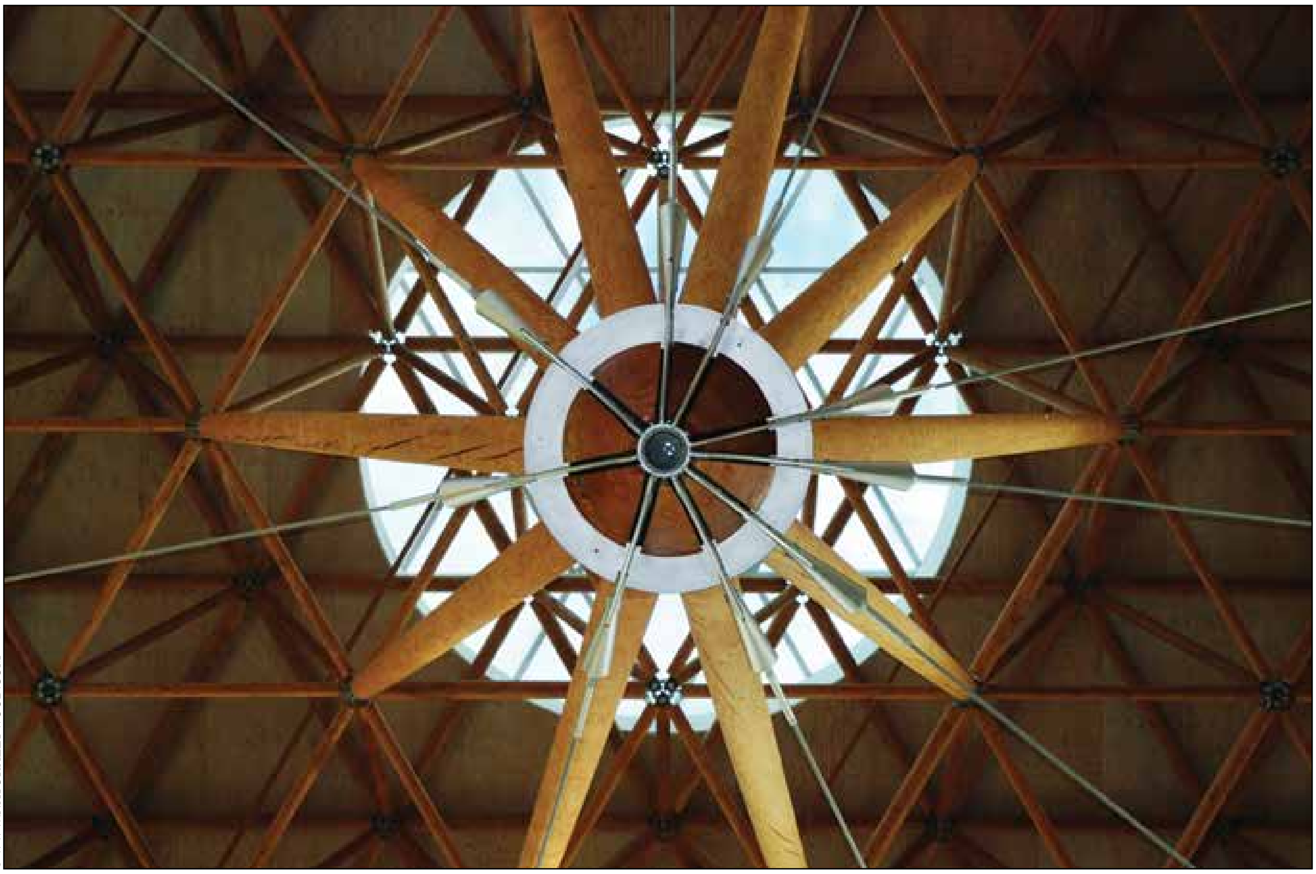

Climate change mitigation through forest sector activities: principles, potential and priorities[1]

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Applying three principles will help develop effective climate change mitigation strategies, including the role of harvested wood products and avoided emissions.

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Globally, forests remove from the atmosphere a significant fraction of the annual anthropogenic CO_2 emissions. It is of considerable scientific and policy interest to understand if, and how, it may be possible to enhance the contribution of the forest sector to climate change mitigation. Simplifying accounting assumptions or assumptions about carbon neutrality of biomass burning may not result in the best choices to improve management of forests, harvested wood products (HWPs), and landfills to achieve climate change mitigation objectives.

Drawing on research carried out in Canada, Sweden and Switzerland, this article looks into the importance of sustainable forest management, maintaining or enhancing carbon stocks, increasing carbon retention in long-lived HWPs, and the use of HWPs to maximize the displacement of emissions from other sectors. It identifies priorities for early action if changes in forest sector activities are expected to contribute to emission reduction targets.

[1] This article is a slightly revised version of the paper with the same title submitted to the XIV World Forestry Congress, held in Durban, South Africa, in September 2015.

Above: Modern engineering can help increase carbon retention in wood products and achieve significant avoided emissions through the substitution of emissions-intensive materials

INTRODUCTION, SCOPE AND MAIN OBJECTIVES

Between 2004 and 2013, global forests removed 10.6 ± 2.9 $GtCO_2$ yr^{-1} from the atmosphere or about 29 percent of the annual anthropogenic CO_2 emissions from fossil fuel burning, cement manufacturing, and deforestation (Global Carbon Project, Le Quéré *et al*., 2014). Combined with the CO_2 uptake by oceans, forests have helped to reduce the airborne fraction of the emitted CO_2 to 44 percent by removing the remaining 56 percent of emissions from the atmosphere. It is therefore of considerable scientific and policy interest to understand if, and how, it may be possible to sustain or enhance the contribution of the forest sector to climate change mitigation.

This interest in potential forest sector contributions to climate change mitigation is reflected in an increase in research and publications on the subject and in the attention the land sector received in the 2015 climate agreement that was reached in Paris. Here we emphasize three principles that should be maintained when conducting analyses of forest sector mitigation options and present results from national-scale analyses in Canada conducted to demonstrate these principles and to evaluate the climate change mitigation potential in Canada's forest sector.

METHODOLOGY/APPROACH

The three key principles of forest carbon accounting for mitigation are to: (1) quantify changes in the net greenhouse gas (GHG) balance that result from changes in human activities, relative to a baseline; (2) estimate emissions, when and where they occur and the type of GHG that is emitted; and (3) quantify changes in carbon stocks and GHG emissions in forest ecosystems, from HWPs, and from substitution of emissions-intensive products such as steel, concrete, plastics and fossil fuels with wood-based products (Lemprière *et al*., 2013). Simplifying accounting assumptions, such as instant oxidation of HWPs removed from the forest or transferred into landfills, or carbon neutrality of biomass burning, result in differences between reported and actual emissions, and may not result in the best choices to improve management of forests, HWPs and landfills to achieve climate change mitigation objectives.

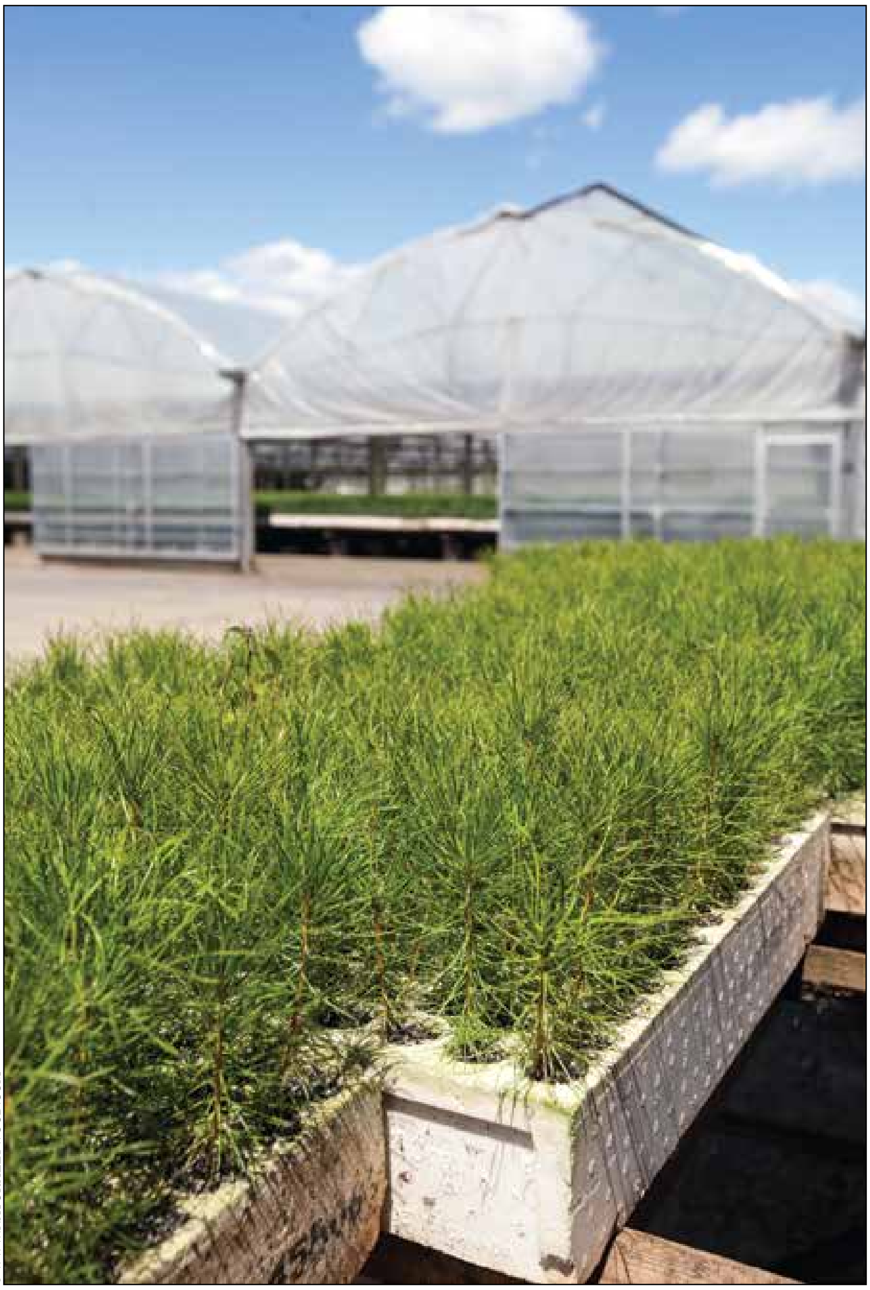
PRINCIPLE #1: BASELINES

Mitigation objectives are achieved when, through changes in human behaviour or technology, GHG emissions are reduced or GHG sinks are enhanced, relative to a baseline (Lemprière *et al*., 2013). The use

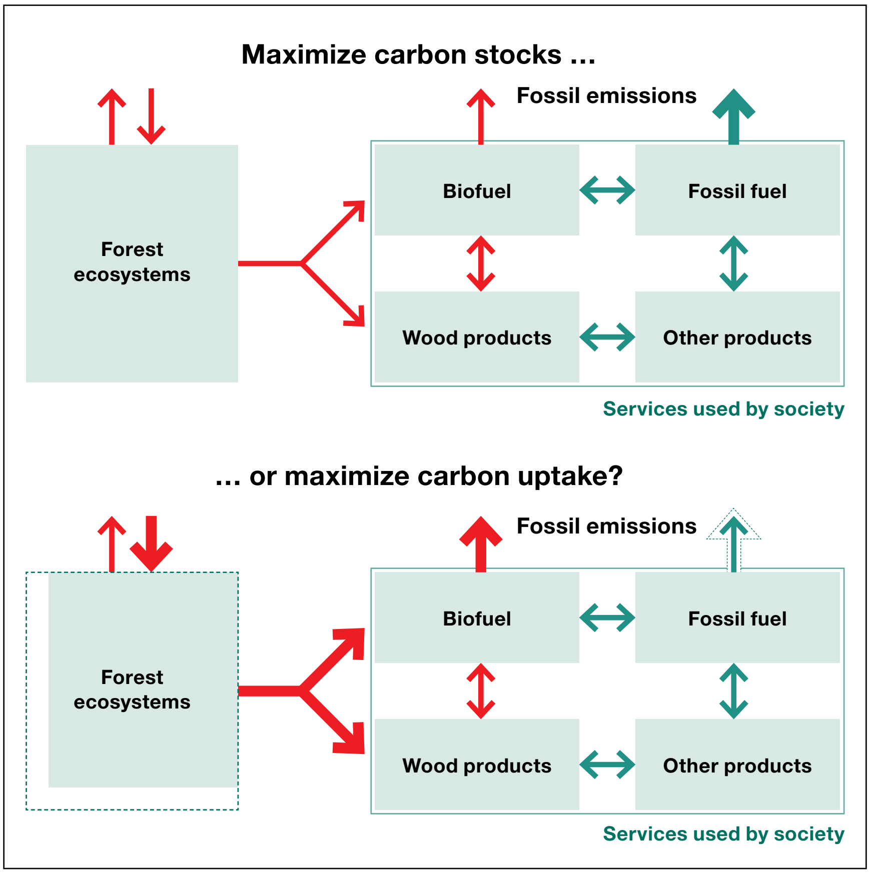
Sustainable management of the forest includes assisted migration of indigenous tree species to better match trees with future climates of a "business-as-usual" baseline removes the effects of age–class legacies in forests (Böttcher *et al*., 2008; Kurz, 2010), and ensures that estimated mitigation benefits are the result of changes in behaviour and not merely the result of ecosystem processes that would have occurred in any case. Baselines are essential in analysis of mitigation to ensure that existing forest carbon sinks are not incorrectly claimed as resulting from climate change mitigation efforts.

PRINCIPLE #2: ESTIMATE EMISSIONS, WHEN AND WHERE THEY OCCUR AND BY TYPE OF GHG

Mitigation actions have different time lines regarding GHG costs and benefits (Nabuurs *et al*., 2007). The simplifying accounting assumptions that have been introduced to facilitate GHG estimation and life-cycle analyses can result in policies that will not benefit atmospheric mitigation goals. For example, the revised 1996 Guidelines of the Intergovernmental Panel on Climate Change (IPCC, 1997) made a simplifying assumption that new carbon additions to HWPs merely replace a similar amount of carbon losses from existing HWP pools and that, therefore, all transfers of carbon from forest ecosystems can be considered as instantaneously oxidized to the atmosphere. This simplification resulted in an incorrect perception of the impacts of forest management on GHG balances and, more importantly, removed incentives to prolong carbon retention in HWPs. Similarly, life-cycle analyses of bioenergy or forest products have sometimes employed a simplifying assumption that all carbon obtained from the forest is carbon neutral, i.e., has no impact on changes in forest ecosystem carbon stocks. This assumption can also lead to incorrect policy conclusions that may not result in the most effective mitigation strategies, because it fails to recognize the impacts of wood harvests on ecosystem carbon stocks, and fails to make clear that the choice of biomass feedstock for bioenergy can have a significant influence on the magnitude and timing of mitigation impacts. Under the internationally agreed rules of the "production approach" used for the reporting of emissions from HWPs, the emissions from biomass used for energy are reported by the country that harvests the biomass. If the biomass is exported and used for energy, then the biomass-importing country can claim that the imported biomass is carbon neutral. So while globally the total emissions are fully reported, this accounting could lead to policy decisions that do not result in the most effective climate change mitigation strategies.



Sustainable management of the forest includes taking advantage of tree improvement programmes to increase sequestration



1
Conceptual model of alternative approaches to managing forest sector carbon stocks and flows. The evaluation of a mitigation strategy should be based on an assessment of net emissions to the atmosphere associated with changes in forest ecosystems, HWPs and substitution effects associated with the use of wood products. Conservation-focused approaches increase forest ecosystem carbon stocks but reduce carbon storage in HWPs and reduce HWPs available to substitute other products (top panel). Wood-use focused approaches can reduce forest ecosystem carbon stocks (relative to conservation-based approaches) but manage forests for higher carbon uptake rates, increased production of HWPs, and larger substitution benefits. (Figure modified from Nabuurs et al.*, 2007.)*

PRINCIPLE #3: ESTIMATE GHG EMISSIONS IN FORESTS, HWPs AND THE AVOIDED EMISSIONS (SUBSTITUTION) THROUGH THE USE OF HWPs

Analyses of mitigation options should be based on an integrated systems approach that considers carbon and GHG effects in three components: forest ecosystems; HWPs; and other sectors, as a result of the atmospheric effects of substitution of emissions-intensive products such as concrete, steel, plastics (Sathre and O'Connor, 2010) or fossil fuels (Ter-Mikaelian *et al.*, 2015) (Figure 1). The assessment of substitution effects should include the emissions associated with the manufacture and transport of both the HWPs and the products they substitute. Mitigation efforts aimed at increasing carbon in one of the three components usually result in decreases in carbon in one or both of the other two components. For example, conservation measures aimed at reducing harvest rates may result in increased forest ecosystem carbon stocks, but at the expense of carbon in HWP or substitution benefits and associated higher emissions from fossil fuels and cement (Figure 1, top panel). Conversely, increasing harvest rates to generate more forest products will decrease forest ecosystem carbon stocks but increase carbon in HWPs and, depending on their use, can lead to increased substitution benefits (Figure 1, bottom panel).

RESULTS

The potential forest sector contributions to climate change mitigation have been assessed in recent national-scale studies. The three principles outlined above have been implemented in studies for Canada, Sweden and Switzerland (Lundmark *et al.*, 2014; Smyth *et al.*, 2014; Werner *et al.*, 2010). All three studies demonstrate that in the long term, the greatest global mitigation benefits are achieved through substitution effects, and that these are higher than the impacts on stock changes under sustainable forest management.

Here we summarize the use of Canada's National Forest Carbon Monitoring, Accounting and Reporting System (Kurz and Apps, 2006) and associated models (Kurz *et al.*, 2009) to estimate the mitigation potential in Canada's forest sector to 2050 (Smyth *et al.*, 2014). Seven scenarios of changes in forest management and two scenarios of changes in wood use were implemented starting in 2015, compared to a baseline of no mitigation activity.

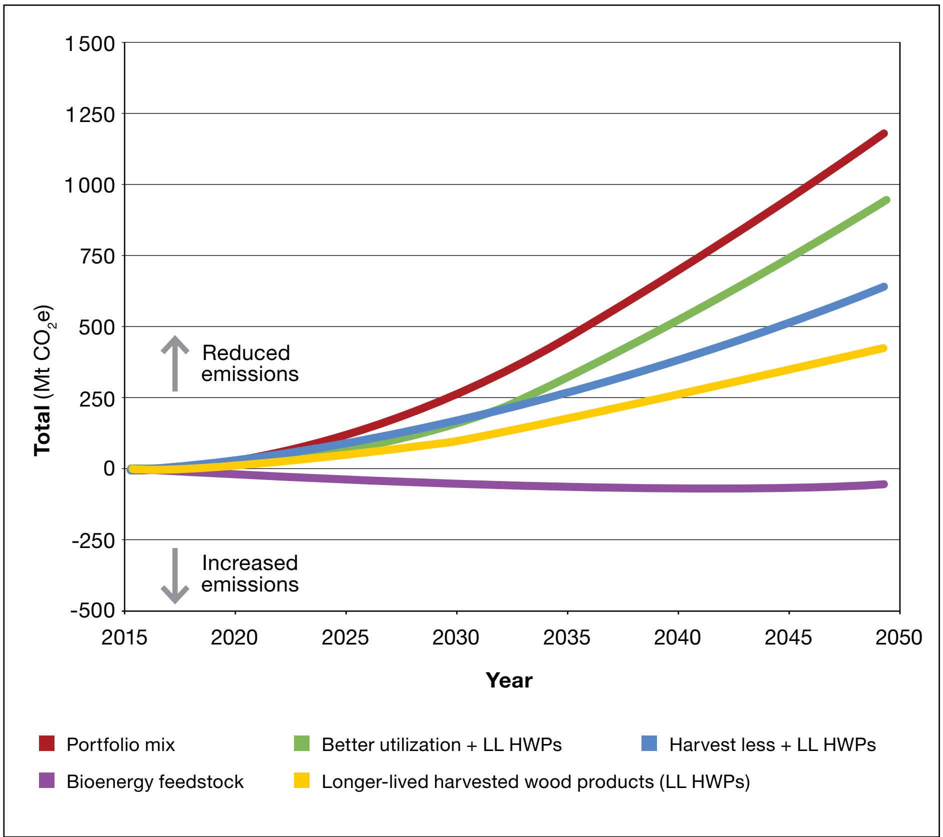
The results show that cumulative mitigation benefits increase over time, with relatively small benefits in the near term (to 2020) but increasingly larger benefits by 2030 and 2050 (Figure 2). Relative to the baseline management of HWPs, a small shift from pulp and paper products towards increased production of long-lived products yielded cumulative mitigation benefits by 2050 of 435 MtCO_2e, while shifting HWP use towards bioenergy increased overall emissions. Combining a "harvest less" forest management scenario with the increased long-lived HWP scenario yielded cumulative mitigation benefits of 600 MtCO_2e. The "better utilization" forest management scenario combined with increased long-lived HWPs yielded 944 MtCO_2e cumulative mitigation benefits. Creating a portfolio mix by combining regionally differentiated mitigation strategies across Canada yielded cumulative mitigation benefits by 2050 of 1 178 MtCO_2e. Preliminary estimates of abatement costs indicate that these large mitigation benefits are also cost-effective compared to mitigation options in other sectors. The analyses also demonstrate that the sooner the mitigation activities are implemented, the larger the mitigation benefits will be in the mid term (2030) and long term (2050).

DISCUSSION

The results of studies in Canada, Sweden and Switzerland all demonstrate that the national forest sector can make meaningful contributions to climate change mitigation efforts, and that these are derived to a large extent through the use of HWPs to achieve emissions reductions in other sectors. The studies also showed that conservation strategies aimed at increasing forest ecosystem carbon stocks did not achieve the largest possible mitigation benefits. In the Canadian study, the assumptions about changes in forest management and changes in HWP use were conservative and informed by the views of provincial resource management experts on the feasibility of implementation of the mitigation strategies.

The results also show that the mitigation benefits increase over time and that the forest sector's potential to contribute to short-term GHG emission reduction goals (2020) is limited. This conclusion is specific to the countries examined because their emissions from deforestation (conversion of forest to non-forest land uses) are small. In countries with high deforestation rates, emission reductions in the short term (2020) can be achieved through strategies aimed at reducing emissions from deforestation and degradation (REDD+).

For countries such as Canada and Sweden, which export much of their HWPs, some of the climate change mitigation benefits of the HWP use strategies are achieved outside the country, as exported HWPs are used to substitute for more emissions-intensive products abroad. Under current carbon accounting rules, the mitigation benefit resulting from substitution abroad does not contribute to the domestic GHG emission reduction targets of the wood-exporting country, and in fact it may adversely affect domestic emissions because reduction in forest carbon stocks (where these occur), and



2
Cumulative mitigation benefits to 2050 of five forest sector mitigation strategies in Canada. Two strategies explore the mitigation benefits (relative to the baseline) of shifting more wood towards longer-lived harvested wood products (LL HWPs) or towards bioenergy feedstock. Two strategies compare changes in forest management (better utilization, increased conservation by harvesting less), each combined with the LL HWP strategy. The mitigation benefits are shown if each of these strategies is implemented across Canada. A final strategy (portfolio mix) is based on choosing the best strategy in each region (Smyth* et al., *2014).

emissions associated with HWP manufacturing, transport and export are counted in the country where they occur. However, the use of long-lived HWPs to substitute for emissions-intensive products such as concrete, steel and plastics does contribute to global reductions in atmospheric CO_2 concentrations and thus serves climate change mitigation objectives.

The harvest of live trees for the production and export of pellets for bioenergy is a special case with strong negative impacts on the GHG balance of the exporting country, which has to account for carbon stock reductions in the forest and the immediate oxidation of the exported biomass carbon, while the importing country that uses these pellets rarely, if ever, achieves a net reduction in actual emissions because fossil fuels are more energy-intensive than biomass. The reduction in reported national emissions associated with the use of imported biomass for energy production therefore is achieved because the biogenic emissions are reported by the exporting country.

Lastly, mitigation benefits in the forest sector do not depend on forest management alone: mitigation benefits can be increased through coordination with the users of wood products to reduce wood waste, increase the use of long-lived HWPs, and maximize the displacement benefits through substitution of emissions-intensive building products. This suggests that building codes (e.g. increasing the number of storeys permissible in wooden buildings), planners (e.g. "Wood First" building strategy), architects, builders, and home buyers can all contribute to achieving mitigation benefits in the forest sector.

CONCLUSIONS

Analyses that apply sound forest carbon accounting principles to quantify the potential of the forest sector to contribute to climate change mitigation in Canada demonstrate the importance of sustainable forest management, maintaining or enhancing carbon stocks, increasing carbon retention in long-lived HWPs, and the use of HWPs to maximize the displacement of emissions from other sectors. The analyses also identify priorities for early actions if changes in forest sector activities are expected to contribute to near-term emission reduction targets.

Construction of the Wood Innovation Design Centre in Prince George, Canada, the tallest contemporary wood building in North America, standing at 29.5 metres high. Increased use of wood in non-traditional buildings holds great potential for avoiding emissions through less use of materials like steel and concrete that are more emissions-intensive on a life-cycle basis

The results of this and other national-scale analyses that follow the three principles outlined above support the conclusion of the IPCC Working Group III Forestry chapter on climate change mitigation options that: "In the long term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fibre or energy from the forest, will generate the largest sustained mitigation benefit" (Nabuurs *et al*., 2007).

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