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24/04/2017

THE SUBSTITUTION EFFECT

Compared to fossil based products, harvested wood products (HWPs) have a low carbon footprint [1]. And if the choice to use wood results in the displacement of more emission-intensive materials or energy sources, a net reduction of greenhouse gas (GHG) emissions can occur [2]. This is known as the substitution effect. For the forest sector, using HWPs to substitute for other materials is recognized globally as a critical component of climate change mitigation strategies and it has the potential to generate a large and sustained climate benefit [3]. It is therefore important to consider the impacts of the substitution effect when developing strategies that aim to reduce carbon emissions.

There are two types of substitution effects: material substitution and energy substitution.

MATERIAL SUBSTITUTION

Material substitution occurs when the use of wood products displaces products/materials that are more emission-intensive, such as concrete or steel. The size of the mitigation impact depends on the end-use of the substituted wood.

Wood used for the construction of buildings, especially multi-use buildings (e.g. office buildings), have the highest level of avoided emissions for all solid wood products when substituting steel and concrete. This is mostly due to the amount of material being displaced and the emission-intensity of steel and concrete [4]. For example, manufacturing one tonne of cement releases approximately one tonne of carbon dioxide (CO_2) to the atmosphere [5], whereas when used in building construction, every one tonne of carbon contained in sawnwood displaces 2.1 tonnes of carbon, and every one tonne of carbon contained in solid wood panels displaces 2.2 tonnes of carbon [6]. Wood used in buildings also has the added mitigation benefit of prolonging the time that carbon remains stored in the wood product. Since B.C. amended the Building Code to allow wood-use for mid-rise residential construction in 2009, 145 five or six storey wood buildings have been completed [12]. Those buildings store 103,000 tonnes of CO_{2e} and have avoided approximately 92,000 tonnes of CO_{2e} that would have been emitted had they been made from steel and concrete instead.

While material substitution has the potential to provide great mitigation benefits, those benefits do not occur in the forest sector. Instead the avoided GHG emissions occur during the production or transportation of the material that the wood is replacing, so it is the industrial or transport sectors that report the reduction of emissions [4]. This makes the accurate determination of the mitigation benefits of material substitution more complicated.

ENERGY SUBSTITUTION

Energy substitution occurs when wood products are used to produce bioenergy, displacing other fuel sources. The largest mitigation benefits from bioenergy occur when biofuel is collected from harvest residues (i.e. biomass left over from forest harvesting, such as tops and branches), and when bioenergy is displacing high-emitting fossil fuels, such as coal [2]. Displacing coal in particular provides greater climate benefits than displacing natural gas or oil because of coal's high emissions intensity [1].

However, the climate change mitigation benefits of bioenergy vary greatly between regions and therefore it is not an effective mitigation strategy for every situation. Its potential varies greatly due to differences in the energy sources that would be substituted, the demand for energy, the availability of harvest residues, transportation distances, and the efficiency of the bioenergy conversion [6]. For example, using harvest residues for bioenergy can have an immediate mitigation benefit in regions where it is common to use slash-burning as a way to reduce wildfire risks and increase the area available for planting. Without such bioenergy production, that biomass would have been burned and carbon would have been released without the added benefit of displacing fossil fuel emissions [8]. Other potentially effective sources of biofuel include wood fibre that occur as by-products from wood product processing and HWPs that have reached the end of their life and are being disposed [7, 9]. On the other hand, in regions connected to the power grid that use largely hydroelectricity, a bioenergy strategy would not be effective. Harvesting live trees for bioenergy is not considered to be effective from a mitigation perspective either, although there may be opportunities in some remote locations or where fast growing trees have been planted as energy crop [10, 13].

The transition from fossil fuels to bioenergy will often feature a "break-even" point. Since bioenergy is less energy intensive than fossil fuels, using bioenergy will initially result in a net increase in emissions. As residues are removed for bioenergy, emissions from decay will be reduced which, combined with the emission benefits of using bioenergy, will result in a switch to a net emission decrease. When comparing bioenergy and fossil fuel alternatives, the time to reaching the break-even point defines when the two alternatives have similar net emissions. After that point, bioenergy based alternatives contribute to net reductions of atmospheric carbon. This too is a regionally-specific factor. The shorter the delay, the more effective bioenergy is as a mitigation strategy [7].

The effectiveness of bioenergy also depends on the efficiency of technologies used for energy conversion [7]. Bioenergy is more efficient in the production of heat rather than electricity, thus greater mitigation benefits result from substituting bioenergy for heat or combined heat and power technologies than for producing power alone [8].

SUBSTITUTION WITHIN CLIMATE CHANGE MITIGATION STRATEGIES

HWPs can provide climate change mitigation benefits due to their ability to replace other, more emission-intensive materials and energy sources. While the benefits that result from the carbon stored in forest ecosystems and HWPs can be limited and temporary, as stored carbon will eventually be released back into the atmosphere (although storage in soils can last for centuries), the benefits from choosing to use wood products over fossil fuels are permanent because it restricts the amount of carbon that enters the atmosphere

[7]. Burning fossil fuels releases carbon that has been stored for millions of years. In contrast, some of the carbon released from burning wood can be offset by the regeneration of a newly planted tree, resulting in an inherent, and more immediate two-way flow of carbon into and out of the atmosphere. Therefore, choosing to avoid fossil fuel emissions is a benefit that is permanent, cumulative, and independent of the wood product's lifespan [11]. The substitution effect can also result in a reduction of GHG emissions outside of Canada's borders when wood exports are used abroad to replace materials or energy sources that are more emission-intensive [9].

The benefits of substitution extend beyond the forest sector. It is important that mitigation strategies are designed with a systems perspective to take full advantage of the multi-sector benefits. For the forest sector, climate change mitigation strategies that consider the substitution effect are able to maximize their effectiveness at delivering net reductions in GHG emissions.

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