available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/envsci

Carbon sequestration in wood products: a method for attribution to multiple parties

Bruce Tonn [a,*], *Gregg Marland* [b]

[a] *Department of Political Science, University of Tennessee-Knoxville, McClung Tower, Room 1018, Knoxville, TN 37996-0410, USA*
[b] *Environmental Science Division, Oak Ridge National Laboratory, P.O. Box 2008, MS 6335, Oak Ridge, TN 37831-6335, USA*

ARTICLE INFO

Published on line 22 November 2006

Keywords:
Carbon sequestration
Harvested wood products
Attribution methodology

ABSTRACT

When forest is harvested some of the forest carbon ends up in wood products. If the forest is managed so that the standing stock of the forest remains constant over time, and the stock of wood products is increasing, then carbon dioxide is being removed from the atmosphere in net and this should be reflected in accounting for greenhouse gas emissions. We suggest that carbon sequestration in wood products requires cooperation of multiple parties; from the forest owner to the product manufacturer to the product user, and perhaps others. Credit for sequestering carbon away from the atmosphere could acknowledge the contributions of these multiple parties. Accounting under a cap-and-trade or tax system is not necessarily an inventory system, it is a system designed to motivate and/or reward an environmental objective. We describe a system of attribution whereby credits for carbon sequestration would be shared among multiple, contributing parties. It is hoped that the methodology outlined herein proves attractive enough to parties concerned to spur them to address the details of such a system. The system of incentives one would choose for limiting or controlling greenhouse gas emissions could be quite different, depending on how the attribution for emissions and sequestration is chosen.

1. Introduction

Inventories of national greenhouse gas emissions do not generally deal with carbon that is sequestered in harvested wood products. This is partly because there is not yet international agreement on which party should report this stored carbon, the party that grew the trees or the party that holds the wood products.

This paper recognizes that sequestration of carbon in harvested wood products (HWP) involves both the producer and the consumer of wood and suggests an approach to attribute carbon sequestered in wood to multiple parties. Section 2 describes the context and the issues and Section 3 then presents an approach for allocating credits. In Section 4 we discuss negotiating the outcome and other thoughts, and in Section 5 we present our conclusions.

2. The importance of attributing carbon sequestered in harvested wood products to multiple parties

When forests are harvested there is an instantaneous decrease in the carbon stocks of the forest. But, if the forest is managed sustainably, regrowth will replace the harvest and there will be no net decrease in the carbon stocks of the forest over the course of time.

Forest harvest does result in some loss of carbon to the atmosphere as carbon dioxide, but some of the carbon

* *Corresponding author*. Tel.: +1 865 974 7041; fax: +1 865 974 7037.
E-mail address: btonn@utk.edu (B. Tonn).
1462-9011/$ – see front matter
doi:10.1016/j.envsci.2006.10.010

removed from the growing forest during harvest is moved to a variety of secondary ''pools''. These secondary pools include, for examples, the carbon in the leaves and branches left on the forest floor and the carbon in long- and short-lived forest products such as lumber and paper. All of the secondary pools are subsequently oxidized at various rates, with eventual release of carbon as CO_2 to the atmosphere. To the extent that input to any secondary pool is greater than oxidation or other removal from this pool, the amount of carbon in the pool will increase. Similarly, these pools could decrease in size over time if removals from the pool exceed the rate at which material is added to the pool. If there is no change in the size of any of these secondary carbon pools over time, then the amount of carbon flowing to the atmosphere each year will be the same as the amount of carbon in the harvested biomass—i.e. a steady state will exist.

The Intergovernmental Panel on Climate Change (IPCC, 1996) methodology for estimating national emissions of greenhouse gases to the atmosphere recommends, as a default methodology, that the amount of carbon in these secondary pools be assumed constant so that CO_2 emissions to the atmosphere can be estimated from the amount of carbon in the forest harvest. In the case of harvested wood products ''this is based on the perception that stocks of forest products in most countries are not increasing significantly on an annual basis'' (IPCC, 1996, p. 5.17). The IPCC has provided more elaboration and discussion in its Good Practice Guidance document (IPCC, 2003).

In fact, available information now suggests that there is an annual increase in the amount of carbon in harvested wood products in at least some countries (e.g., UNFCCC, 2003) and hence that forest harvest is not an accurate measure of the rate at which carbon is being released to the atmosphere. The IPCC methodology (IPCC, 1996) and Good Practice Guidance (IPCC, 2003) note that countries can report the increased amount of carbon stored in harvested wood products if they can demonstrate that the stock of wood products is actually increasing with time. Pingoud (2004), Skog (2004), Row and Phelps (1996), Marland and Marland (2003), and others have all described simple mathematical methods whereby we can estimate the rate at which carbon is being stored in forest products, and thus the rate at which carbon is being released to the atmosphere from forest harvests; if we can estimate the rate of production of wood products and the mean lifetime of those products.

Despite recent international efforts to document, inventory, and mitigate the rate of emissions of greenhouse gases such as CO_2, there is no consensus on how to attribute the accumulation of carbon in forest products, whether in use or in waste disposal sites. That is, if carbon is being sequestered in wood products, what party should account for this sequestration. Failure to yet achieve consensus is partly because these accumulations of carbon are generally modest in size, partly because there is concern that this carbon storage in wood products is simply a delay of emissions that is only temporary, and partly because of methodological problems in estimating the amount of carbon so sequestered and in attributing this sequestration to the appropriate party. This short paper accepts the notion that the amount of carbon involved may be significant for some countries or some companies that may come under emissions restrictions, it agrees that aggregate storage of carbon occurs even if individual units of storage are only temporary (Marland et al., 2001), it asserts that the problems of data and estimation are amenable to simple solutions, and it focuses on the clearly contentious issue of attribution. To reiterate, if carbon is sequestered in wood products, what party would show this in its emissions accounts?

The fact that multiple parties are involved in activities that govern net carbon emissions to the atmosphere is not unique to harvested wood products. Emissions from electric power generation, for example, are accounted at the power plant even though the electricity is used in many ways by many users. Efforts to limit the use of electricity will reduce emissions from the power plant, not from the party that has reduced its final consumption. Emissions reduction projects in the energy sector generally are likely to involve multiple interests and investments. The responsibility for emissions or credit for emissions reductions are developed and shared by the market. International consensus has developed methods to account for emissions from fossil-fuel combustion and we count on markets to distribute costs or credits. This allocation creates clear problems when there are negotiated or legislated limits on emissions for some parties, but we currently have procedures for accounting for emissions from combustion of fossil fuels that have been widely accepted. What is unique about carbon stored in harvested wood products is that we do not have agreed, accepted accounting procedures for the stored carbon. After over a decade of discussion there is still no international consensus on how to account for stocks of stored carbon that could be of considerable importance to some parties. This paper offers an approach for getting by this impasse and accounting for carbon sequestered in harvested wood products by sharing credits among the multiple, contributing parties. This approach may have value in additional circumstances where currently accepted procedures do not appropriately attribute debits and credits among contributing parties. A simple example is a coal-fired power plant in one country where much of the electricity is exported to a neighboring country.

It should be pointed out that harvested wood products impact greenhouse gas emissions in multiple ways. Wood products substitute for other materials that often require more fossil-fuel energy for their production and use and wood can be burned directly to displace fossil fuels, either before or after being used for some other purpose. These impacts on carbon emissions to the atmosphere may be more important than the carbon physically retained in the harvested wood products, and they may involve multiple parties; but all of these impacts on carbon emissions (including impacts on emission of other greenhouse gases) are embraced within current, accepted accounting procedures. This paper addresses only the carbon that is physically sequestered in wood products.

The problem of attribution for carbon stored in wood products came into focus at international meetings in Sao Paulo, Brazil (1996) and Dakar, Senegal (1998) (Brown et al., 1998; Lim et al., 1999). This later workshop reported three alternative approaches for dealing with wood products. These three approaches suggest different system boundaries among parties and can be summarized briefly as follows:

(1) The flow approach adopts the same philosophy used for emissions from fossil fuels in tracking carbon emissions, reporting would be of actual carbon fluxes to or from the atmosphere at the time and place that they physically occur.
(2) The stock-change approach adopts a pure accounting for changes in carbon stocks, reporting stock changes where and when they occur regardless of whether the inputs and outputs occur as solid materials or as CO_2 exchanges with the atmosphere.
(3) The production approach adopts a philosophy of continuity, reporting all stock changes as continuous derivations from the original forest harvest, i.e. the party that harvested the wood would continuously report the changes in the stock of the harvested wood products derived from its forests as this actually (or statistically) occurred, regardless of who physically held the carbon-containing products.

The differences among these three approaches in terms of attribution for carbon emissions and sequestration can be demonstrated with a simple example in which Party A harvests one unit of wood (from a forest that is assumed to be sustainably managed, and thus maintains a constant carbon pool) and sells this wood to Party B. Party B then burns half of the wood and stores half in durable products. Under the flow approach, Party A would report one unit of C removed from the atmosphere and Party B would report one-half unit of emissions to the atmosphere. Under the stock-change approach, Party A would report nothing (that is no change in the carbon stocks of either the forest or of the pool of harvested products) and Party B would report one-half unit of sequestration. Under the production approach Party A would report one-half unit of sequestration and Party B would report nothing.

When taken to completion, all three of the approaches described above accurately report that a net one-half unit of carbon has been removed from the atmosphere and stored, but the attribution for this carbon sequestration is considerably different. This difference could be very important in a reporting and accounting format where parties, whether countries or companies, have some legal restraint on CO_2 emissions. Whether this restraint is a cap-and-trade limit as envisioned under the Kyoto Protocol or some sort of carbon tax, the burden will be differently imposed depending on the system of accounting and attribution chosen. From a different perspective, the system of incentives one would choose for limiting or controlling greenhouse gas emissions could be quite different, depending on how the attribution for emissions and sequestration is chosen.

In national submissions to the United Nations Framework Convention on Climate Change, on accounting for carbon sequestered in wood products, the European Union, Japan, and New Zealand all noted the potential impact of accounting approaches on the equity between producing and consuming countries and the potential for impacts on international trade (UNFCCC, 2004). A technical paper of the UNFCCC secretariat (UNFCCC, 2003) discussed some of the environmental and market implications of the different approaches for accounting, including the implications for parties that are not governed by emissions restraints. The UNFCCC technical paper suggests that the management of forests and wood products could be affected by the choice of accounting approach.

The seventh meeting of the Conference of the Parties to the UNFCCC, meeting in Marrakesh in 2001, prescribed specifically that parties should account for five biomass pools: above-ground biomass, below-ground biomass, litter, dead wood, and soil organic carbon; and decided pointedly that "any changes to the treatment of harvested wood products shall be in accordance with future decisions of the Conference of the Parties" (UNFCCC, 2002, p. 55). The pool of carbon in harvested wood products is not recognized, nor even mentioned, in the Kyoto Protocol.

Interestingly, the production of wood by one party with use and sequestration by another party requires participation and cooperation by both parties, and yet all of the accounting systems described above are such that one or the other will get credits for carbon sequestration. To provide incentives for both parties to participate in an efficient, collaborative effort to reduce net CO_2 emissions suggests an attribution approach whereby the contributions of both would be acknowledged and mitigation (sequestration) would be attributed to the two parties in proportion to their contributions.

Accounting under a cap-and-trade or tax system is not necessarily an inventory system, it is a system designed to motivate and/or reward an environmental objective. We describe a system of attribution whereby credits for carbon sequestration in harvested wood products would be shared among multiple, contributing parties. Although we describe this approach in terms of sequestering carbon in wood products, the same approach could easily be applied to any activity that involves multiple parties to yield a net decrease in emissions of greenhouse gases. A particularly interesting example would be emissions from bunker fuels, fuels used in international commerce. Currently the emissions from combustion of bunker fuels are not included in the accounts of any countries because there is not yet international agreement on where the emissions should be accounted.

3. A method to attribute carbon sequestration in harvested wood products to multiple parties

3.1. *The parties*

Assume that multiple parties are involved in a project involving the production and use of wood products. We identify the parties involved as

$$P = \{P_1, P_2, \ldots P_N\}.$$

These might include, for example, the country that produced the wood, the country that purchased and used the wood, and the country that purchased secondary wood products like furniture.

The methodology allows a great deal of flexibility in specifying parties. It is expected that countries will be the most important parties involved in accounting for carbon sequestration associated with HWP and this is the primary focus in this paper. Additionally, the set of parties could include non-profit organizations that may be directly involved in carbon sequestration activities or indirectly involved, say as

brokers of agreements. As is discussed below, the methodology is also flexible in how carbon sequestration results are attributed to parties that are not nation states. The set of parties could also include companies, projects, or any other entities with an imposed constraint on CO_2 emissions within a country.

3.2. Carbon sequestration in harvested wood products

How much carbon was sequestered by the project involving production and use of wood products? Let's define this amount as CS, for carbon sequestered. The purpose of this methodology is to attribute CS to all parties P involved in the project in proportion to their contributions.

Estimating CS in harvested wood products should be fairly straightforward. The amount of carbon in lumber by weight is well known and the amount of lumber derivable from forests is also well known. On the other hand, defining how much carbon is 'sequestered' in wood products may be more difficult to accomplish. The question is the point at which carbon is considered to be sequestered.

One approach to this problem would be to simply choose an acceptable minimum for the expected sequestration period. For instance, 100 years is a possibility that is compatible with the choice of comparing the different greenhouse gases on the basis of their global warming potential impact integrated over 100 years. Another approach would be to decrement the amount of carbon sequestered that is attributed to the Parties as the wood products oxidize and release carbon into the atmosphere. The Marrakesh Accords (UNFCCC, 2002, p. 56) are quite explicit that "reversal of any removal due to land use, land use change and forestry activities be accounted for at the appropriate point in time". That is, if credits are awarded when carbon is sequestered, there must be debits if the carbon is subsequently released. This later approach is discussed in more detail in Section 4.3 below. For now we assume that the quantity CS can be reliably estimated.

3.3. Project components

How did the project involving the production and use of wood products actually result in the sequestering of carbon? What were the components of the project? Examples of project components include: natural resources (e.g., the wood itself), intellectual capital (e.g., new technology to prevent the wood from oxidizing quickly), brokering (e.g., in the event that a third party helped organize the project), value-added investment (e.g., the money spent to manufacture wood products), and end use (e.g., the purchase of wood products, such as furniture and building materials). Let's define the set of project components as

$$C = \{C_1, C_2, \ldots C_M\}.$$

3.4. Scoring project components across parties

How much of each 'project component' did each party provide to sequester the amount of carbon, CS, described above? This can be recorded by completing the following Table 1, where each S_{ij} is between 0.0 and 1.0 and the sum of each row is equal to 1.0.

Table 1 – Weights for the contributions of each party to each component of the project

	P_1	P_2	P_j	P_N	Total
C_1	S_{11}	S_{12}	S_{1j}	S_{1N}	1.0
C_2	S_{21}	S_{22}	S_{2j}	S_{2N}	1.0
C_i	S_{i1}	S_{i2}	S_{ij}	S_{iN}	1.0
C_M	S_{M1}	S_{M2}	S_{mj}	S_{MN}	1.0

3.5. Weighting project components

How much did each project component contribute to the successful sequestration of the amount of carbon CS, described above? Each project component must be assigned a weight, U_j, between 0.0 and 1.0. The sum of all the U_j's needs to equal 1.0

$$U = \{U_1, U_2, \ldots U_M\}.$$

3.6. Calculating attribution weights across parties

Finally, the total amount of carbon sequestered by the project can be attributed to each party. Define the portion of CS attributed to P_i as W_i. For P_i, the attribution weight, W_i, would equal $(U_1 \times S_{1i} + U_2 \times S_{2i} + \cdots + U_j \times S_{ji} + \cdots + U_M \times S_{Mi})$. The amount of sequestered carbon attributable to P_i would be $W_i \times$ CS. These general calculations would be performed for each party.

3.7. A numerical example

Let's examine a simple example. Assume there are four parties that contributed to a project that sequestered 5000 MtC: a wood producer and exporter, a project broker, a wood importer that transformed the raw wood into finished products, and a party that bought and held the finished wood products for its own use. Let's also assume that there are four project components, the wood production, the brokering process, the manufacturing process, and end use.

Table 2 contains hypothetical weights for the contributions of each party to each of the four components. Also shown are the weights for the project components (last column). In this example, only one party exports wood, Party 1, although the method allows for additional exporters, who could also be importers and end users. In fact, in this example, three parties are end users of wood products, Parties 1, 3, and 4. It is assumed that only one party imports wood and subsequently produces finished wood products, Party 3. Lastly, the project broker, Party 2, is assumed to be a non-governmental organization; this is why Party 2 is not an exporter, importer or end user. Notice that the other three parties also played roles in the brokering process in addition to the lead project broker.

When the algorithm presented in Section 3.6 is applied to these data the results are as shown in Table 2. Party 1, the wood exporter, is attributed the highest fraction of the sequestered carbon, 0.43; followed by Party 3, the wood

Table 2 – Example with four parties and four project components

	P_1 wood exporter	P_2 project broker	P_3 wood importer	P_4 wood products end user	Project component weights
C_1 wood	1.0	0.0	0.0	0.0	0.4
C_2 brokering	0.1	0.7	0.1	0.1	0.1
C_3 production	0.0	0.0	1.0	0.0	0.3
C_4 end use	0.1	0.0	0.3	0.6	0.2
Attribution fraction	0.43	0.07	0.37	0.13	
Attribution total (MtC)	2150	350	1850	650	

importer, 0.37; Party 4, the end user, 0.13; Party 2, the project broker, 0.07. Of the 5000 MtC sequestered by the project, Parties 1, 3, 4 and 2 were attributed 2150, 350, 1850, and 650 MtC, respectively.

3.8. *Generalized approach*

It may not be possible to explicitly specify the scores (i.e., S_{ji}'s) and/or the project component weights (i.e., U_j's). In the general case, it is sufficient to specify relations between the scores (e.g., $S_{11} > S_{12}$) and the project component weights (e.g., $U_1 > 2 \times U_2$). In the example above, it may be that relationships among the project components weights could be specified (e.g., $C_1 > C_3 > C_4 > C_2$) but not their explicit values. Non-linear optimization can be used to find the best set of scores and weights, using an objective function of maximizing the entropy among the attribution weights (i.e., maximize $H = -LN(W_1 \times W_2 \times \cdots \times W_N)$). This objective function states that when uncertainty exists about how to attribute sequestered carbon, it is better to attribute the carbon as equally as possible to the parties to emphasize the importance of cooperation, given the constraints represented by the relations between the scores and project component weights.

4. Negotiations and other thoughts

4.1. *Negotiations*

In a real project it would be a significant task to agree on the set of weighting factors described above. Who would decide the magnitude of CS, what parties are involved in producing CS, how to decompose the project into components, how to weight the project components, and how to weight each party's contributions? It is suggested that the wood producers take the lead in these negotiations. After all, without the wood, no carbon would be sequestered in the first place. It can also be assumed that the wood producers' behaviors were most animated to sequester carbon. The wood producers would work with the other parties to establish the details of the methodology presented above.

If the parties cannot agree on the details, then it is recommended that an arbitration process should be implemented. The lead party would submit to an arbiter its view of the details surrounding the project. The other parties would then be expected to submit their own version or versions of the details. The arbiter would select amongst the versions submitted for arbitration. It can be argued that the mere threat of arbitration, with its inherent uncertainty in outcome and certain negative impacts on future collaboration amongst parties, would be enough motivation for the parties to agree to the details of the carbon sequestration project.

4.2. *Adjusting attribution weights due to additionality*

The method presented above does not distinguish between projects that were wholly conceived to sequester carbon in wood products and projects that would have taken place in any case in the course of normal business operations (or any situation in between). Both Article 6 and Article 12 of the Kyoto Protocol have phrasing that would limit credit for emissions reductions to those that are "additional" to what would have occurred in the absence of the project, and these have given rise to the notion of "additionality". In terms of attributing credit for sequestering carbon in wood products, once the attribution weights have been determined in the methodology described above, these weights could be adjusted to account for additionality. It is suggested that additionality be considered for each party separately and for each party's contribution to each project component separately. Let's define the additionality adjustment factors for Party i as

$$A_i = \{A_{i1}, A_{i2}, \ldots A_{im}\}$$

A_{ij} is equal to 1.0 when the party's contribution to project component j was solely to sequester carbon and would not have taken place otherwise. A_{ij} is equal to 0.0 when the party's contribution to project component j would have taken place in its entirety without consideration to the goal of sequestering carbon. A value of A_{ij} between 0.0 and 1.0 indicates that the party contributed more than was necessary only to satisfy business concerns (e.g., planted more trees).

For P_i, the adjusted attribution weight, W_i', would equal $(A_{i1} \times U_1 \times S_{1i} + A_{i2} \times U_2 \times S_{2i} + \cdots + A_{ij} \times U_j \times S_{ji} + \cdots + A_{im} \times \cdots \times S_{1i} + A_{i2} \times U_2 \times S_{2i} + \cdots + A_{ij} \times U_j \times S_{ji} + \cdots + A_{im} \times U_M \times S_{Mi})$. *The adjusted amount of sequestered carbon attributable to* P_i *would be* $W_i' \times CS$.

4.3. *The loss of sequestered carbon*

Carbon sequestration can be characterized by describing a discrete mass of carbon and monitoring whether or not it is isolated and remains isolated from the atmosphere. It can also be characterized by identifying a larger mass of carbon and monitoring whether it increases or decreases with time. (The IPCC (2001) defines carbon sequestration as "The process of increasing the carbon content of a carbon reservoir other than the atmosphere.") In either case, if credit is received for sequestering the carbon or increasing the mass of stored carbon, then debits must occur if the carbon is lost or if the

mass decreases over time. It has been proposed (e.g., Kirschbaum, 2003, and others) that this problem be avoided by requiring that credits should not be awarded unless it is virtually certain that sequestration is "permanent", but debits for loss of sequestered carbon are quite feasible and there are many reasons that even temporary storage has value (see e.g., Marland et al., 2001). Certainly no carbon stored in wood products is expected to remain there permanently.

If a discrete mass of wood products can be identified and monitored, it is straightforward that losses from this mass be accounted back to the parties who received credits for its initial sequestration.

The more likely situation is that production and use of wood products results in an increase in the total mass of wood products held by Party A. This can be accounted by estimating the annual production of wood products and the annual loss of wood products, or by estimating the annual change in the stock of wood products. The first case would result in both credits and debits annually, while the second case would result in credits so long as the mass was increasing and debits anytime the total mass was decreasing. In both cases, debits could be distributed in proportion to the receipt of credits earlier. In both cases, also, it must be agreed which parties are responsible for the legacy of wood products that existed at the time accounting began. Presumably (but not necessarily), the host party, Party A, would accept responsibility for losses from the initial, legacy stock of wood products. The allocation of debits could be made more complex, but perhaps more equitable, if the wood products were divided into classes according to categories of expected lifetime.

4.4. *Attribution of sequestered carbon to parties without emissions limitations*

The discussion above is cast in terms of a project among parties that have legal or tax limitations on greenhouse gas emissions. Presumably this would generally be countries with commitments to limit emissions. However, the methodology is flexible enough to include any country with emissions limitations plus other nation states, and even companies or other parties that are not nation states. The example presented in Section 3.7 above, for instance, assumes that a transnational, non-governmental organization acted as a 'broker' to coordinate the initiation and completion of the project. This organization can be included in the set P and, ultimately, the methodology could attribute some portion of CS to this organization.

One question, then, would be how to deal with portions of CS attributed to these types of organizations. The simplest approach would be not to attribute that portion to any nation states for the purpose of accounting carbon sequestration under the terms of an agreement like the Kyoto Protocol. Alternatively, by prior agreement, the portion could be attributed to any other parties (i.e., nation states) where the non-governmental organization is located and/or that might have contributed funds to the operation of the organization. Lastly, the non-governmental organization could be allowed to transfer their portion of CS to parties that are nation states in any way they wish. This last approach could be viewed as being the most preferable approach because it would justify the decision to include non-governmental organizations as distinct parties in this process.

In addition to non-governmental organizations, companies can also be expected to play a major role HWP carbon sequestration. It is recommended that portions of CS attributable to companies be further attributable to nation-states based on the location of company operations. Given this recommendation, companies may not need to be designated as explicit parties in this process. However, if a small set of companies are expected to be important contributors to CS and to negotiations surrounding the process, then the set of parties should probably explicitly include specific companies.

5. Conclusion

This paper presents a methodology to attribute carbon sequestered in harvested wood products to multiple parties. The method can accommodate any number and types of parties and projects of any size and complexity. It is suggested that wood producers take the lead in implementing the methodology. If it proves difficult to exactly specify inputs into the methodology (e.g., project component weights and party contribution weights), a generalized methodology can be implemented that requires only relationships among weights. If simple relationships cannot be agreed upon, then it is suggested that the parties enter into an arbitration process.

The methodology proposed is not simple and it can be anticipated that there will be many challenges to implementing this attribution methodology. As is typical, the devil is in the details. Are the requisite data available? How should the amount of carbon sequestered be determined? Should sequestered carbon be decremented over time, and if so, how? Who should act as arbitrator? How can one decide how much wood would have been produced in any case? But the methodology offers a way to acknowledge the multiple contributions to limiting greenhouse gas emissions in an area that has defied international agreement for over a decade. It is hoped that the methodology presented herein proves attractive enough to parties concerned with carbon sequestration to spur them to address these types of questions. The UNFCCC Technical Paper (UNFCCC, 2003) poses the question whether new alternatives should be considered for dealing with wood products in national inventories of greenhouse gas emissions. We would answer this query with a "yes", alternatives should be considered that involve a sharing of credits when efficient sharing of activities results in sequestration of carbon.

REFERENCES

Brown, S., Lim, B., Schlamadinger, B., 1998. Evaluating approaches for estimating net emissions of carbon dioxide from forest harvesting and wood products. Meeting report, IPCC/OECD/IEA Programme on National Greenhouse Gas Inventories. Dakar, Senegal, May 5–7, 1998. Intergovernmental Panel on Climate Change, Geneva.

IPCC, 1996. Greenhouse gas inventory reference manual, vol. 3, revised 1996 IPCC Guidelines for National Greenhouse Gas

Inventories. In: Houghton, J.T., Meira Filho, L.G., Lim, B., Treanton, K., Mamaty, I., Bonduki, Y., Griggs, D.J., Callander, B.A. (Eds.), Intergovernmental Panel on Climate Change. Hadley Center Meteorological Office, Bracknell, UK.

IPCC, 2001. Climate Change 2001; Mitigation. In: Metz, B., Davidson, O., Swart, R., Pan, J. (Eds.), Contribution of Working Group III to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, p. 719.

IPCC, 2003. Good Practice Guidance for land use, land-use change and forestry. In: Penman, J., Gytarsky, M., Hiraishi, T., Krug, T., Kruger, D., Pipatti, R., Buendia, L., Miwa, K., Ngara, T., Tanabe, K., Wagner, F. (Eds.), IPCC National Greenhouse Gas Inventories Programme. Intergovernmental Panel on Climate Change, Hayama, Kanagawa, Japan.

Kirschbaum, M.U.F., 2003. Can trees buy time? An assessment of the role of vegetation sinks as part of the global carbon cycle. Climatic Change 58, 47–71.

Lim, B., Brown, S., Schlamadinger, B., 1999. Carbon accounting for forest harvesting and wood products: a review and evaluation of possible approaches. Environ. Sci. Policy 2, 207–216.

Marland, E., Marland, G., 2003. The treatment of long-lived, carbon-containing products in inventories of carbon dioxide emissions to the atmosphere. Environ. Sci. Policy 6, 139–152.

Marland, G., Fruit, K., Sedjo, R., 2001. Accounting for sequestered carbon: the question of permanence. Environ. Sci. Policy 4, 259–268.

Pingoud, K., 2004. Methods for estimating emissions and removals resulting from harvested wood products and their relation to approaches for accounting. Paper Presented at the UNFCCC Workshop on Harvested Wood Products. Lillehammer, Norway, August 30–September 1, 2004.

Row, C., Phelps, B., 1996. Wood carbon flows and storage after timber harvest. In: Sampson, Hair, (Eds.), Forests and Global Change, vol. 2, Forest Management Opportunities for Mitigating Carbon Emissions. American Forrests, Washington, DC.

Skog, K., 2004. Harvested wood products in the U.S. national greenhouse gas inventory: methodology and accounting. Paper Presented at the UNFCCC Workshop on Harvested Wood Products. Lillehammer, Norway, August 30–September 1, 2004.

UNFCCC, 2002. Report of the conference of the parties on is sevention session, held at Marrakesh from 29 October to 10 November 2001. United Nations Framework Convention on Climate Change, FCCC/CP/2001/13/ add.1, January 21, 2002.

UNFCCC, 2003. Estimation, reporting and accounting of harvested wood products. United Nations Framework Convention on Climate Change FCCC/TP/2003/7, October 27, 2003.

UNFCCC, 2004. Issues relating to harvested wood products: submissions from Parties. United Nations Framework Convention on Climate Change FCCC/SBSTA/2004/MISC.9, May 10, 2004.

Bruce Tonn conducts research in environmental and energy policy, sustainability, methods to support decision making, and futures studies. His training is in engineering and planning.

Gregg Marland has been analyzing greenhouse gas emissions and potential approaches for mitigating emissions since the 1970s. He was trained as a geochemist and has been involved in many studies of energy and environment. He has been a lead author on six IPCC reports, including the special report on land-use change and forestry and the report on methodologies for estimating greenhouse gas emissions.