b) simplicity; and (c) scale independence. Stakeholder goals to be examined are: (a) stimulation of rural economies (b) food security, (c) GHG reductions, and (d) preservation of forests. Given that it is unlikely that all countries will accept greenhouse gas emission targets in the future, we find that: 0-combustion factor accounting systems rank low on comprehensiveness but are relatively simple and scale-independent. Systems with a 1-combustion factor tend to be more comprehensive, and can be both simple and scale-independent. End-user systems vary in comprehensiveness, tend to be complicated and are scale-dependent. While stimulating rural economies, the current system (0-combustion factor) does not foster food security, reduce GHG emissions or preserve forests. 1-combustion factor approaches can support rural economies and food security but tend not to preserve forest. In value-chain approaches, mandates to use biofuels determine impacts on rural economies and food security. These systems can be effective in forest preservation and achieving GHG reductions.

Keywords: agriculture, biofuels, decision making, emissions, greenhouse gas (GHG)

1 INTRODUCTION

As has been pointed out by numerous authors, the current accounting system for greenhouse gas (GHG) emissions under the Kyoto Protocol (KP) and the EU Emissions Trading Scheme (EU-ETS) does not capture the full extent of 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 [1, 2, 3] As a result, pressure is increasing to alter the accounting system.

Under the KP accounting system, carbon dioxide (CO_2) emissions released from the combustion of biomass are not counted not in the energy sector, but rather as changes in levels of carbon stocks in the land use sector. However, as the carbon stock changes often occur in nations that do not have GHG obligations (for example, deforestation in developing countries) or in nations that have chosen not to report changes in carbon stocks that are not associated with a land use change (i.e. not chosen Article 3.4) 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 KP.

This “incomplete” accounting system has two consequences. First, since bioenergy has no emissions in the energy sector, the EU-ETS and many nations are giving energy producers powerful incentives to use bioenergy. Second, there is an incentive for the biomass for bioenergy to come from those nations where changes in carbon stocks are not counted.

Clearly, bringing more land use sector emissions into accounting systems solves much of this problem.

However, there are other ways that the problem can be solved. For example; limiting the source of biomass to nations where carbon stock changes are counted and/or increasing the responsibility of the energy sector for bioenergy emissions would also help. Accounting approaches that do one or all of these could potentially lead to the better alignment of bioenergy use with its GHG consequences. This study focuses on evaluating accounting options that seem to offer these benefits. As there are consultation processes on how to address bioenergy emissions within regulatory frameworks on going in both the current EU and US, this discussion of accounting options is timely.

2 THE BASIC ACCOUNTING APPROACHES

In contrast to fossil fuel carbon stocks, biomass carbon stocks can be replenished relatively quickly by growing new biomass to replace biomass combusted for bioenergy. This is the basic reason why bioenergy can mitigate climate change.

Figure 1 shows the flows of GHGs to and from the atmosphere and the trading of biomass (as carbon, C) between producer and consumer. The biomass producer has three GHG flows: CO_2 absorbed by plants; CO_2 oxidised by plants (both of which are shown as Bio-CO2); and fossil-CO_2 and non-CO_2 emissions that occur during biomass production, conversion and transportation.

The biomass consumer has two streams: CO_2 from the combustion of biomass (bioenergy CO_2) and fossil-CO_2 and non-CO_2 emissions from combustion and distribution. In this discussion, we have assumed that conversion occurs with the producer, but this may not necessarily be the case.

Figure 1 shows where the *physical* emissions, carbon uptake and carbon transfer occur in reality. To illustrate the differences in the accounting systems, we will introduce variations to this diagram. Subsequent diagrams show the location in which *accounting* of emissions occurs rather than the location of the actual *physical* flows.

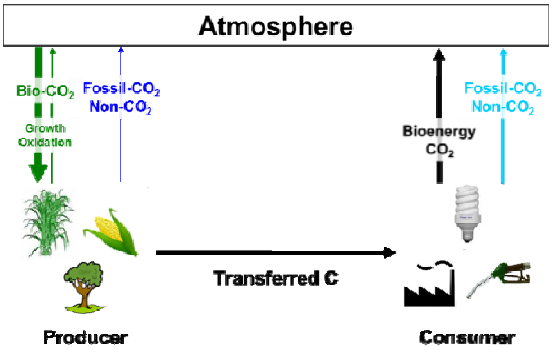

Figure 1: Physical greenhouse gas emissions and flows of carbon in a bioenergy system

There are three basic philosophies that form the basis of all the approaches to accounting for emissions from use of bioenergy.

1. CO_2 emissions produced when biomass is burnt for energy are not counted at the point of combustion but are accounted for in the land use sector as carbon stock losses. We term this a *combustion factor = 0* approach.
2. CO_2 emissions are produced when biomass is burnt for energy are accounted for in the energy sector; uptake of CO_2 from the atmosphere by plants and soils may, or may not, be accounted for (a *combustion factor = 1* approach); and
3. 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. We term this a *value chain* approach

2.1 Combustion factor = 0 approaches

In a combustion factor = 0 approach emissions due to combustion of biomass are counted as carbon stock losses in the land use sector (see Figure 2). The Intergovernmental Panel on Climate Change (IPCC) methodology for calculating emissions from bioenergy, which was adopted under the KP, 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 (Bio-CO_2 $\geq$ 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 and it is assumed that this carbon stock loss will be registered in the accounting system. 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.

The reasons that the IPCC methodology chose a combustion factor = 0 approach are many:

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 CO_2 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"[4].
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"[5]
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 CO_2 emissions described in the Land Use Change and Forestry chapter"[6].
4. "Reporting is generally organised according to the sector actually generating emissions or removals. There are some exceptions to this practice, such as CO_2 emissions from biomass combustion for energy, which are reported in AFOLU Sector as part of net changes in carbon stocks"[7]
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"[8]
6. "Net emissions or removals of CO_2 are estimated in the AFOLU sector and take account of these emissions" [9]

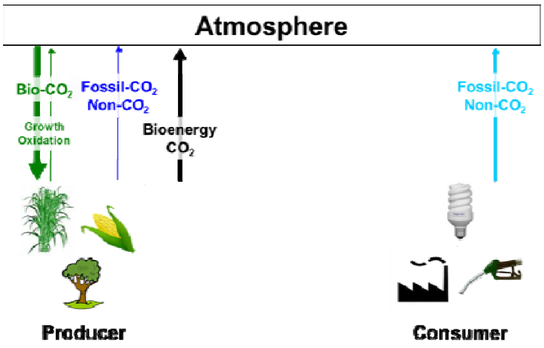

Figure 2: Location of where the physical flows are theoretically accounted for in a 0-combustion factor approach

Even though the above reasoning is correct, as already mentioned, 0-combustion factor approaches have an accounting flaw if the nation where the biomass is extracted does not participate in the accounting system.

This is often the case within the Kyoto Protocol.

To compensate for the accounting flaw a few modifications to current system have been proposed. One way is to impose a correction factor so that some portion of emissions from bioenergy is accounted for in the energy sector. This correction would be designed to compensate for emissions due to carbon stock reductions, and possibly also GHG emissions, caused by biomass conversion in or transportation from such countries. A land use change (LUC) carbon tax or correction factor could be global or nation-specific [10].

Another option to correct the accounting flaw is to use policies (a policy overlay) that restrict bioenergy to some types of biomass, or biomass that comes from "acceptable" lands or "acceptable" trading partners. The EU Renewable Energy Directive [11] uses this option. Of course, the policies would then have to define what constituted "acceptable". For example, an "acceptable" trading partner may be a nation which has accepted economy-wide GHG emission restrictions including from carbon stock changes from all lands.

2.2 Combustion factor = 1 approaches

Combustion factor=1 accounting approaches treat CO_2 emissions from biomass exactly the same as emissions from fossil fuels. Emissions are accounted for in energy sector and emissions other than carbon stock losses are accounted for elsewhere in the accounting system (Figure 3). One can see that the location of where the physical flows are theoretically accounted for in a 1-combustion factor approach mimics the actual physical greenhouse gas emissions and flows of carbon (Figure 1) perfectly.

For combustion factor = 1 approaches we have identified two options. One option is that only the flow to the atmosphere from the combustion of biomass is considered. We use the term 'tailpipe' to refer to this option. Under this option, emissions from bioenergy are treated in the same way as emissions from fossil fuels and carbon stock changes are not measured in determining the impact of use of biomass for energy. 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.

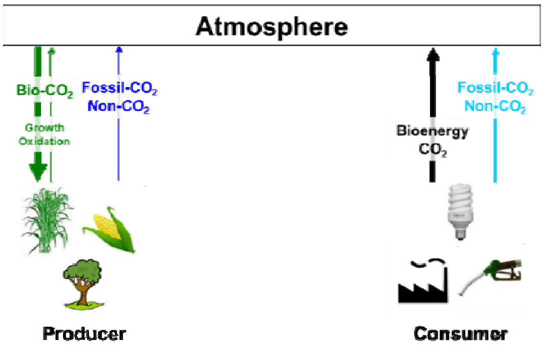

Figure 3: Location of where the physical flows are theoretically accounted for in a 1-combustion factor approach

A second option, which we term point "Point of uptake and release" (POUR) accounts emission from bioenergy and the total net CO_2 uptake by plants from the atmosphere. 'Net uptake' refers the sum of carbon stock changes in the landscape *plus* carbon removed from the landscape for all purposes. The carbon embodied in products removed from the landscape represents carbon removed by plants from the atmosphere. Therefore, like positive carbon stock change, it constitutes a 'negative' emission. By including carbon embedded in wood removed from the landscape, double counting is avoided.

Under POUR, the biomass producer accounts for all carbon taken up through plant growth, and the consumer accounts for emissions from combustion of the biomass. It is not necessary to measure the fluxes. In the case of the biomass producer, they can be estimated from the changes in carbon stocks plus the amount of traded carbon. The biomass consumer needs to track how much biomass is consumed.

Though we are focusing on bioenergy in this paper the POUR approach could be expanded to include biomass embodied in products of all types, such as food, long- and short-lived wood products and energy products, over the same period. Since the POUR method accounts for the total CO_2 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.

2.3 Value chain approaches

In value-chain approaches, GHG emissions and CO_2 removals that occur throughout all the production, conversion, transportation and consumption processes are considered the responsibility of the consumer. So all flows appear on the consumer side of our schematic diagram (Figure 4).

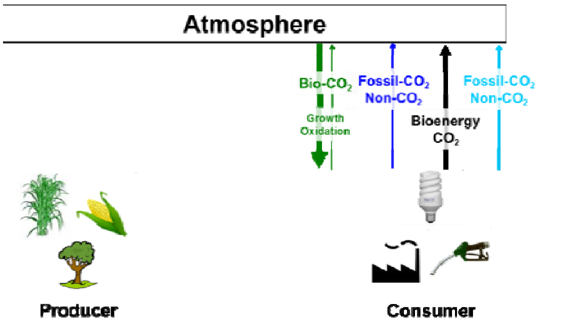

Figure 4: Location of where the physical flows are theoretically accounted for in a value-chain approach

The EU Renewable Energy Directive and US Renewable Fuels Standard (RFS2) [12] are value-chain approaches that try to ensure that biofuel use is in line with its GHG consequences. They include emissions due to production of biofuels regardless of where in the world they occur.

In fact, as already mentioned, the EU Renewable Energy Directive has components of the 0-combustion factor approach with a policy overlay and it also has characteristics of a value chain approach. The policy overly is that 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 criteria are provided for forests, wetlands and land with potential tree cover.

The RFS2 also is a hybrid, value chain with a policy overlay. In the case of the RFS2, there is a 'positive' list of acceptable biomass types and lands from which biomass can be used.

Simplistic value-chain approaches are prone to double counting since the nation where the biomass is produced may also account for GHG emissions in part of its economy. 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 accounts of entities using bioenergy, they would be counted twice. DeCicco [13] has proposed a system in which GHG emissions calculated along the value chain can be corrected for potential double counting.

A numerical example of emissions from bioenergy in different accounting approaches is given by Pena et al, 2011 [14].

3 EVALUATION OF ACCOUNTING SYSTEMS

In this section, we evaluate alternative accounting approaches based on general criteria. The evaluation builds on a landmark paper discussing accounting systems [15]. This paper recommended five criteria: accuracy, simplicity, scale independence, precedence and incentives. Instead of these, we use the following three:

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

Our reasoning for a reduced set of criteria is that is there is some overlap in the five original criteria and that "incentives" are not a fundamental trait of the accounting system. They are an outcome of the accounting system.

Incentives are discussed as item unto themselves in section 4.

3.1 Comprehensiveness over space and time

For environmental integrity, we clearly would like to have comprehensiveness over space and time. However, as mentioned in the introduction, we must consider the reality that the emissions from use of bioenergy in developing countries may not be covered because these countries may not take on GHG-limitation obligations.

Given the assumption above, the current 0-combustion factor approach is poor in terms of comprehensiveness over space. 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 KP. Modified 0-combustion factor approaches attempt to compensate for this incompleteness by applying a correction factor to emissions or policies that place restrictions on the origin of biomass. Using an 'acceptable trading partner' approach, the spatial coverage gap may be closed 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, potential emissions from its use, unaccounted for. 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 [16].

On the other hand, combustion factor = 1 approaches have significantly better spatial coverage of bioenergy emissions. If the country where the biomass is sourced does not participate then the approach 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 amount of unaccounted for emissions is potentially much lower than a 0-combustion factor approach.

If the producing nation does not participate then a combustion factor=1 approach also fails to account for the atmospheric removals of CO_2 that result when forest recovers from the biomass harvest. As this omission concerns removals, that is, negative emissions, partial participation will generally results in overestimating the environmental damage and underestimating the benefits from bioenergy. However, if major emissions occur in addition to those caused by combusting harvested biomass for example, from drainage of peatland then even combustion factor = 1 approaches underestimate emissions.

Value-chain approaches include some or all emissions due to cultivation, conversion and transportation of biomass to end users. However, value-chain approaches are based on specific bioenergy systems or batches of biomass. As a result, it is extremely challenging to include land use change that occurs outside the specific system in the value chain. This is the indirect land use change (iLUC) issue.

3.2 Simplicity

Simplicity is one of the main reasons that the existing 0-combuston factor approach was selected. The approach 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 'as simple as possible' given that the accounting system should achieve reasonable coverage.

Modifications to the 0-combustion factor approach could also be simple. In principle, use of a correction factor is relatively simple; however, in practice, it may be quite difficult to estimate and agree on such factors.

Policy overlays also add complexity because they 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. Take for example, the difficulty in the KP defining "forest".

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. 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.

Furthermore, correction factors 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 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)

A combustion factor = 1 approach that only accounts for emissions (i.e. the tailpipe accounting system) may be the simplest of all approaches. It requires only that bioenergy emissions or the amount of biomass consumed for bioenergy be measured and then converted to CO_2.

However a realistic 1-combustion factor approach, like POUR is significantly more complicated. It requires measuring carbon stock changes and information on the total amount of biomass sold by producers in the producing nation as well as measuring bioenergy emissions in the consumer nation. This becomes increasingly more complex when biomass can be used for multiple uses. 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.

Value-chain approaches are even more complicated than 0- and 1-combustion factor approaches. These approaches require that emissions from direct and indirect LUC, land management changes, cultivation, conversion processes and transportation be tracked and associated with a particular lot of bioenergy.

3.3 Scale independent

The 0-combustion factor approach was originally designed to be scale independent. Carbon stock level accounting, upon which it is based, can take place at any scale from the stand level up to the national level.

However, measurements of forest-carbon stock changes give very different results depending on the scale at which they are taken. For example, annual forest regrowth at the national or landscape level can exceed or fully compensate for removals for bioenergy. This is not true at the stand level. This apparent paradox occurs because most of the regrowth at the landscape level has nothing to do with the current removal for bioenergy. The regrowth is a result of past harvesting or disturbance. To properly understand the impacts of bioenergy one requires the use of forward baselines that indicate carbon stock levels over time with and without removal of the biomass [17, 18]. Modified versions of the current approach will all inherently have the same scalability issues as the current approach.

1-combustion factor approaches may have greater scale independence than 0-combustion factor approaches.

For example, the tailpipe method is fully scale independent because it only accounts for emissions. However, POUR suffers from the same scale problems as in 0-combustion factor approaches.

Value-chain approaches are not scale independent. However, scaling-up is possible through use of national-level estimates of GHG emissions at each step along the value chain. Although this is possible the two prominent value chain approaches the EU Renewable Energy Direct and the US RFS2 are batch-based and the results do not enter into any national GHG accounting system.

3.4 Summary

Table I summarizes our evaluation of accounting approaches according our chosen criteria. The first three columns show how each accounting system ranks against each of the three criteria. The values in parentheses are the rank of each approach for each criterion. The final two columns show (a) the combined ranking for each approach 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. However, POUR also presents well. If comprehensiveness is considered twice as important, POUR ranks better than tailpipe. Value-chain approaches generally receive a lower ranking because of their complexity.

4 IMPACTS OF ACCOUNTING SYSTEMS ON STAKEHOLDER GOALS

Accounting systems can support or hinder stakeholder goals because they tend to provide incentives or disincentives for specific actions. For example, we have already suggested that 0-combustion factor accounting approaches provide strong incentives for energy consumers to use bioenergy to meet GHG obligations, particularly if the carbon stock losses occur in another country.

Bioenergy producers and consumers face a set of problems that use of bioenergy may help solve. These problems include:

- energy security and energy price increases;
- food security 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.

In addition, the rural economies in both producer and consumer nations are also facing problems such as:

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

To tackle these problems, nations promote use of bioenergy to achieve goals such as: a) increasing energy security; b) stimulating the rural economy; and c) reducing GHG emissions.

At the same time, the stakeholders may promote preservation of forests to: a) reduce GHG emissions; b) maintain or enhance livelihoods based on forest products (including bioenergy); and c) maintain habitat and other environmental services.

Some goals are mutually supportive while others are in direct competition with one another. We have distilled the above list to two goals that are served by bioenergy—stimulation of rural economies and GHG reductions—and two goals that may be 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, it tends to be fostered or hindered under the same circumstances that support domestic rural economies. For similar reasons, we have bundled maintenance or enhancement of forest-based livelihoods and environmental services is fostered or hindered under the same conditions as preservation of forests.

4.1 Stimulation of rural economies and food security

As already mentioned, an unmodified 0-combustion factor approach provides a strong stimulus to use bioenergy. This stimulates production of both agricultural and forest biomass [19]. However, this stimulus may result in price increases for food, replacement of food and feed crops with energy-oriented crop production. This may lead to an increase in food imports in nations where agricultural supply is not sufficient to meet both demands [20]. Price increases tend to benefit farmers but can burden the general population, particularly its poorer segments.

Modified 0-combustion factor approaches use factors or taxes that increase the costs of using bioenergy for energy companies and thus weaken the biomass stimulus.

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.

The opposite is generally true for 1-combustion factor approaches. Having the energy consumer account for GHG emissions from bioenergy combustion removes the incentive for consumers, which need to reduce GHG emissions, to use bioenergy. In fact, since in most applications, biomass results in more CO_2 emitted per unit of energy than fossil energy, the use of bioenergy may increase rather than alleviate difficulties in meeting GHG obligations. So, a 1-combustion factor approach would, in general, tend to decrease demand for biomass, fail to stimulate rural economies and have less negative impacts on food security. The POUR approach may overcome this disincentive since credit is given for the removal of CO_2 by biomass. However, there must be a mechanism to transfer the credits from the biomass producer to the biomass consumer who is in need of GHG reductions.

Value-chain approaches have been implemented in conjunction with mandates to reduce GHGs and the mandates rather than the accounting system are driving increased use of bioenergy and thus stimulating rural economies. 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.

4.2 GHG reductions

Because of the current and, probably, future incomplete participation in binding GHG targets, an unmodified 0-combustion factor accounting approach fails to promote GHG reductions. In fact, it may actually result in more emission than the continued use of fossil fuels [21]. All modifications of the 0-combustion factor approach try to correct this failure and ensure reductions in GHG emissions. However, the effectiveness of the modifications in achieving GHG emission reductions is questionable. It is not clear whether a correction factor or tax would effectively reduce emissions or simply add to the cost of bioenergy.

The 1-combustion factor approaches can be effective ways to control GHG emissions. The fact that combustion of biomass generally generates more CO_2 emissions to produce a unit of energy than the combustion of fossil fuels increases the difficulty of achieving the goal of reducing GHG emissions by using woody biomass in the short term [17, 18, 22, 23]. A POUR approach, in fact, may induce nations without GHG obligations to track carbon stock changes and biomass removed from the landscape.

Making users responsible for value-chain GHGs can translate into incentives both to produce and to purchase biomass with the lowest GHG profiles. For this reason, 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.

4.3 Preservation of forests

The extent to which an accounting approach preserves forests is closely related to its ability to reduce GHG emissions. The unmodified 0-combustion factor approach, for example, does neither very successfully.

Modifications to the 0-combustion factor approach may also fail to preserve forests. For example, the EU Renewable Energy Directive uses crown-cover criteria in combination with accounting for carbon stock changes only if land use change occurs. This combination 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 prevent deforestation or degradation.

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 POUR, on the other hand, credits may be received for removals embodied in harvested wood. So there is a strong incentive to harvest. However, credits are received for carbon in wood sold minus carbon stock losses. Hence POUR may provide an incentive to sustainable forest management. The true impact of POUR on forest preservation could only be determined through economic analyses beyond the scope of this study.

The impact of a value-chain approach to bioenergy on forests will depend greatly on the specifics of its design and the mandates In fact the mandates play a larger role in the impact on forest preservation, than the accounting system. Without mandates, and it is unlikely that forest biomass would be used for energy because of it higher emissions per unit of energy than other options.

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

4.4 Summary

Table II summarizes our evaluation of accounting approaches in support of stake holders' goals. The first four columns show how each accounting system ranks against each of the four criteria. The values in parentheses are the rank of each approach for each criterion. The final two columns show (a) the combined ranking for each approach if the separate criteria are given equal weight, and (b) the ranking if stimulation of rural economies is considered more important than other criteria.

We find that the 0-combustion factor approach with trading partners that also have committed to a GHG limitation is the best option. This is somewhat to be expected as this accounting approach was designed with this assumption. However, given the reality of partial participation, continuing the 0-combustion factor approach without modification behaves very poorly.

The 1-combustion factor and value-chain approaches do very well in reducing GHG emissions and generally do well overall. If stimulation of rural economies is considered twice as important, then POUR and value-chain approaches continue to rank favourably.

5 CONCLUSIONS

The current accounting system for emissions from bioenergy gives entities with GHG obligations an incentive to use bioenergy at the expense of maintenance of carbon stocks. In this paper we develop and examine alternative approaches to accounting for bioenergy emissions that could potentially redress this system weakness.

The problem arises because the KP's accounting of bioenergy is a "0-combustion factor" approach. Emissions from the combustion of biomass for energy are not accounted in the energy sector, but in the land use sector as carbon stock losses. This works well when all nations are participating in a GHG target. However in reality, this is not the case. Many countries do not have GHG targets and some countries that do, don't include emissions from forest management. They include only emissions from changes from forest to non-forest. In this way, the KP provides an incentive for KP compliant nations to obtain biomass for energy from nations without KP obligations. The EU-ETS provides energy producers with a powerful incentive to use bioenergy regardless of its carbon stock implications.

The report develops alternatives to account 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 during combustion as done for fossil fuels, the 1-combustion factor approach; and (3) holding bioenergy consumers responsible for net GHG emissions generated along the bioenergy value chain.

The report examined several options within each of these categories. For example, the problem caused current 0-combustion factor approach can be minimised by imposing a carbon tax or emission correction factor on biomass used for energy or by restricting biomass to specified types and sources.

Applying a 1-combustion factor 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 would be included. Emissions that would not be included would be those due to soil and litter pool losses, and 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.

The report also reviews 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). Value-chain approaches differ from the previous two significant ways.

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.

Finally, the report evaluates all accounting approaches against a set of general criteria and selected stakeholder goals. The general criteria are comprehensiveness 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, food security, GHG reductions and preservation of forests. The results of this evaluation are shown in Table III.

Table I: Subjective evaluation of accounting approaches according to criteria

Approach	Comprehensiveness	Simplicity	Scale	Evenly Weighted	Comprehensiveness Favoured
Combustion factor = 0 approaches					
Unmodified	Low (6)	High (1)	Yes with drawbacks (1)	3	4
With emission correction	Acceptable (4)	Low (5)	Yes (1)	4	5
With 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	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. The final two columns show (a) the combined ranking for each approach if the separate criteria are given equal weight, and (b) the ranking if comprehensiveness is considered more important than other criteria

Table II: Subjective evaluation of accounting approaches' support of goals

Approach	Stimulate Rural Economies	Protect Food Security	Reduce GHG Emissions	Preserve Forests	Evenly Weighted	Stimulation Favoured
Combustion factor = 0 approaches						
Unmodified	High (1)	Low (8)	Low (9)	Low (8)	9	7
With emission correction	Lower than unmodified (4)	Higher than unmodified (7)	Depends on mandates (7)	Depends on mandates (6)	8	8
With acceptable lands	Selective (5)	Uncertain (3)	Depends on programme details (7)	Depends on programme details (6)	7	6
With acceptable nations	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	High (1)	Low (8)	High (1)	Low in the short term (5)	4	3
Value-chain approaches						
EU - RED	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	Depends on structure of cap-and-trade (5)	Depends on structure of cap-and-trade (3)	High (1)	Like high (1)	3	4

Note: The values in parentheses are the rank of each approach for each criterion. The final two columns show (a) the combined ranking for each approach if the separate criteria are given equal weight, and (b) the ranking if stimulation of the rural economy is considered more important than other criteria. The DeCicco approach is discussed in detail in Pena et al [14].

Table III Combined subjective evaluation of accounting approaches

Approach	Rank (comprehensive favoured)	Rank (stimulation favoured)	Combined Rank
Combustion factor = 0 approaches			
Unmodified	4	7	7
With emission correction	5	8	9
With acceptable lands	6	6	8
With acceptable nations	6	1	3
Combustion factor = 1 approaches			
Tailpipe	1	8	6
POUR	1	3	1
Value-chain approaches			
EU - RED	3	5	5
US - RFS2	3	2	2
DeCicco	3	4	3

With regard to comprehensiveness, the combustion factor=0 approaches do not perform so well. Whereas the value chain and combustion factor=1 approaches perform better. However there is a trade-off. These last two approaches are not as simple as the first type (0-combustion factor). Finally, the value chain approach is not so easily scaled from a “lot” or biomass chain to a national total.

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. An exception may occur if in a POUR accounting approach a credit transfer mechanism is implemented which transfers credits for emission removals in the rural sector to bioenergy consumers. With a credit transfer mechanism available to all nations, POUR could be effective in controlling GHG emissions because it reveals whether use of biomass across all products is resulting in net increases or decreases in carbon stocks, that is, net GHG emissions or removals. 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.

In table III we attempt to combine the two evaluation techniques. This table suggests that there are several alternative approaches to accounting for emissions due to bioenergy that can potentially meet both general criteria and stakeholders’ goals more satisfactorily than the current system. However, none of the available options emerges as a clear winner. POUR is of interest because it would reveal the net carbon stock balance from all uses of biomass, 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.

6 ACKNOWLEDGEMENTS

This research was also partially funded under the rubric of an EC-funded project entitled, 'Bioenergy, sustainability and trade-offs: Can we avoid deforestation while promoting bioenergy?' (Agreement: EuropeAid/ENV/2007/143936/TPS).

EUROPEAID
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The objective of the project is to contribute to sustainable bioenergy development that benefits local people in developing countries, minimizes negative impacts on local environments and rural livelihoods, and contributes to global climate change mitigation. The project will achieve this by producing and communicating policy relevant analyses that can inform government, corporate and civil society decision-making related to bioenergy development and its effects on forests and livelihoods. The project is managed by CIFOR and implemented in collaboration with the Council on Scientific and Industrial Research (South Africa), Joanneum Research (Austria), the Universidad Autónoma de México and the Stockholm Environment Institute.

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