Evaluating options for managing British Columbia's forest sector to mitigate climate change

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This report has been produced as part of research being carried out by the PICS Forest Carbon Management Project.

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1. EXECUTIVE SUMMARY

Forests play an important role in regulating climate. Changes in how forests and harvested wood products are managed can also offer substantial opportunities to mitigate climate change by reducing greenhouse gases (GHG) emissions or increasing carbon removals from the atmosphere[1-3].

To evaluate the credibility and public acceptability of such forest carbon management alternatives, a British Columbia-wide engagement process is being carried out with stakeholders, First Nations and the general public. The goal of this engagement is to identify the broad objectives that should underpin the province's future forest carbon management strategies, and to seek input on the options presented.

This initiative is part of the Forest Carbon Management Project supported by the Pacific Institute for Climate Solutions (PICS) that aims to generate recommendations for regionally specific climate change mitigation activities for BC's forest sector, while maximising the environmental, economic and social benefits for British Columbians.

This document brings together the results from a first round of consultation with stakeholders and First Nations across British Columbia (BC), as well as the separate modelling results of different BC forest and harvested wood product management strategies. The analyses conducted thus far demonstrate that several of the potential mitigation activities in the forest sector can make a substantial contribution to BC's legislated greenhouse gas (GHG) emission reduction targets, with co-benefits for employment and other indicators.

The document does not rank alternatives, nor does it recommend any course of action. Instead its purpose is to explain and depict the potential climate mitigation and socioeconomic impacts of various management approaches. This document also highlights other key considerations, such as impacts on culture, biodiversity, and ecosystem services, as identified in the first consultation round.

The main objective of this report is to inform the next round of workshops that will be carried out during the summer of 2017. During these workshops, participants will be asked to share their relative preference for, and perceived acceptability, credibility and effectiveness of, mitigation alternatives for BC's forests and forest sector.

Comments and feedback to this report would be welcome and can be provided to: picsra@uvic.ca

2. HOW FORESTS CAN CONTRIBUTE TO CLIMATE CHANGE MITIGATION

Climate change driven by human activities is one of the leading environmental threats of the 21st century. It is caused by the increased concentration of greenhouse gases (GHGs) in the atmosphere, mainly due to the global burning of fossil fuels. Land-use change, for example permanently removing forest and using the land for agriculture or urban development (also known as deforestation), has a lesser but nevertheless important role in producing GHGs. Globally, forests remove from the atmosphere about 30% of the carbon emitted from the burning of fossil fuels.

A forest is considered a "carbon source" when it emits more carbon than it removes from the atmosphere, whereas it is considered a "carbon sink" when it removes more than it emits[4]. Forest ecosystems and products made from wood comprise various carbon pools, which are reservoirs that store, capture or release carbon. We can reduce future atmospheric GHG concentrations through strategies that reduce emissions or increase GHG removals from the atmosphere. Activities that reduce emissions or increase removals compared to business-as-usual or "baseline" levels are considered climate change mitigation actions.

The Canadian province of BC has ambitious legislated targets to reduce its GHG emissions by 33% by 2020 and 80% by 2050 compared to the 2007 level. In 2016 the government stated in its Climate Leadership Plan that forestry offers "significant opportunities to take action against climate change"[5].

Net carbon flow in the forest sector varies considerably from year to year, largely as a result of variations in the damage caused by natural disturbances like forest fires and insect infestations. BC forests, including the emissions from harvested wood products, were a sink between 1990 and 2002, but became a net carbon source in 2003 and have emitted more than they sequestered since then. This shift from sink to source is mainly due the large amount of trees killed by the mountain pine beetle outbreak and an increase in wildfires. Wildfires release carbon and other GHG immediately and kill trees, while the mountain pine beetle kills trees. Disturbances thus reduce carbon sequestration in the short term while increasing decay[6]. During the period 2009 to 2014, the average net emissions from forests and harvested wood products were 29 million tonnes of CO_2 equivalent ($MtCO_2e$), equal to almost half of BC's total GHG emissions[7].

Changes in how forests and harvested wood products are managed to reduce GHG emissions and increase removals are globally acknowledged as valuable mitigation strategies[1-3, 8] that can also offer additional benefits such as employment, biodiversity and water conservation. It is also important to consider mitigation opportunities from increasing the carbon stored in wood products [2, 9] and increasing substitution of wood products for other products and fossil fuels whose production and use cause more GHG emissions on a life-cycle basis[10].

The way we manage our forests, the types of wood products we produce and how we use and ultimately dispose of those products, can greatly influence the carbon balance of our forest sector.

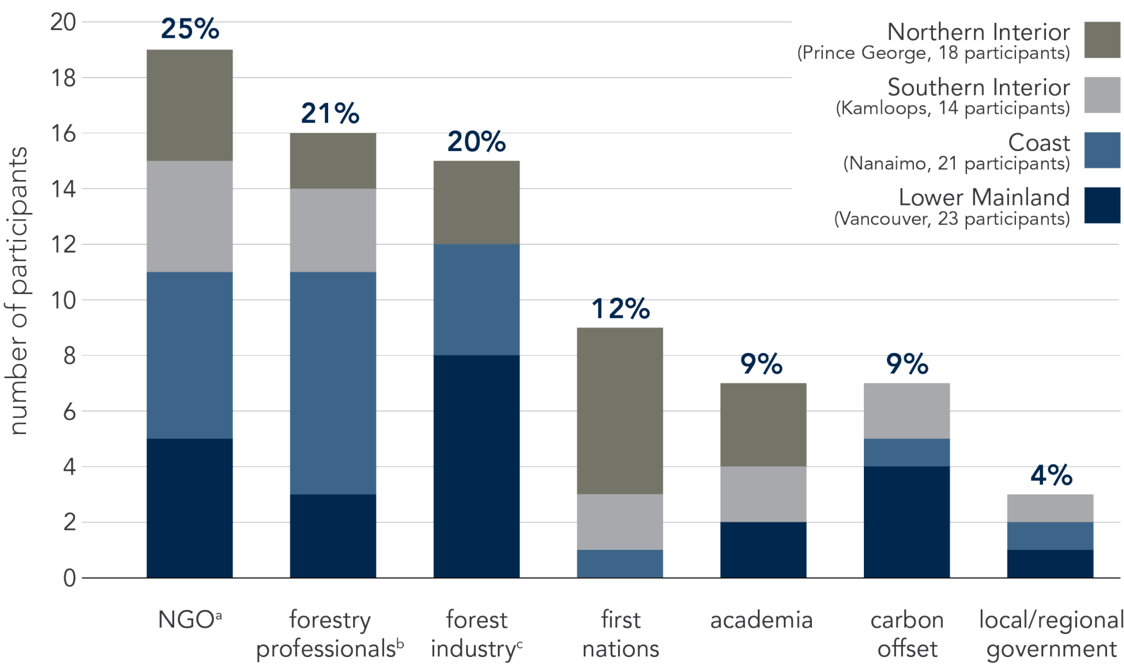
3. PROJECT OVERVIEW: ENGAGEMENT PROCESS

The objective of the province-wide engagement process is to allow stakeholders, First Nations and the general public to provide their relative preference for, and perceived acceptability, credibility and effectiveness of, mitigation alternatives for BC's forests and forest sector. This engagement process is part of the Forest Carbon Management Project supported financially by PICS; it is not a consultation by Government. While the outcomes will inform the ongoing research, results may or may not be taken into consideration by any government agencies. The engagement process is separated into three phases. The two first phases were conducted independently and by different researchers. The third phase is ongoing.

Phase 1 aimed at identifying important objectives to be considered when generating and evaluating climate change mitigation strategies in BC's forest sector. To do so, five 3.5 hour workshops hosted by researchers from the University of British Columbia (UBC) were held between February and March 2016 in four different regions of the province: Lower Mainland (2 workshops, Vancouver), Southern Interior (Kamloops), Northern Interior (Prince George), and the Coast (Nanaimo). A total of 76 participants from different sectors and First Nations organizations with interest in, and knowledge of, BC's forest sector participated in the workshops. The resulting aggregated list of objectives can be found in section 4 of this document.

Participant Representation during Phase 1 Workshops

Representation by region of different groups of actors during Phase 1 workshops, in number of participants. Percent of total for each group is also shown.



[a] includes environmental (15), tourism (2) and development (2) NGOs
[b] includes consultants (12) and community forest representatives (4)
[c] includes large forest companies

Phase 2 involved a group of experts affiliated with UBC and Natural Resources Canada collaborating on the development of six climate change mitigation alternatives in BC's forest sector. These alternative management strategies, while all incorporating forest carbon mitigation, focus on different underlying approaches, such as conservation, management intensification or the use of wood products. The economic and socioeconomic impacts of the strategies were then evaluated with complex modelling methodologies. The methodologies used for the modelling are detailed in Appendix 1 and in the scientific publications from this project and related research, the alternatives evaluated are described in section 5 and the results from the modelling are summarized in section 6.

Phase 3 aims to bring together the results of the previous phases by allowing stakeholders, First Nations and the general public to provide feedback and evaluate the mitigation alternatives identified during *Phase 2*. One day-long workshops will be held during summer 2017 in each of the four regions previously visited during *Phase 1*. This document has been prepared to inform these workshops. The evaluation will be weighed against the objectives identified during *Phase 1*.

To complement the results from the workshops, an online survey was also distributed to the general public in February 2017 to evaluate the level of support in the BC general population for the implementation of possible forest carbon mitigation strategies in BC's forests. The results of this survey are being analysed and will be available in late summer 2017.

4. PHASE 1: KEY OBJECTIVES FOR EVALUATING FOREST SECTOR CARBON MITIGATION STRATEGIES

4.1. Objectives identified during Phase 1 workshops

As discussed above, the goal of the workshops carried out between February and March 2016 was to identify the main objectives that stakeholders and First Nations believe should be considered when evaluating climate change mitigation strategies in BC's forest sector. Over 30 objectives were identified, and an aggregated list of 12 objectives and their sub-objectives was generated based on the results of the workshops.

MAINTAIN ECOSYSTEM SERVICES.

· maintain water quality and quantity
· maintain air quality
· maintain soil quality
· maintain recreational, cultural and spiritual opportunities

INCREASE CLIMATE CHANGE ADAPTATION AND FOREST RESILIENCE.

Increase the natural capacity of BC's forests to:
· adapt to climate change
· respond to climate change perturbations by resisting damage and recovering quickly

ENSURE EVIDENCE-BASED DECISION MAKING.

Ensure that future forest carbon mitigation strategies make use of:
· the best available science
· First Nations traditional knowledge

MAXIMIZE THE CLIMATE CHANGE MITIGATION POTENTIAL OF THE FORESTS AND FOREST SECTOR.

· maximize carbon sequestration from BC forests and forest sector
· minimize greenhouse gases emissions from BC forests and forest sector

MAINTAIN EXISTING BIODIVERSITY.

· ensure biodiversity conservation
· ensure the protection of natural old growth forests

INCREASE RESILIENCE OF LOCAL COMMUNITIES.

· increase sustainable economic opportunities
· increase local government revenues
· increase local participation in decision-making

RECOGNIZE FIRST NATIONS RIGHTS AND CLAIMS TO FOREST LANDS.

· recognize First Nations existing titles and claims
· respect First Nations rights
· ensure inclusion of First Nations in decision-making

INCREASE ECONOMIC OPPORTUNITIES FOR FIRST NATIONS.

· increase generated revenues
· increase employment
· increase professional development

ENSURE SOCIAL LICENSE AND POLITICAL FEASIBILITY.

Ensure that future forest carbon mitigation strategies make use of:
· ensuring participation and public sense of ownership
· promoting public awareness
· maximizing administrative flexibility, adaptability and feasibility

INCREASE PROVINCIAL NET ECONOMIC BENEFITS OF FOREST-RELATED MITIGATION.

· increase industry competitiveness
· maximize efficiency of resource use
· increase the production of value-added products (e.g., long-lived wood products)

INCREASE PROVINCIAL SOCIOECONOMIC BENEFITS.

· maximize direct employment from the forests and forest sector
· maximize indirect employment from the forests and forest sector

MINIMIZE THE NEGATIVE IMPACTS ON LOCAL FOOD SECURITY.

· minimize the negative impacts on local food security, defined as the reliable access to a sufficient quantity of locally-produced food

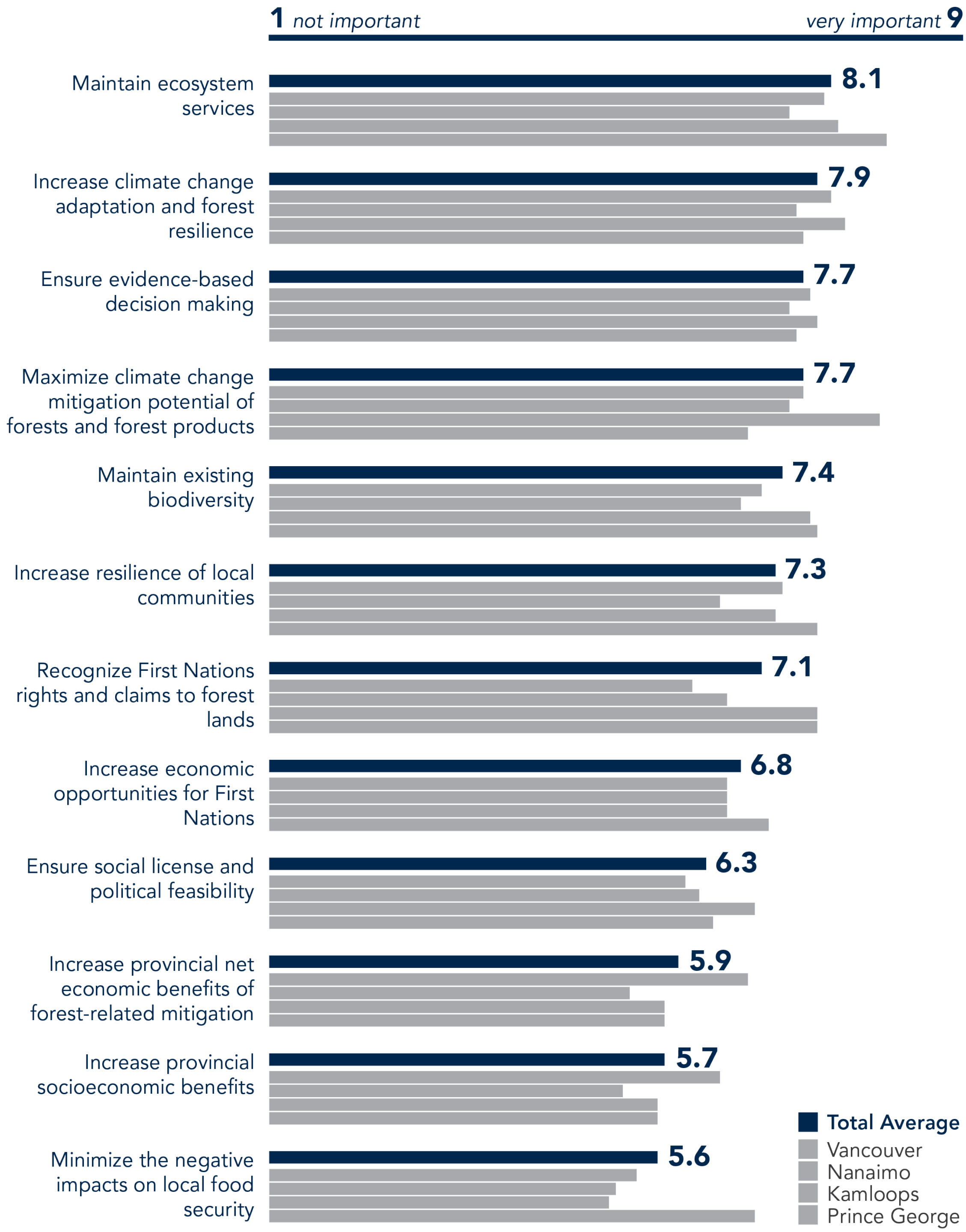
4.2. Ranking of identified objectives

Following the workshops, participants were invited to participate in a follow-up survey. A total of 52 out of 76 participants responded to the survey (68% response rate). Notably, participants were asked to weight the relative importance of the objectives by answering the question: *"Based on your preferences, how important are each of the following 12 objectives in developing new forest management strategies for climate change mitigation in BC?"* An average of this valuation is presented in the following figure.

Respondents were also asked to describe their overall level of agreement with the aggregated list of objectives. A majority of respondents (84%) either "agreed" or "strongly agreed" with the list of objectives identified during the workshops. Because of this level of agreement, no modification was made to the list.

Survey Results

Average score on the relative importance of each objective



5. PHASE 2: ALTERNATIVE STRATEGIES FOR CLIMATE CHANGE MITIGATION IN BC'S FOREST SECTOR

This document describes six mitigation alternatives. Five of the strategies affect the management of forest ecosystems, the sixth deals with the use of wood and its allocation to short- and long-lived product types. The harvested wood product strategy can be combined with any of the other five ecosystem management scenarios. It is important to note that the alternatives being examined in this study are not the full suite of mitigation alternatives, and some options, such as those related to silviculture, reduced deforestation (i.e., reducing the permanent conversion of forest to non-forest uses) or afforestation of non-forest lands are not included, but have been discussed elsewhere[9].

The figures on subsequent pages show generic representations of GHG emissions and carbon removals from the atmosphere. Arrows pointing upward refer to GHG emissions, including carbon dioxide (CO_2) and other GHGs such as methane (CH4) and nitrous oxide (N2O), which are produced for instance during the combustion of wood and fossil fuels. In contrast, arrows pointing downward refer to removals of CO_2 from the atmosphere, for example by creating more forests that absorb more of the gas as they grow.

5.1. Higher Utilization strategy

A *Higher Utilization* strategy consist of two concurrent activities:

(i) *higher utilization of wood from harvest cut blocks so that more wood is extracted per hectare, thereby lowering the area harvested while keeping the harvest volume unchanged.*

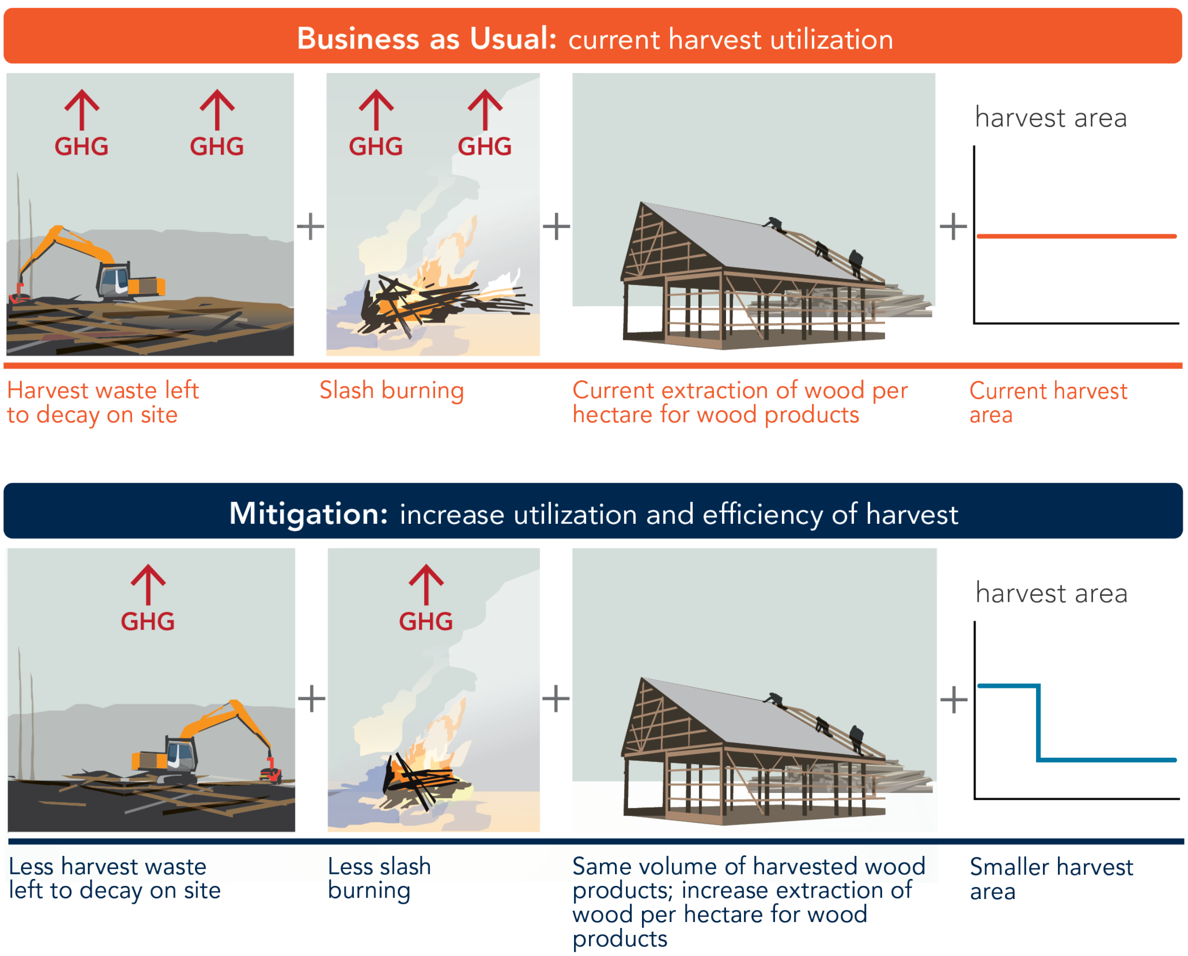
(ii) *increased proportion of salvage harvesting following natural disturbances to replace green tree harvesting.*

Higher utilization of wood from harvest cut blocks

Currently, harvesting residues are mainly left to decay or to be burned on site. Possibilities exist to increase the utilization of wood from harvest cut blocks – i.e. remove more of the wood on each hectare harvested. This strategy will reduce the amount of harvesting residues left to decay or to be burned on site and will reduce the area harvested while maintaining harvest volume.

Higher Utilization in Managed Forests

Higher utilization of wood from harvest cut blocks



Changes in the modelling parameters and assumptions to represent this strategy:

2017-2020: utilization rate increased from 85% to 86.5% of merchantable volume at harvest cut blocks

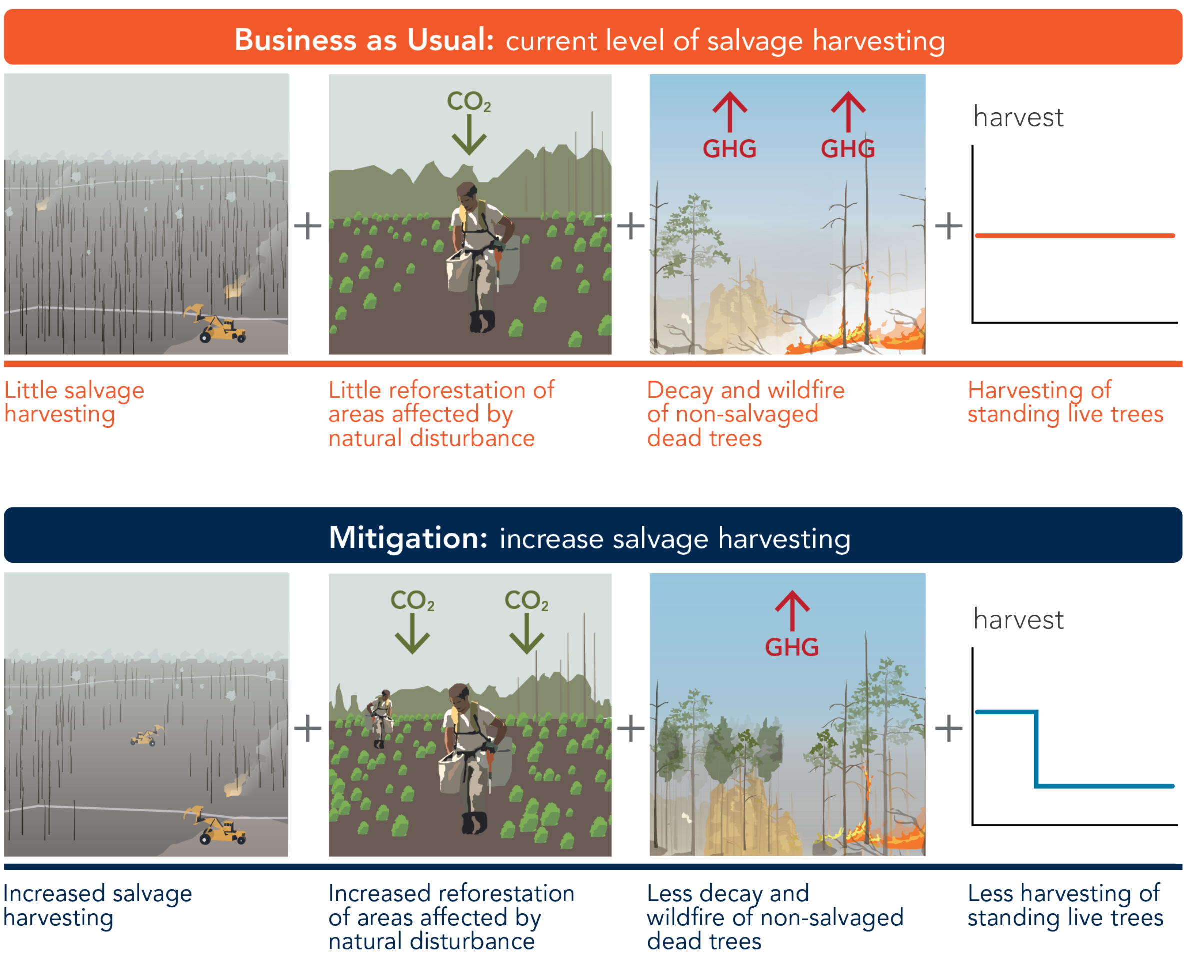
2021-2050: utilization rate increased from 86.5% to 90% of merchantable volume at harvest cut blocks

Increased proportion of salvage harvesting

Salvage harvesting refers to the harvesting of trees in forests affected by natural disturbances such as fire and insects. When natural disturbances kill trees, the risk of forest fire is increased and emissions associated with decay on site rise. In such cases, salvage logging can reduce risks of wildfire. Furthermore, harvesting trees already killed because of natural disturbances means that harvesting of live trees can be reduced. Live trees can continue to remove carbon from the atmosphere and dead trees that would otherwise decay in the forest over time will instead be used for wood products.

Salvage Harvesting

Increased proportion of salvage harvesting following natural disturbances



Changes in the modelling parameters and assumptions to represent this strategy:

2017-2020: increase the proportion of volume harvested from snags from 6% to 7%

2021-2050: increase the proportion of volume harvested from snags from 7% to 10%

5.2. Harvest Less strategy

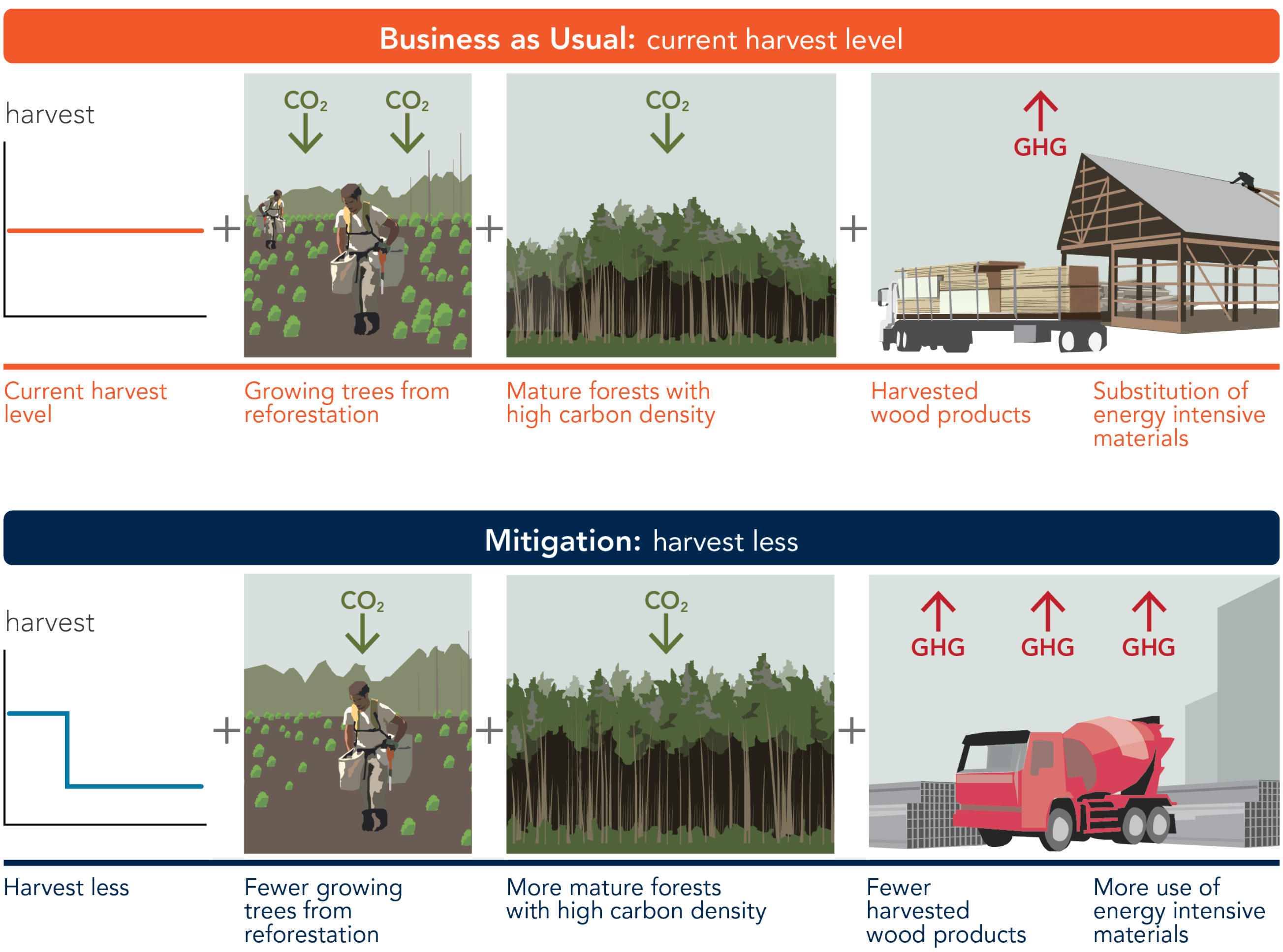
A *Harvest Less* strategy consists of one main activity:

(i) A reduction in harvest with a corresponding decrease in production of wood products.

Reducing harvest volume should result in forested landscapes with higher carbon density (i.e. tons of carbon per hectare). However, this also means that there will be less carbon sequestration from regenerating forest and the production of wood products will decrease, leading to greater use of more emissions-intensive material in place of wood. Therefore, a reduction in timber harvesting generates trade-offs between increasing carbon storage in forest ecosystems or in wood products.

Harvest Less in Managed Forests

Reduced harvest with corresponding decrease in production of wood products



Changes in the modelling parameters and assumptions to represent this strategy:

Reduce annual harvest volumes by 2% from 2017 to 2050

5.3. Harvest Residue for Bioenergy strategy

A *Bioenergy strategy* consists of two concurrent activities:

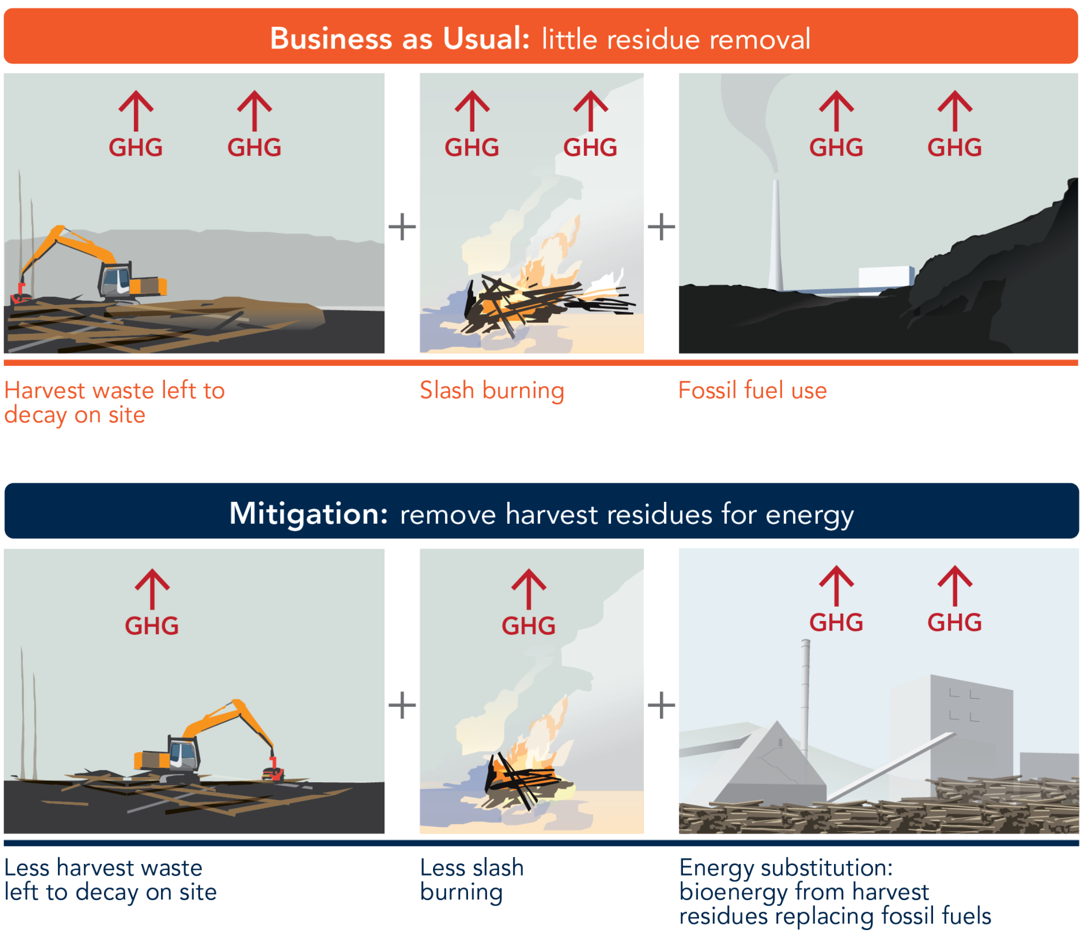
(i) *A recovery of a portion of harvest residues for local bioenergy production.*

(ii) *A reduction of on-site burning of harvest residues (pile-burning of slash).*

Some of the harvesting residues that are normally left on site could be collected to produce local bioenergy to replace high emissions fossil fuels. Furthermore, the emissions from the residues that would have been burned in the forest (i.e. slash burning) will be avoided if the residues are instead collected and used for energy.

Harvest Residue for Bioenergy in Managed Forests

Recovery of harvest residues for local bioenergy production and reduced on-site burning



Changes in the modelling parameters and assumptions to represent this strategy:

2017-2020: use 10% of harvest residues for bioenergy and reduce slashburned area from 50% of the harvested area to 40%

2021-2050: use 25% of harvest residues for bioenergy and reduce the slashburned area from 40% of the harvested area to 25%

5.4. Old Growth Conservation strategy

An *old growth conservation strategy* consists of one main activity:

(i) *Prevent the harvesting of old growth forests, defined as stands older than 250 years old.*

In addition to their cultural, recreational and biodiversity values, a hectare of old growth forests stores a larger amount of carbon (i.e. it has a higher carbon density) than a hectare of younger, managed forest. Old growth forests typically store more carbon because they have a greater proportion of older, larger trees. The age at which forests are considered to be “old growth” varies across the province, but our modelling sets the age definition at 250 years and older. Regionally differentiated age constraints will be assessed in future scenarios.

In the absence of natural disturbances, a strategy of restricting the harvest of old growth forests will result in forested landscapes with higher carbon density than landscapes in which old-growth is harvested. However, depending on the region of BC and the type of forest, the carbon balance of forests older than 250 years can be a sink, neutral or a source. As well, the impact of this strategy depends on whether the harvest volume in the management unit falls, so that fewer wood products are produced, or whether the harvest volume can be maintained by shifting harvest to areas of forest less than 250 years old in the same management unit. Therefore, the mitigation benefits of this strategy can vary greatly across BC.

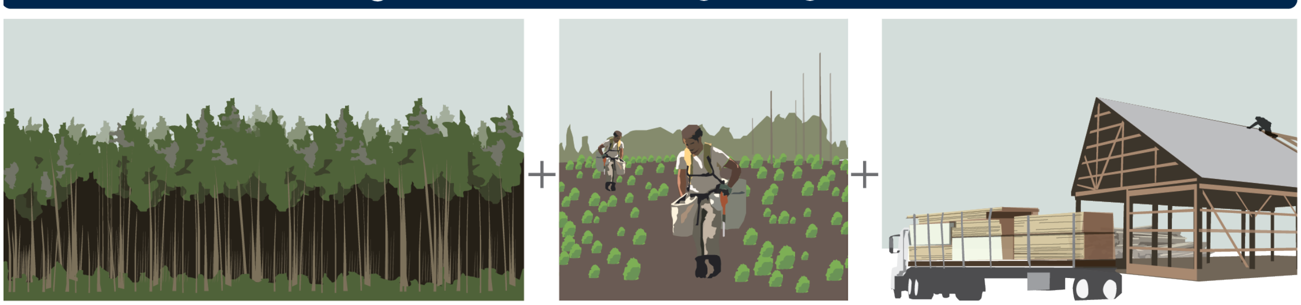
Old Growth Conservation in Managed Forests

Decreased harvesting of old growth forests (stands more than 250 years old)

Business as Usual: current harvest level in old growth forests

Less old growth forests + Reforestation + Harvested wood products

Mitigation: restrict harvesting in old growth forests



More old growth forests + Reforestation + Harvested wood products

The preceding figure does not show generic representations of GHG emissions and carbon removals because the strategy can have very different effects depending on whether the forest in the baseline is a sink, neutral or a source, and whether harvest and wood product volumes can be maintained.

Note that the implementation of this strategy in the modeling initially assumed that harvest volumes would be maintained by shifting harvesting to stands less than 250 years old in the same management unit. When this was possible, the area of reforestation with young growing trees would remain the same or increase while the same volume of harvested wood products would be produced. However, this was not always possible in the modelling so that restricting harvest to stands less than 250 years old resulted in not achieving harvest volume targets in some management units. Thus, in these management units, this strategy effectively becomes the harvest less strategy described in Section 5.2 above. Future research will try to separate these two strategies and address other stakeholder and expert feedback received on this scenario.

Changes in the modelling parameters and assumptions to represent this strategy:

Across BC, restrict harvest to stands less than 250 years old from 2017 to 2050 and seek to maintain harvest volumes unchanged

5.5. Longer-Lived Wood Products strategy

This strategy can be implemented in addition to any of the other strategies which are focussed on changes in ecosystem carbon management. A Longer-Lived wood products strategy consist of one main activity:

(i) The production of a commodity mix shifted towards a greater proportion of long-lived products (sawnwood, other solid wood and panels), at the expense of pulp and paper products. Both the baseline harvest volume and the proportion exported for each product is assumed to remain unchanged.

To analyse the impact of wood products on atmospheric carbon, one has to evaluate a product's whole life cycle, from extraction to end-of-life management. Excluding improved end-of-life management, the two main mitigation opportunities related to wood products are:

1) Increasing the time that carbon is stored in wood products.

2) Increasing avoided emissions through increased material substitution.

Storage of carbon in wood products

The time over which carbon is stored in wood products depends on the products' life duration. Some products have very short useful life, such as paper, whereas others provide long-term carbon storage such as the lumber used in constructing single family homes and commercial buildings[11]. If relatively more of the harvest is used for long-lived products the carbon will remain out of the atmosphere for longer.

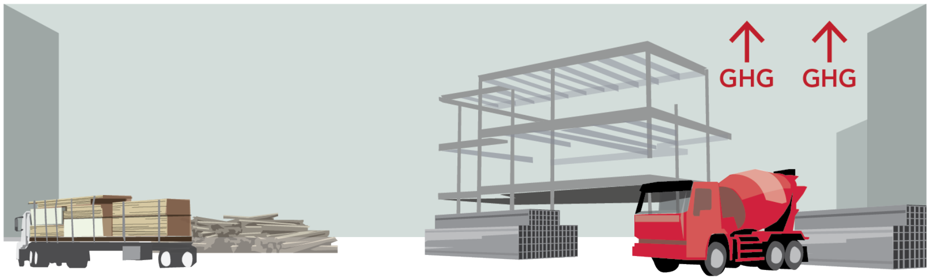
Increase material substitution

Wood can substitute for various products with higher GHG emission impacts on a life-cycle basis (e.g., steel studs, concrete walls and floors, cement). For instance, the use of steel or concrete framing instead of wood in houses in the USA was shown to lead to 26% and 31%, respectively, more GHG emissions than the use of wood[12]. The life-cycle emissions of wood need to be considered relative to the life cycle emissions of the alternative products.

Longer-Lived Wood Products

Increased proportion of long-lived wood products in production as compared to pulp and paper

Business as Usual: current production of long-lived products



Carbon storage in long-lived wood products

Materials that are more emissions intensive

Mitigation: increase use of long-lived wood products

More carbon storage in long-lived wood products

Material substitution: long-lived wood products replacing emissions intensive materials

Changes in the modelling parameters and assumptions to represent this strategy:

2017-2020: reduce harvest products used for pulp and paper by 1.6% and allocate this harvest amount to panels

2021-2050: reduce harvest products used for pulp and paper by 4% and allocate this harvest amount to panels

5.6. Rehabilitation strategy

A rehabilitation strategy consists of one main activity:

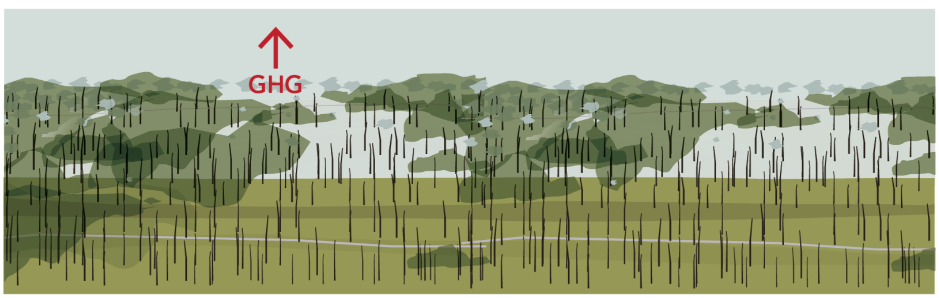
(i) The reforestation of underproductive site where no trees would otherwise be planted.

Rehabilitation involves planting trees in areas that have been damaged by wildfires or insect infestation and are not successfully regrowing. Rehabilitation could be implemented with or without removal of dead overstory. Where dead overstory trees are removed ecosystem carbon stocks will initially be lowered, followed by increased carbon sequestration due to accelerated regrowth and reduced wildfire risks for trees killed by insects.

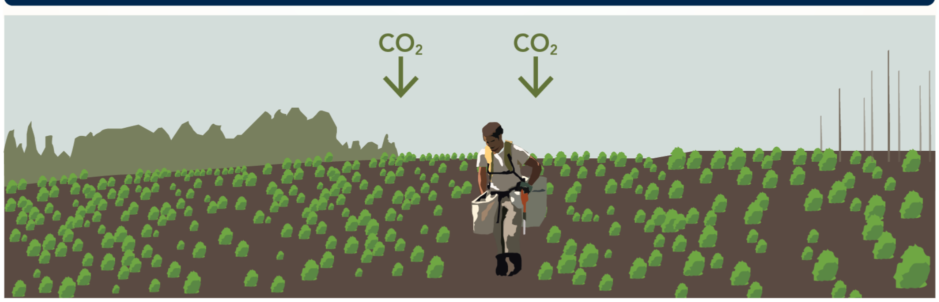
Rehabiliation

Reforestation of underproductive sites where no trees would otherwise be planted

Business as Usual: no change



Mitigation: rehabilitation



Growing trees from rehabilitation

This strategy was not included in the modelling during Phase 2.

6. PHASE 2: MODELLING THE STRATEGIES' SOCIO-ECONOMIC, CLIMATE CHANGE MITIGATION AND FINANCIAL IMPACTS

The potential impacts of five of the six mitigation strategies presented in the previous section were evaluated as part of phase 2 of the PICS forest carbon engagement process. The results of this analysis have been published in the scientific journal *Mitigation and Adaptation Strategies for Global Change*[13].

All the results are based on domestic mitigation, defined as the sum of forest sector mitigation plus displacement effects in BC resulting from the use of BC harvested wood products (see Appendix 1). Additional mitigation benefits occur outside BC, e.g. in Canada or abroad where BC wood products are used to substitute emission-intensive materials or fossil fuels. Such mitigation benefits help lower global atmospheric GHG concentrations, but they are not included in this summary.

The modelling considered the years 1990 to 2050, with mitigation activities starting in 2017. All of the results are reported as annual averages, except job creation, which shows a total for 2017 to 2050This document only highlights provincial results. Geographically differentiated results for BC's different forestry regions (e.g., interior, coast) will be discussed during the workshops.

Importantly, the modelling and its results represent early research and, as in any scientific project, are constrained by available data and assumptions. While the results provide an idea of potential impacts of the different alternatives and can enhance discussions, no policy conclusions should be drawn, at least until additional model analyses are completed. Phase 3 of the engagement process will allow the project to incorporate feedback on the initial analyses to refine assumptions and input data, improve estimates of mitigation outcomes, and assess how mitigation options are affected by potential effects of climate change on forests.

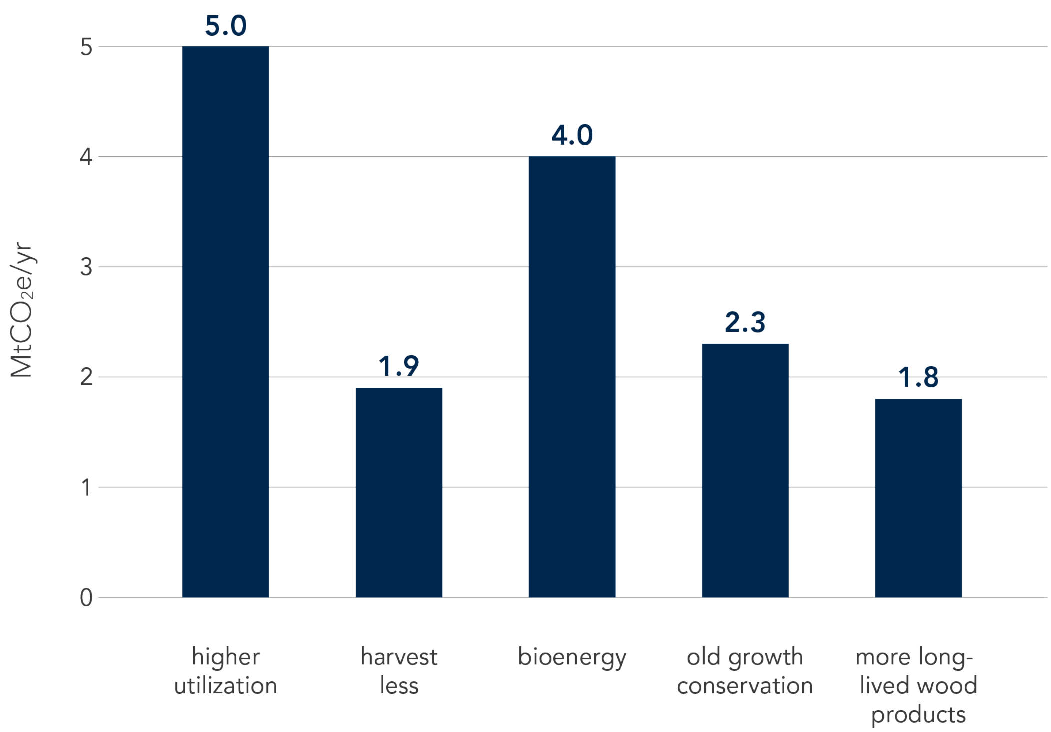
The sixth strategy – rehabilitation – was not included in the modelling. However, since it may represent an important mitigation strategy that has been proposed by the government in the Climate Leadership Plan,[5] the team has decided to also include it as one of the alternatives considered in the engagement process. We unfortunately do not have results on the climate, economic and socioeconomic impacts of a *rehabilitation strategy* at the provincial scale level like the five other strategies. However, section 6.6 provides some idea of the potential impacts of such a strategy.

6.1. Climate change mitigation potential

The average annual mitigation potential of each strategy, relative to the baseline for the years 2017-2050 was evaluated for the whole province in million tonnes of CO_2 equivalent per year ($MtCO_2e/yr$). The areas with negative impacts were excluded from the analysis because mitigation actions with anticipated negative outcomes will not be implemented.

Annual Domestic Mitigation Potential

Average total annual domestic mitigation potential of mitigation strategies for the years 2017-2050 in British Columbia, in millions of tonnes of CO_2 equivalent per year ($MtCO_2e/yr$)



In 2014 the total GHG emissions of the province were 67.2 $MtCO_2e$[14].

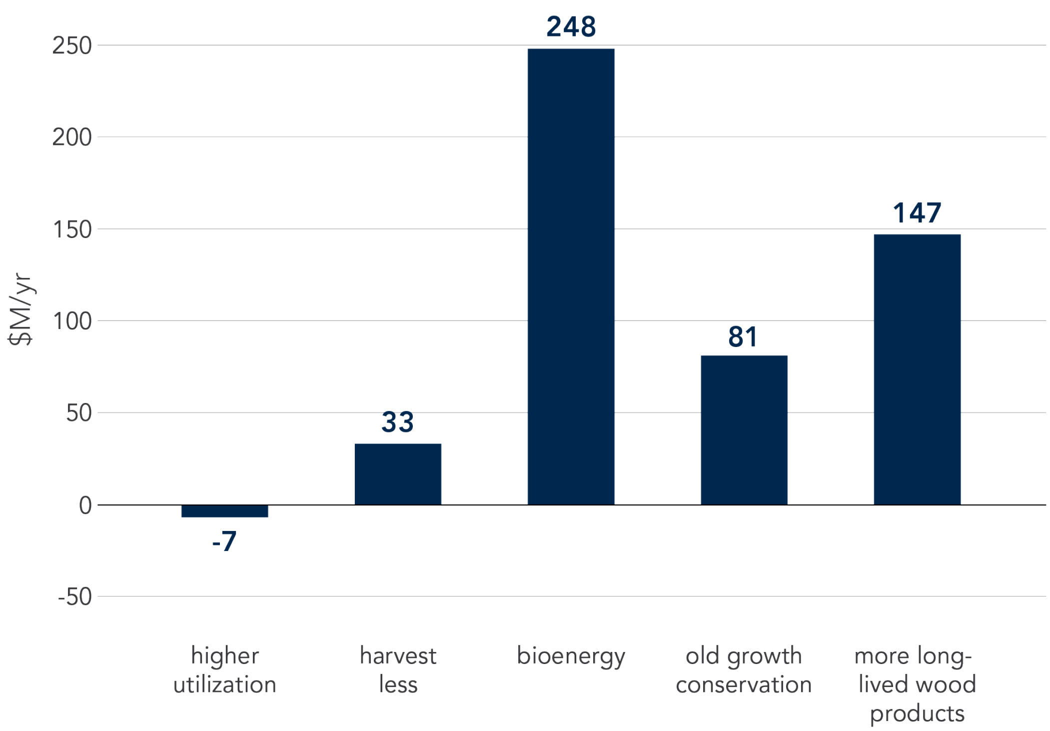
6.2. Mitigation cost

Mitigation cost is defined as the total domestic cost of implementing a mitigation strategy by considering its impact on the total net revenues of both the forest sector and other industries/sectors.

First, the average annual domestic cost of each strategy for the years 2017-2050 was calculated in millions of Canadian dollars per year ($M/yr). Mitigation scenarios that reduce harvest may result in compensation for tenure holders. These costs were not considered here.

Annual Total Domestic Mitigation Cost

Average total annual domestic cost of mitigation strategies for the years 2017-2050 in British Columbia, in millions of Canadian dollars per year ($M/yr)

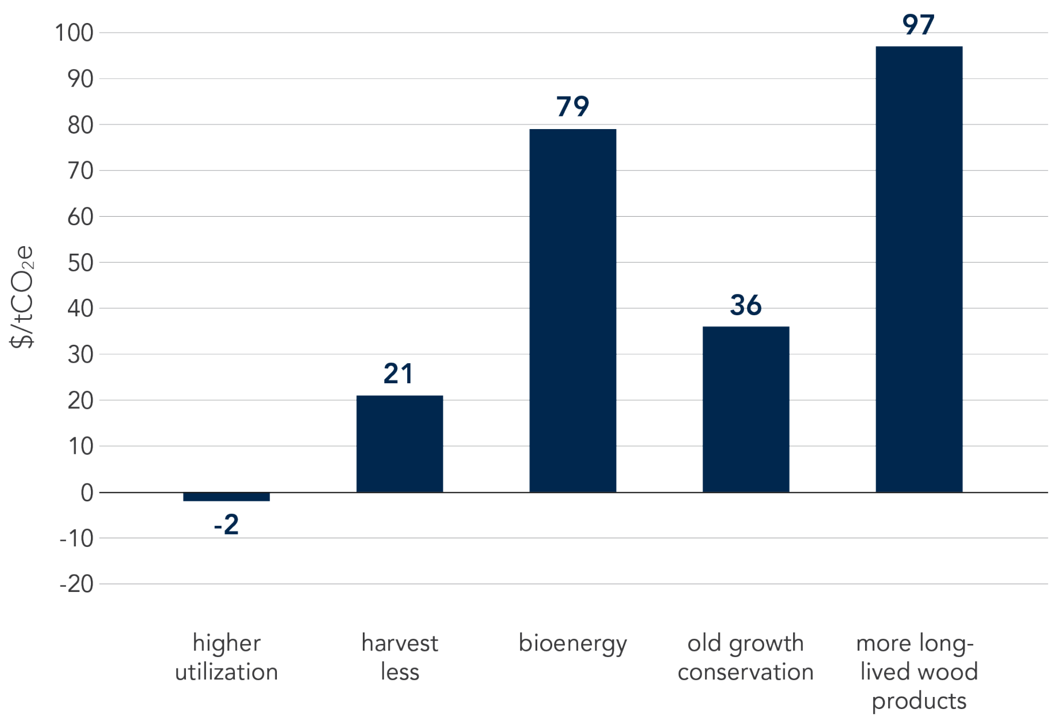


In 2013 the total revenue of the forest industry in BC was $15.7 billion[15].

Second, the average mitigation cost per tonne of CO_2 of each strategy for the years 2017-2050 was calculated by dividing total domestic cost by domestic mitigation impact. Discount factors were used to adjust for the fact that the mitigation and cost occur over time - this is a standard approach in this type of analysis.

Annual Domestic Mitigation Cost per Tonne of CO_2e

Average annual domestic cost of mitigation strategies per tonne of CO_2e for the years 2017-2050 in British Columbia, in Canadian dollars per tonne of CO_2e ($/t$CO_2e$)



In 2017 BC's carbon tax was $30 per tonne of CO_2e.

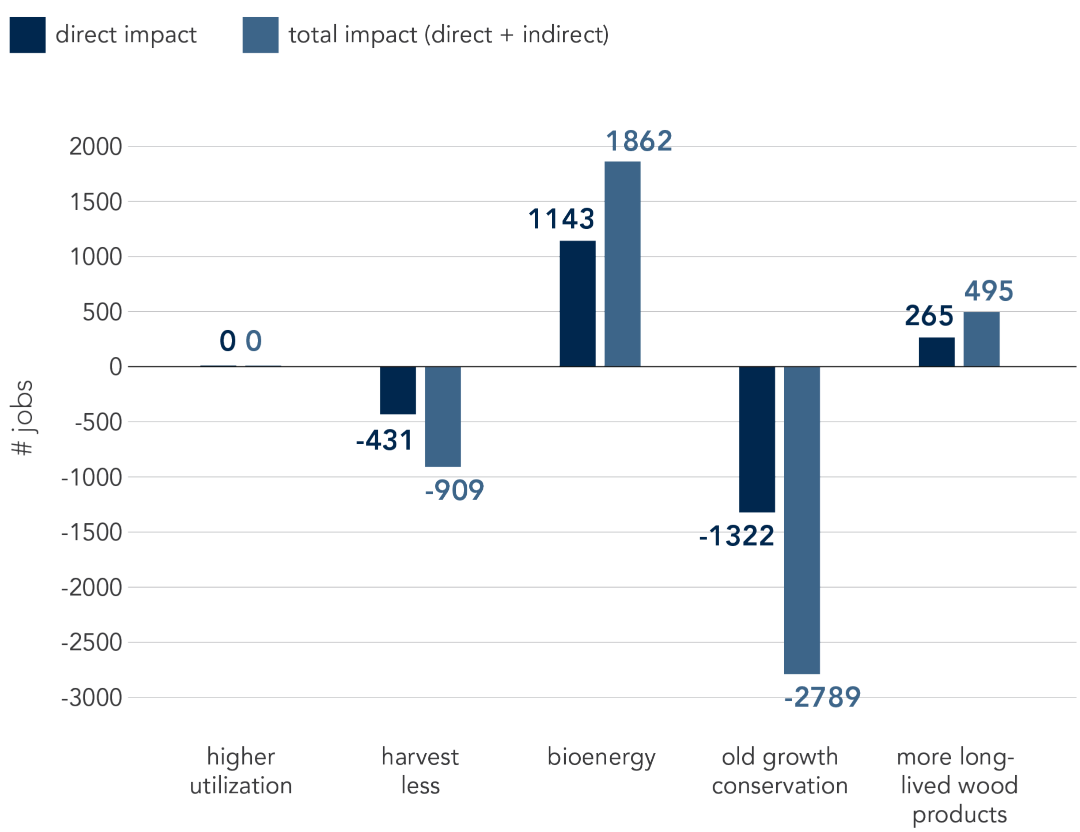
6.3. Socioeconomic impact – employment

The employment impact is defined as the number of additional jobs created.

The direct and total employment impact of each strategy for the years 2017-2050 was evaluated in full-time equivalent employees. The number of jobs can be considered as jobs created in 2017 that last until 2050. The direct employment impact accounts for jobs directly generated by the forest industry, while the total employment impact accounts both for jobs directly created by the forest industry (direct) and jobs in all the other sectors that are supported or induced by the forest industry (indirect).

Direct and Total Impact on Employment

Direct and total (direct + indirect) impact of mitigation strategies on employment for the years 2017-2050 in British Columbia, in number of full-time equivalent jobs (# jobs)



In 2013 the forest industry directly generated a total of approximately 63,500 full-time jobs and supported an additional 82,300 full-time jobs in other sectors, for a total employment impact of 145,800 full-time jobs[15].

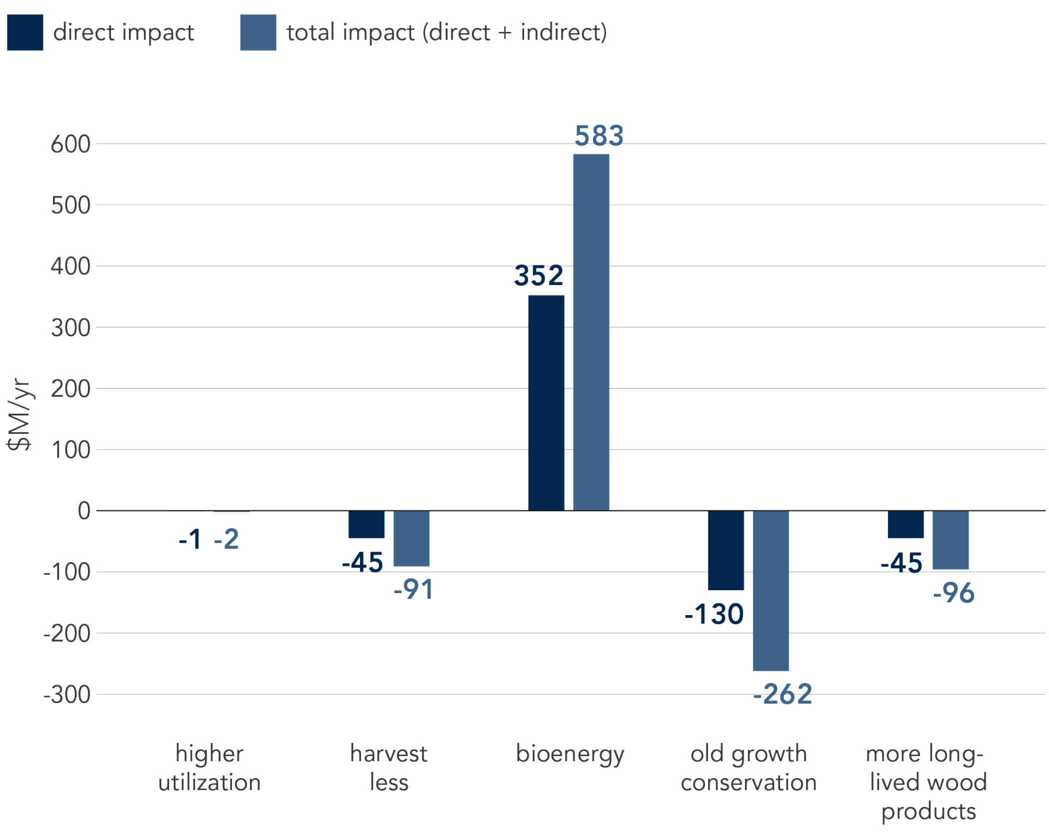
6.4. Socioeconomic impact – Gross Domestic Product (GDP)

GDP is defined as "the additional value of a good or service minus the cost of inputs used to produce it from the previous stage of production"[15]. In other words, it is the value of all final goods or services produced.

The average annual direct and total impact of each strategy on GDP for the years 2017-2050 was evaluated in millions of Canadian dollars per year ($M/yr). The direct impact on GDP accounts exclusively for the goods and services directly produced by the forest industry, whereas the total impact on GDP accounts for the goods and services produced by the forest industry and by all other sectors.

Annual Direct and Total Impact on Gross Domestic Product

Average annual direct and total (direct + indirect) impact of mitigation strategies on Gross Domestic Product (GDP) for the years 2017-2050 in British Columbia, in millions of Canadian dollars per year ($M/yr)



BC's GDP was $226.61 billion in 2013[16]. During the same year, the forest industry generated a direct impact on GDP of $5.8 billion and a total impact on GDP of $12.4 billion (2.5% and 5.5% of provincial GDP, respectively)[15].

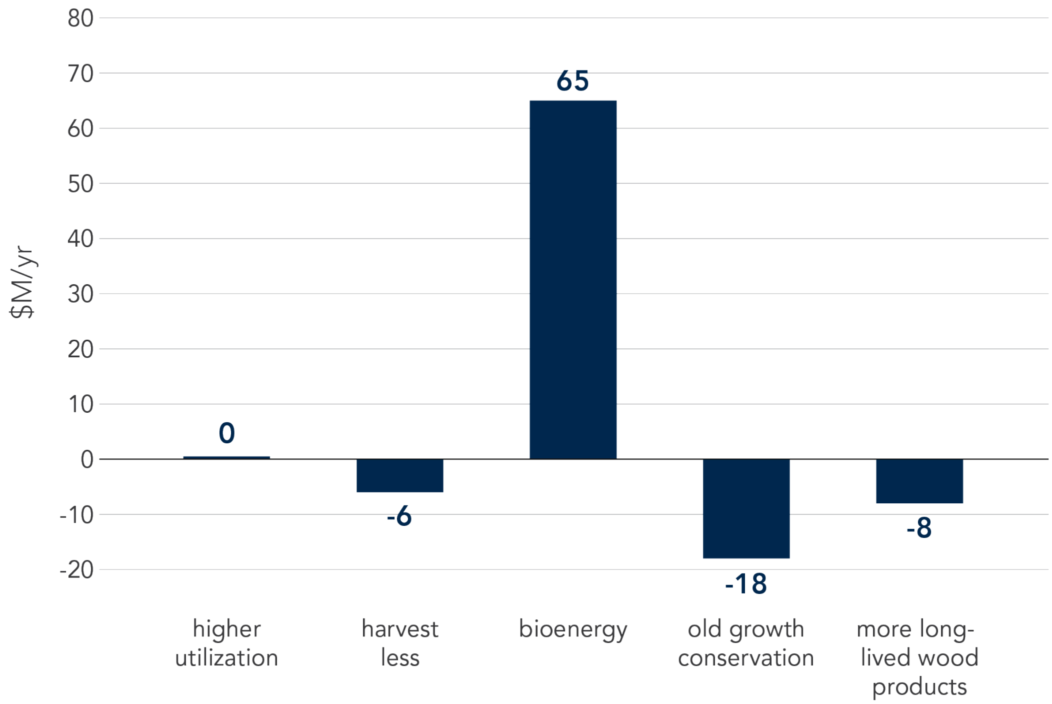
6.5. Socioeconomic impact – government revenue

The impact on government revenue is defined as the total revenue created for all levels of governments, including municipal, provincial and federal.

The average annual impact of each mitigation strategy on total government revenues for the years 2017-2050 was evaluated in millions of Canadian dollars per year ($M/yr).

Annual Impact on Total Government Revenue

Average annual impact of mitigation strategies on total government revenue (municipal, provincial, and federal) for the years 2017-2050 in British Columbia, in millions of Canadian dollars per year ($M/yr)



In 2013 the forest industry generated almost $2.5 billion in total governmental revenue, including $934 million for the federal government, $1.4 billion for the provincial government and $150 million for municipal governments[15].

6.6. Potential impact of the Rehabilitation strategy

In the Climate Leadership Plan published in August 2016, the Government of BC introduced the new Forest Carbon Initiative:

> "This initiative will focus on enhancing the carbon sequestration of Mountain Pine Beetle and wildfire impacted sites — capturing the carbon benefits of new reforestation, while avoiding emissions from burning slash. This work will build on existing forest management programs, such as the recently announced Forest Enhancement Society and Forest for Tomorrow.
>
> The Forest Carbon Initiative will rehabilitate up to 300,000 hectares of impacted sites over the first five years of the program. By 2050, the ten-year program is expected to lead to an annual reduction in greenhouse gas emissions of up to 11.7 million tonnes."

Implementation of such a rehabilitation program will require, (1) criteria for the selection of sites that can be rehabilitated, (2) stand-level estimates of carbon losses associated with site preparation, and (3) stand-level carbon gains resulting from rehabilitation. Mitigation benefits can then be estimated as the difference in carbon balance of disturbed sites with and without rehabilitation. The costs and benefits of such rehabilitation efforts in different ecosystem types and following different types and intensities of natural disturbances will also need to be established.

The potential future contributions of rehabilitation efforts to a regionally-differentiated mitigation portfolio in BC's forest sector are the subject of ongoing research.

7. PHASE 3: CONCLUSION AND NEXT STEPS

The analyses conducted thus far have demonstrated that several of the mitigation activities in the forest sector can have substantial beneficial impacts on the GHG balance of BC and make a meaningful contribution to GHG emission reduction targets with co-benefits for employment and other indicators. The analyses also demonstrated the opportunities for regionally-differentiated mitigation strategies. In fact, Xu et al.[13] identified mitigation portfolio options in which the mitigation strategies with the greatest GHG benefits were combined, applying in each forest management unit the most effective strategies identified in these analyses. One such portfolio contributed 35% of BC's GHG reduction target by 2050 at a cost of less than \$100/tCO_2e while providing additional socio-economic benefits.

The analyses presented here are preliminary results. Not all available options have been addressed. Moreover, those options that were analysed were generally based on very cautious and conservative assumptions about the scale at which such actions could be implemented in the short term. Furthermore, as previously discussed, the project team is seeking feedback on the scenarios and results to allow further improvements before any policy conclusions can be drawn. Additional modelling is ongoing to further improve the estimates, and to take into consideration ecosystem responses to climate change. Feedback from the stakeholder consultation process will inform these analyses.

The decision-making around future forest carbon mitigation strategies for BC's forests and forest sector will need to weight other factors in addition to the strategies' climate effectiveness and economic efficiency, including their broader social and environmental impacts, potential compensation requirements, implications for other forest values, and administrative feasibility. For instance, a strategy aimed at maximizing carbon mitigation might not maximize biodiversity conservation or local economic development and job creation. Conversely, a strategy that does not provide substantial mitigation might provide substantial job creation.

The one-day workshops to be held during spring and summer 2017 will revisit the same four regions canvassed during Phase 1. Participants will have the opportunity to evaluate the Phase 2 modelling results of the potential mitigation strategies in terms of the main objectives that were previously identified, thereby allowing for the consideration of a larger set of values than the results presented in this document.

The results of this overall study will provide insights into the potential public acceptability of existing and prospective climate change mitigation alternatives. In particular, this study will identify the values taken into account by stakeholders, First Nations and the public when evaluating mitigation strategies in BC's forest sector, thereby informing the design and evaluation of current and potential future activities in BC. Feedback from the stakeholder consultation process can also lead to additional scenarios to be considered and analysed during the next phase of the PICS Forest Carbon Management Project.

APPENDIX 1. DESCRIPTION OF THE MODELLING PROCESS

Most of this summary, as well as the results from the modelling exercise, comes from a recent scientific publication by Xu et al[13]. A brief summary of the methods used to estimate the mitigation, economic and socioeconomic potential of each mitigation option is described below. For more details on the methods used please consult the publication and references cited therein, or contact the research team.

Climate change mitigation analysis

The modelling analyses deploy models and estimation methods that are based on well-established, peer-reviewed and scientifically accepted tools. Like all such methods they are subject to scientific uncertainties and assumptions and these are explained in more detail in a number of scientific publications[13, 17, 18].

In line with the IPCC's definition of mitigation[19], the mitigation potential of mitigation options is defined as *the amount of reduced GHG emissions or increased carbon removals from the atmosphere that they generate compared to business-as-usual, or "baseline scenario"*. The baseline scenario is defined as *the forest management activities and use of harvested wood products that would occur in the absence of mitigation activities*. This document presents the "domestic mitigation potential" of each mitigation option, defined as *the sum of forest sector mitigation plus substitution effects in BC resulting from the use of BC harvested wood products*. Substitution benefits, e.g. from the use of wood harvested in BC outside of BC are therefore not included here, but they will also contribute to climate change mitigation.

The analysis was conducted for 74 forest management units (FMUs) in BC stratified into five ecozones and three forest regions, as identified in Canada's 2016 National GHG Inventory Report[20]. The mitigation potential in each FMU was examined for the period from 2017 to 2050, and the total cumulative mitigation was calculated by aggregating the results in each FMU, provided that positive mitigation benefits were observed. Mitigation actions with anticipated negative outcomes will not be implemented.

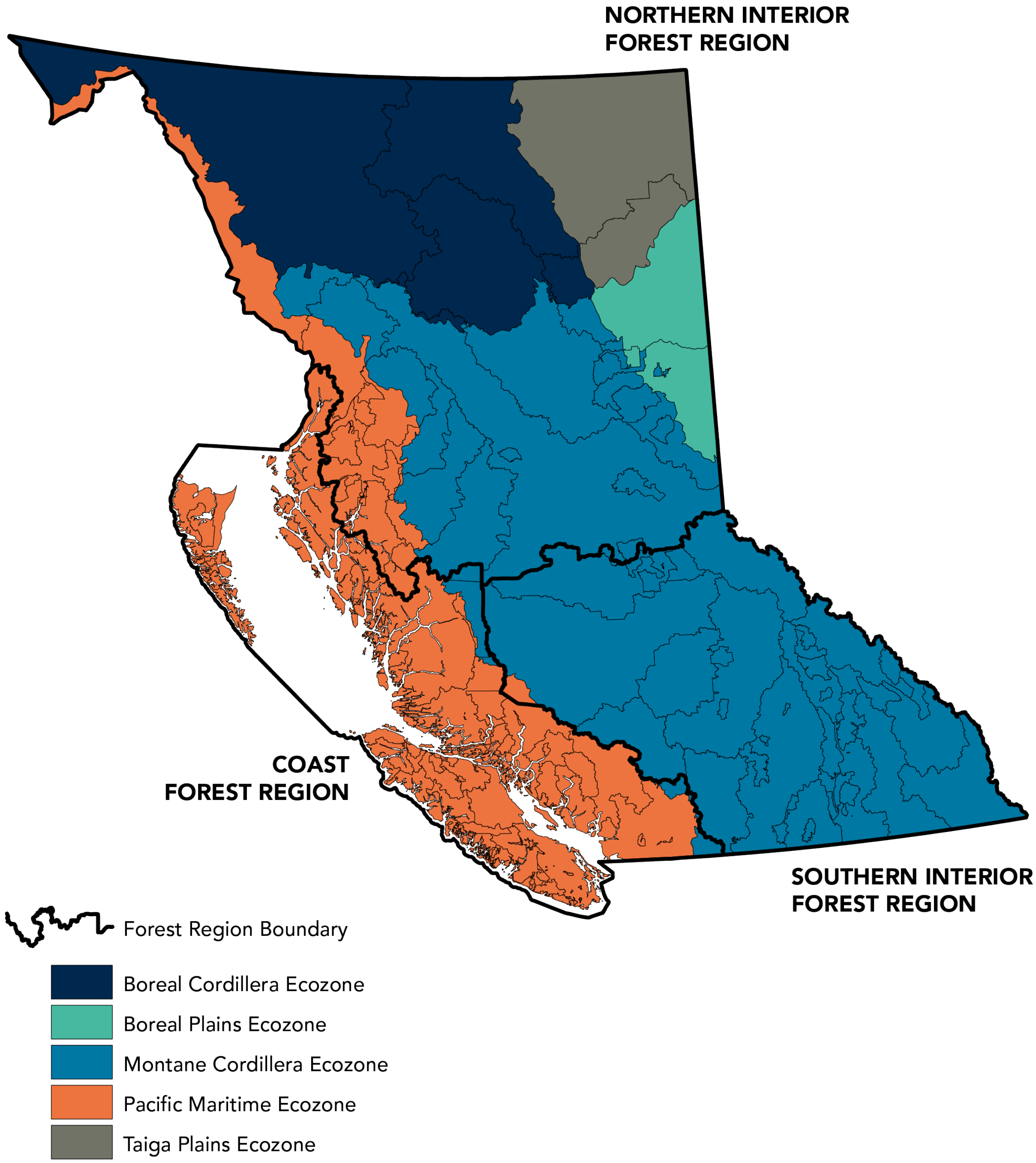
When planning a mitigation strategy in the forests and forest sector it is important to understand the trade-offs between increasing carbon storage in forest ecosystems and seeking to obtain mitigation benefits through use of wood[9, 21]. To calculate the net effect on emissions and removals of a mitigation alternative, one has to apply a "systems perspective" that takes into account how a mitigation strategy affects each of these three elements[2, 9]:

1) *Forest emissions and removals*: GHG emissions occur through respiration by plants and trees, decay of dead organic matters, and direct emissions from forest fires and/or slash burning.; Carbon sequestration occur through trees' photosynthesis and storage of carbon in wood and other biomass.

2) *Storage of carbon in wood products*: During harvest, some of the carbon is transferred to wood products. Short-lived (e.g., paper) and long-lived (e.g., lumber, panels in buildings) wood products store carbon for varying periods equivalent to the duration of their use. And depending on their fate after end use (recycling, land fill, burning) carbon can be stored further or released to the atmosphere.

Ecozones and Forest Regions

Forest management units categorized by ecozones (colors) and forest regions (thick lines).

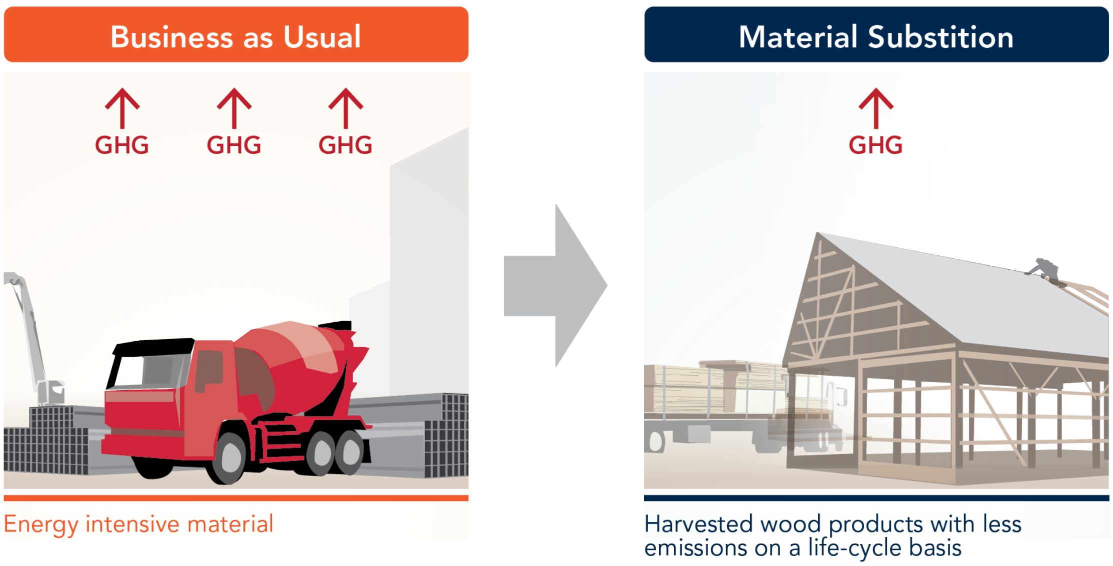


3) *Substitution effects*: The use of wood products can offset emissions of more energy-intensive products or fossil fuels. Two types of substitution exist:

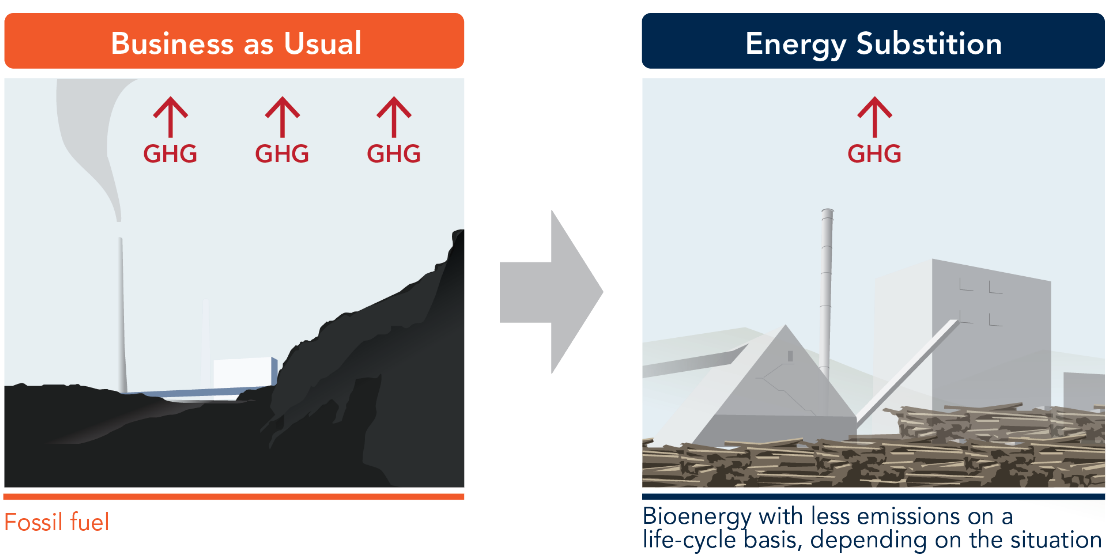
The use of solid wood products to offset emissions that would have otherwise ensued from using more emissions-intensive products is referred to as **material substitution**.

Similarly, **energy substitution** involves the production of energy with woody biomass instead of using high emissions fossil fuels that are more emissions-intensive on a life cycle basis.

Material Substitution



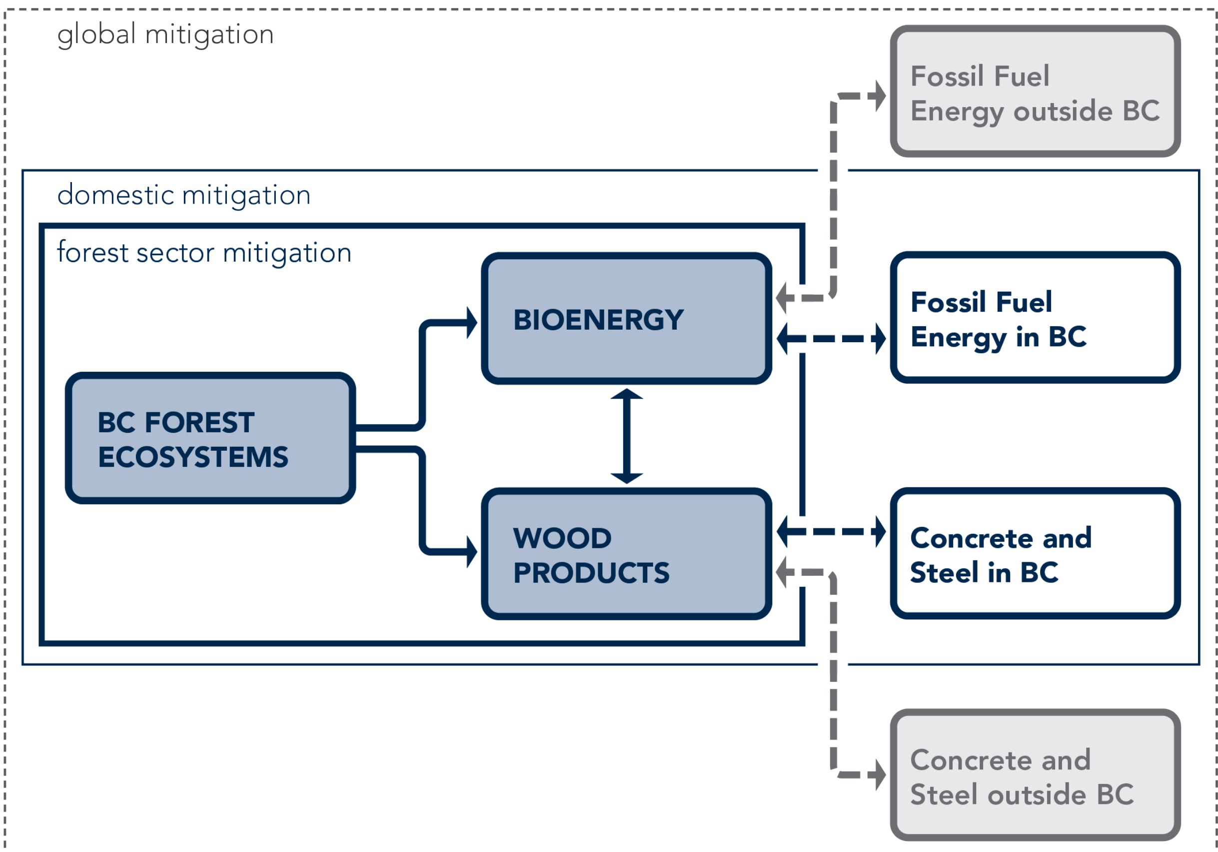
Energy Substitution



A "systems perspective" was employed to calculate the net effect of each mitigation option on (1) forest emissions and removals, (2) storage of carbon in wood, and (3) substitution effects in other sectors.

A systems perspective that includes multiple sectors

The solid arrows refer to carbon flows within the forest sector, and the dashed arrows represent susbstitution effects between biofuel and fossil fuel and between long-lived products and other emissions-intensive products such as concrete/steel[21].



Forest emissions and removals

The GHG emissions and removals in the forest ecosystem resulting from mitigation strategies were estimated using the Carbon Budget Model for the Canadian Forest Sector (CBM-CFS3)[22]. CBM-CFS3 simulates annual carbon transfers that are associated with ecosystem processes and natural and anthropogenic disturbances (e.g., wildfire and harvesting). The model integrates forest inventory data, growth and yield data, and information on forest management practices and natural disturbance impacts. The mitigation impacts on the forest ecosystem were modelled by comparing changes in the carbon fluxes between the baseline scenario and the scenario with implementation of mitigation strategies. For this study, the forest inventory data were mainly from BC Ministry of Forests, Lands, and Natural Resource Operations.

Storage in harvested wood products

In accordance with international reporting rules[23], carbon stored in harvested wood products manufactured from wood harvested in BC is counted, as are the emissions resulting from the decay and burning of such harvested wood products, including wood used for bioenergy abroad. However, domestic mitigation does not account for the displacement effects that occurred outside BC as a consequence of the use of exported wood products manufactured from wood harvested in BC.

The carbon that was transferred out of the forest ecosystem due to harvest was modelled by the Carbon Budget Model Framework for Harvested Wood Products (CBM-FHWP) – an analytical tool that tracks the fate of harvested carbon throughout the lifetime of harvest wood products. CBM-FHWP tracks the carbon flow associated with harvested wood products harvested in Canada that are used in Canada or abroad. This framework is one of the tools that are used to generate the estimates reported in Canada's annual GHG National Inventory Report. The framework modeled harvested wood product carbon with assumptions around the half-life (i.e., the time until half of the entire pool of a given product reaches the end of its life) of different products[23]:

- Sawnwood and other industrial roundwood: 35-year half-life
- Panels: 25 year half-life.
- Pulp and paper: 2 year half-life.

Bioenergy emissions resulting from discarded products were included in the framework by assuming that 10% of discarded solid wood and paper products were used for energy and the rest went to landfills assuming instant oxidation. Bioenergy emissions resulting from the use of harvest residues are estimated in the year of harvest.

Substitution

Both material and energy substitution effects were considered in all individual strategies. Emissions related to substitution were calculated by employing substitution factors. Substitution factors are commonly used to indicate how many tonnes of carbon emissions from alternatives can be avoided per tonne of carbon in wood-based products used[24].

Material substitution

Three housing construction buildings were considered in the model: single-family home, multi-family home, and multi-use building. All substitution factors assumed concrete and steel would be used as an alternative to BC wood. National average substitution factors were applied[25]:

- 2.1 tC/tC for sawnwood
- 2.2 tC/tC for panels

Energy substitution

For avoided emissions for bioenergy in BC we estimated substitution factors using a linear programming (LP) model that maximized avoided emissions in each FMU (see Smyth et al. for more details[25]).

Economic and socioeconomic analyses

The domestic mitigation costs (in Canadian dollars) were estimated using the Model for Economic Analysis of Forest Carbon Management (MEA-FCM) which was originally designed and employed by Lemprière et al.[26]. We defined mitigation cost as *the total cost to implement a mitigation strategy which equals the change between the baseline and a mitigation scenario in the present values of the total net revenues of both the forest sector and other industries/sectors affected by substitution*.

The socio-economic impacts of mitigation strategies were analyzed using multipliers from the national Input-Output model[27]. The value of a multiplier refers to the increase/decrease in an indicator (e.g., gross domestic product (GDP)) if the demand for the output of a given industry increases/decreases by $1 (or $1 million for employment). In this study, multipliers were used to assess impacts on employment, GDP, and government revenues in BC's economy in response to changes in the forest sector resulting from the implementation of mitigation strategies. We considered both direct effects and indirect effects on those indicators, where the former refers to the impacts directly induced from a change in an industry's output, and the latter measures the impacts of further output changes due to interactions among industries within BC in response to the initial changes in the directly affected industry.

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