QUANTIFICATION PROTOCOL FOR DIRECT REDUCTIONS IN GREENHOUSE GAS EMISSIONS ARISING FROM CHANGES IN FOREST HARVESTING PRACTICES

Version 1.0

June 2011

Specified Gas Emitters Regulation

Government of Alberta

Alberta

Disclaimer:

The information provided in this document is intended as guidance only and is subject to periodic revisions. This document is not a substitute for the law. Please consult the *Specified Gas Emitters Regulation* and applicable legislation for all purposes of interpreting and applying the law. In the event that there is a discrepancy between this document and the *Specified Gas Emitters Regulation* or other legislation, the *Specified Gas Emitters Regulation* and other legislation prevail.

All Quantification Protocols approved under the *Specified Gas Emitters Regulation* are subject to periodic review as deemed necessary by the Department, and will be re-examined at a minimum of every 5 years from the original publication date to ensure methodologies and science continue to reflect best-available knowledge and best practices. Any updates to protocols occurring as a result of the 5-year and/or other reviews that are not due to legal requirements will apply at the end of the first credit duration period for applicable project extensions and for all new projects coming forward.

Where a project condition differs from approved government methodologies, or the project developer is unclear on protocol interpretation relative to their specific project, the project developer must contact Alberta Environment to discuss an appropriate interpretation and receive approval for any methodology changes prior to undertaking the project.

Any comments, questions, or suggestions regarding the content of this document may be directed to:

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1.0 Offset Project Description

This quantification protocol describes the process for quantifying annual greenhouse gas emission reductions/removals arising from a change in forest harvesting practice from full tree harvesting with tree length hauling and chipping in a wood room at the mill to chipping using portable chippers. Emissions reductions are achieved by improving harvest and transportation efficiency as well as reducing the amount of harvest debris disposal when compared to the baseline condition (Appendix A).

Portable chipping technology may be deployed in three locations: in-block, at satellite yards, or at the mill. All portable chipping applications must be tracked in the project condition, but only in-block chipping will result in a reduction in greenhouse gas emissions. Use of portable chipping technology in a satellite yard or at the mill does not result in increased harvest efficiency or reductions in harvest debris disposal compared to the baseline condition.

Figure 1 below shows a process flow diagram for the baseline and three project conditions being quantified in this protocol.

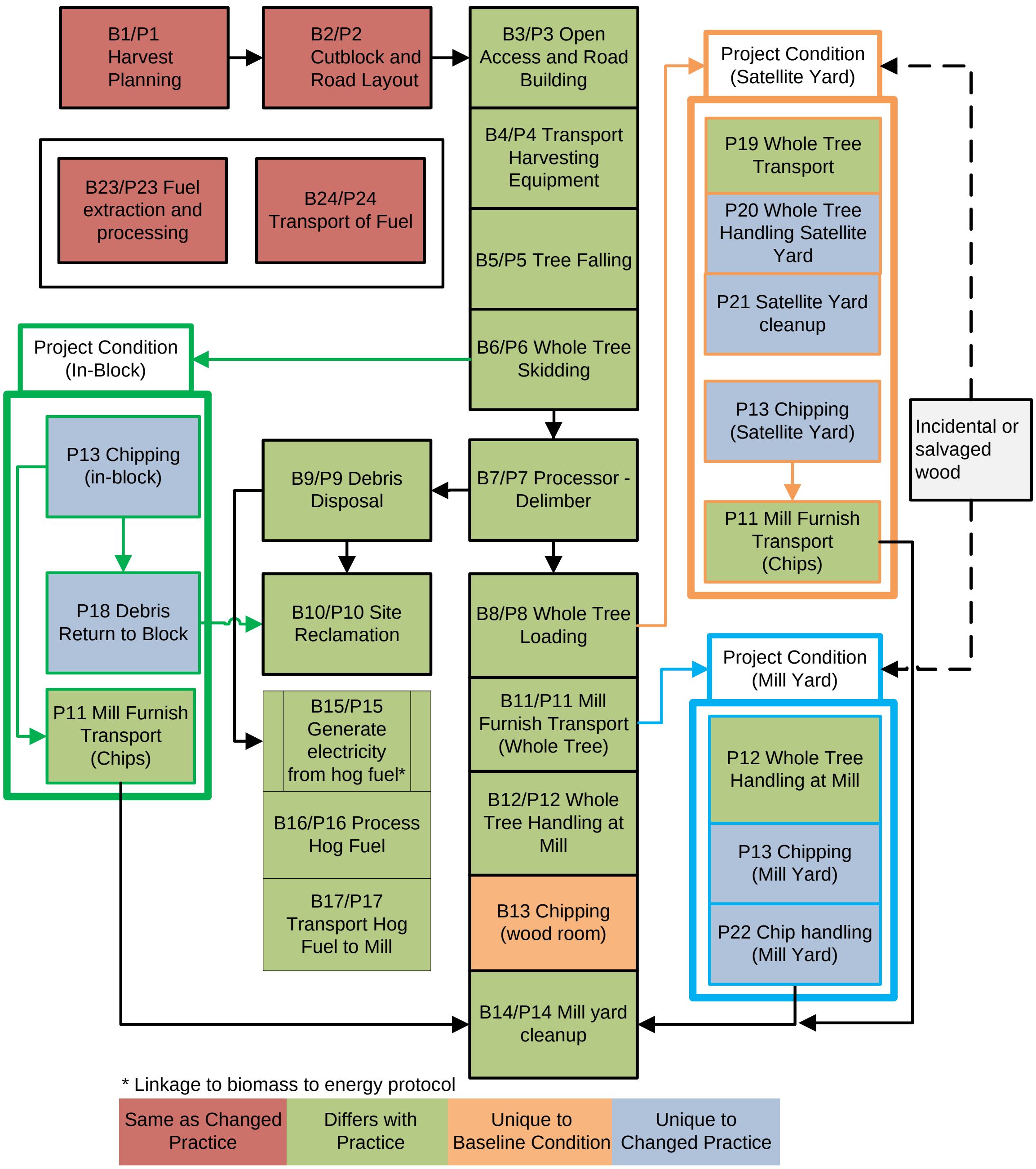


Figure 1. Baseline and Project Condition process flows. Project Condition process flow depends on the location of the changed harvest practice (in-block, satellite yard, mill yard). Wood is obtained from a controlled harvest or from uncontrolled sources (incidental or salvaged wood).

1.1 Protocol Scope

This protocol quantifies direct reductions in greenhouse gas emissions associated with reduced energy consumption needed to supply annual mill furnish, and reductions in harvest debris disposal. This includes all harvests within the planning unit (Forest Management Agreement (FMA) area) and scheduled harvests on private lands and all incidental mill furnish including salvage wood[1] supplied by others (e.g., softwood quota holders and industrial oil and gas development) operating within the planning area. Mill furnish transportation and cleanup emissions are also within scope. Incidental wood that is supplied for chipping resulting from upstream activities, including access road building and harvesting by third parties operating within the forest management area, are related but are outside the scope of this protocol. Harvesting that is outside the scope would include harvest of non target species, and/or incidental harvest of target species where they are a minor component of the stand. However, once wood is transported to the satellite or mill yard, all subsequent emissions (controlled emissions) from chipping, mill furnish transportation and cleanup are within scope and must be quantified. Where transportation distances to a satellite yard for incidental or salvaged wood increase relative to baseline, the increased distance must be quantified and included in the project condition (Figure 1, P19).

Baseline Condition for Timber Harvesting Practices

The baseline condition for timber harvesting is full tree harvest and tree length hauling to a mill site for processing. Baseline emissions are the sum of all controlled emissions related to supplying mill furnish including harvesting, transportation (hauling), chipping, harvest debris disposal, and emissions from wood handling and cleanup.

This protocol uses a combination of three baseline approaches to quantify emission sources as shown in Table 1 below.

More information on establishing and quantifying the project baseline is provided in Section 2.0 below.

[1] Salvage wood represents a small portion of total annual mill furnish and is included for inventory completeness. The amount, species, quality, and location of salvaged wood are highly variable. Where salvage wood is reported as production for annual timber depletion accounting, it must be included in the project and treated in the same manner as incidental wood. All activities that occur prior to chipping (e.g., access road construction, harvesting, and transportation to the satellite or mill yard) are related but are outside the control of the project developer and are excluded. Salvage wood that is not included in the annual allowable cut is excluded from this protocol.

Table 1: Components of the Baseline Condition.

Component	Type	Static / Dynamic	Units*
Harvesting B3, B4, B5, B6, B7, B8, B10	Comparison based	Dynamic	Emissions / unit harvest CO_2e /m^3
Transportation B11	Projection based	Dynamic	Diesel fuel emissions / Litre CO_2e / L
Wood Room Chipping B13	Historic based	Dynamic	Emissions / unit chipped CO_2e /m^3
Debris disposal B9, B15	Projection based	Dynamic	Emissions / unit debris CO_2e / kg
Handling & cleanup B12, B14	Historic or Comparison based	Dynamic	Emissions / unit harvest CO_2e /m^3

* Carbon dioxide equivalent (CO_2e) includes CO_2, CH_4 and N_2O emissions.

Project Condition for Timber Harvesting Practices
The project condition (portable chipping) can be conducted in three locations as shown in Figure 1 above. Portable chipping is typically done in-block, but also may be undertaken in a satellite yard or in the mill yard. Satellite and mill yard portable chipping is typically used to process incidental or salvage wood that is not associated with a controlled harvest within the scope of this protocol.

1. **In-block portable chipping** is the primary practice in which entire trees, including large limbs and trees below nominal merchantability standards are chipped. This practice results in increased transportation efficiency, increased utilization (recovery of chips per unit area harvested), and a reduction in harvesting debris requiring disposal.

2. **Satellite yard portable chipping** is primarily used for processing incidental deciduous volume cut in coniferous or coniferous-leading mixed wood cutblocks. In these cases, utilization more closely approximates the baseline condition as aspen logs must be hauled by truck to the satellite yard.

3. **Mill yard portable chipping** is used primarily for processing wood salvaged from industrial oil and gas development. Like satellite yard chipping it results in reduced utilization due to the requirement to haul aspen logs to the mill yard.

The use of portable chipping technology in satellite and mill yards results in an increase in greenhouse gas emissions resulting from a replacement of centralized wood room chipping using electricity generated from biomass, natural gas or coal with portable chippers, which use diesel. These emissions are included for completeness and must be quantified. Reductions in emissions due to increased tree utilization are also not realized with satellite yard or mill yard portable chipping where the amount and disposal of harvest debris is unchanged from the baseline condition. More information on project emissions quantification and calculations are provided in Section 3.0 below.

Functional equivalence is achieved by using a common metric of units of carbon dioxide equivalent (CO_2e) per annual harvest volumes (m^3). Relevant greenhouse gas emissions for this protocol are shown in Table 2, and CO_2e emission factors are described in Appendix A.

Table 2: Relevant Greenhouse Gases.

Specified Gas	Formula	100-year GWP	Applicable to Project
Carbon Dioxide	CO_2	1	Yes
Methane	CH_4	21	Yes
Nitrous Oxide	N_2O	310	Yes
Sulphur Hexafluoride	SF_6	23,900	No
Perfluorocarbons*	PFCs	Variable	No
Hydrofluorocarbons*	HFCs	Variable	No

* A complete list of perfluorocarbons and hydrofluorocarbons regulated under the *Specified Gas Emitters Regulation* is available in Technical Guidance for Offset Project Developers.

1.2 Protocol Applicability

Projects implemented under this protocol must be able to demonstrate they meet the requirements of the Alberta offset system and this protocol including having:

- Verifiable records on harvest volume for each year where an offset will be claimed.
- Spatial records and/or maps of harvest locations and transportation road networks for each year where an offset will be claimed.
- Comparable harvest and/or records suitable for establishing baseline operating conditions. Comparable harvest includes harvest system, species harvested and similar terrain.

Specifically, projects implemented under this protocol must:

1. Demonstrate that a change in harvest practices resulting in an overall reduction in greenhouse gas reductions has occurred including all quantified emissions reductions resulting from in-block portable chipping and emissions increases resulting from the use of portable chippers at satellite and mill yards.

2. Ensure reductions in harvest debris biomass used for energy production (hog fuel) resulting from the increased utilization of trees with application of in-block portable chipping is captured. When hog fuel volumes are not known and are not quantified using the Quantification Protocol for Diversion of Biomass to Energy from Biomass Combustion Facilities then this protocol must be co-implemented with the Quantification Protocol for the Diversion of Biomass to Energy from Biomass Combustion Facilities. With co-implementation an equivalent amount of greenhouse gas emissions from fossil fuels required to produce the same amount

of biomass generated energy must be discounted. This is further explained in flexibility mechanism 2 (Appendix B).

When greenhouse gas emissions reductions from the use of hog fuel in a biomass combustion facility are already captured under a related biomass project, co-implementation of the biomass to energy protocol is **NOT** required. Co-implementation is also not required if hog fuel biomass is known and discounted prior to quantification. Discounting of known hog fuel biomass eliminates any potential overlap between the protocols. Discounting of hog fuel biomass must occur wherever increase in tree utilization achieved through in-block portable chipping technology occurs (i.e., at the harvest block), if hog fuel locations are not known then discounting must occur for all harvest blocks within a nominal economic haul distance[2] from the biomass combustion facility.

1.3 Protocol Flexibility

Two flexibility mechanisms are described for this protocol. Quantification methods for flexibility mechanisms are provided in Appendix B.

1. This protocol requires greenhouse gas emissions calculations based on diesel fuel consumed. Diesel fuel consumption can be quantified from aggregate volumes, fuel purchase and use records, or where sufficient records exist, fuel use can be quantified based on hours of operation and equipment type. Fuel use rates in both cases are **not** discounted for idling or downtime, and all fuel is assumed to be consumed within the scope of the protocol.

   More information on calculating fuel use from hours of operation and equipment type is provided in Appendix B.

2. Reductions in harvest debris attributable to blocks greater than the nominal economic hog fuel haul distance from the mill are assumed to be disposed in-block and may be subtracted from the in-block portable chipping project condition emissions reductions rather than added to the baseline condition. More information on subtracting harvest debris disposal from the project condition is provided in Appendix B.

   When volume and location specific information is not available, reductions in harvest debris volumes within the nominal economic hog fuel haul distances from the mill must be assumed to be hog fuel, and must be discounted from the project condition to avoid double counting with the biomass to energy protocol. Discounting is calculated based on the amount of non-renewable fuel that would be needed to produce an equivalent amount of power as hog fuel being discounted. **This requires co-implementation of the biomass to energy protocol.**

[2] Nominal economic haul distance is determined from several factors including access road type and condition, transportation fuel costs, price of electricity, forest stand condition and location.

1.4 Glossary of Terms

Biomass: For the purposes of this protocol, biomass is defined to include forest harvest debris and mill residues, agricultural crops and wastes, wood and wood wastes.

CIE-D emissions: CIE-D refers to Combustion Internal Engine Diesel. This abbreviation is used to refer to diesel engine fuel consumption and associated emissions.

Combustion: For the purposes of this protocol, combustion is limited to the aerobic combustion of biomass in the presence of air.

Co-gen: Co-generation (also called combined heat and power (CHP)) is the use of a heat engine or a power station to simultaneously generate electricity and useful heat and/or steam. It is one of the most common forms of energy recycling. For the purposes of this protocol, the co-gen plant is powered by biomass in the form of hog fuel and/or materials recovered from mill processes, and supplemented by natural gas.

Coniferous leading mixedwood: Refers to a forest or forest stand composed of both coniferous (softwood) and deciduous (hardwood) tree species, in which conifers compose 50% or more of the stand volume.

Dispositions: Refers to a number of harvest blocks grouped for management or contracting purposes.

Debris: See Harvest debris.

Feller-buncher Large motorized vehicle with an attachment that can cut and gather several trees. The feller-buncher uses its boom to fell, group, and orient trees to facilitate pickup by grapple skidders.

Full tree harvest: Trees are felled and transported to roadside with branches and top intact. This term is used synonymously with whole tree harvest.

Harvest debris: Refers to the unmerchantable material remaining after harvesting. It includes tree tops, limbs, and trees below merchantability standards and is used synonymously with slash.

Harvest year: The annual harvest schedule does not coincide with calendar year because the majority of harvesting occurs in the winter months

	after the ground has frozen and ends with breakup and/or thaw, typically in April. Harvest year is therefore May to April.
Hog fuel:	Refers to wood residues processed through a grinder or chipper into coarse chips which are then used for fuel.
Incidental wood:	Wood from other harvest operations that occur within a forest management area. This is typically the undesirable or non-target species portion of the harvest. For example, for a softwood quota holder, this would be the hardwood component of a mixed species stand.
In-block:	Actions or activities that occur within the spatial boundaries of a harvest block.
Mill furnish:	Mill furnish refers to unprocessed or partially processed wood fibre delivered to a forest products manufacturing facility.
Mill yard:	Refers to a location adjacent to the mill and/or processing facility. With regard to this protocol any activity that changed as a result of implementing use of portable chippers, and occurs adjacent to the mill, is referred to as mill yard. This includes changes in chipping, wood handling and cleanup.
Portable chipping:	Use of a portable machine that debarks and chips full trees including large branches and tops. Portable chippers can be located in-block (at roadside), in a satellite yard, or in the mill yard and typically replaces centralized chipping located at the mill.
Realized hog:	Refers to the real hog fuel weight or volume calculated from scale measurements.
Salvage wood:	Collection and use of trees that are not part of a scheduled harvest. These trees are felled for access and road building and/or for construction and are typically from oil and gas operations. The amount, species, and quality of salvaged wood are highly variable.
Satellite yard:	Refers to a location that is used to collect, store and process wood from many harvest blocks into mill furnish.
Tree length hauling:	Trees are processed at roadside to remove branches and tops then transported as full length logs.
Wood room:	The part of a mill that sorts and processes wood fibre for the manufacturing facility. In this protocol the wood room debarks and chips trees as the first step in the pulping process.

2.0 Baseline Condition

The project comparison is between full tree harvesting with tree length hauling and chipping in the wood room (baseline condition), and full tree harvesting with portable chipping (project condition). Emissions reductions achieved are the difference in the project emissions compared to the baseline emissions.

Emission Reduction = Emissions $_{\text{Baseline}}$ – Emissions $_{\text{Project}}$

The Baseline Condition is a hybrid, and contains comparison-based, projection-based, and historic-based components. Baseline Condition emissions are calculated as follows:

Emissions $_{\text{Baseline}}$ = Emissions $_{\text{Harvest}}$ + Emissions $_{\text{Transportation}}$ + Emissions $_{\text{Wood room}}$ + Emissions $_{\text{Debris disposal}}$ + Emissions $_{\text{Handling \& cleanup}}$

Each baseline component referenced in Table 1 above is explained in more detail below.

Harvesting Practices
The baseline condition for harvesting practices consists of the traditional full tree harvest system with tree length hauling which is practiced throughout Alberta. Also, in Alberta, opening access and road clearing/construction are integrated into the harvest operations. Greenhouse gas emissions associated with harvesting are from combustion of diesel fuel used in clearing/construction and harvesting equipment.

Baseline practices are assessed using a **comparison** with current industry practices being undertaken by other Alberta companies. Once established, the comparison harvest must be reviewed **annually**. This ensures that technological advancements and improvements in efficiency in full tree harvesting are captured in the baseline calculations.

Transportation Emissions
Transportation emissions are from combustion of diesel fuel, and efficiencies represent a significant portion of the claimable greenhouse gas emissions reduction. However, transportation emissions vary significantly with haul route and road networks used and can differ considerably between operators and from year to year. The "as-built" road network must be used for quantifying transportation emissions from each harvest block or group of harvest blocks to the mill. Short road segments within harvest blocks may be estimated (modeled) but must be the same for Baseline and Project conditions.

The baseline, therefore, uses the actual blocks harvested annually for quantification of transportation emissions and compares directly with the project condition using a **projection based** baseline. This dynamic approach to transportation emissions results in haul routes being virtually identical between baseline and project conditions, and emissions reflecting only the difference in transportation efficiency (i.e., number of required loads for tree length hauling vs. chip hauling). Included in the transportation emissions are picker trucks used to transport salvage to the mill for processing.

Wood Room Operations

Wood room operations are present in the baseline, but are absent in the project condition where the wood room is typically closed and replaced with portable chipper use as needed. These emissions must be added to the baseline and adjusted for annual harvest volume to ensure that the baseline captures all emissions that should be accrued to it. Therefore, a **historic benchmark** approach must be used to quantify wood room energy use. The historic benchmark is determined using wood volume chipped and energy used while the wood room was still in operation, to calculate energy use per unit volume. This allows for wood room emissions to be adjusted for annual total volume chipped (total volume is sum of harvest, incidental and salvage volume) for each offset quantification year.

Debris Disposal Emissions

In the baseline condition, harvest debris is disposed of by open combustion in the harvest block (Appendix A). In order to account for differences in emissions attributable to debris disposal between the baseline condition and in-block chipping project condition, the initial difference in debris biomass must be calculated. The difference in debris biomass represents an increase in efficiency between full tree harvesting and in-block chipping. The harvest debris difference is calculated as a proportion (increased utilization for in-block chipping) of the tonnes harvested and may be estimated directly from scaled weight or volume numbers.

The increased utilization proportion for in-block chipping must be determined prior to application of the protocol (Appendix C). The increased utilization proportion is composed of large branches, ends, and harvest of smaller trees that in the baseline condition would be harvest debris and/or hog fuel. Under the baseline condition, all additional debris biomass not transported to the mill as hog fuel is disposed of by in-block combustion.

Note: Harvest debris disposal requirements for the satellite yard and mill yard project conditions are identical to the baseline condition because all use the same full tree harvest and tree length hauling.

Handling and Clean-up Emissions

Greenhouse gas emissions associated with handling and clean-up are from combustion of diesel fuel used in equipment. Significantly more wood handling and cleanup are required under the baseline condition compared to the project condition (Appendix A). This includes additional loading, unloading, piling, and forwarding to the wood room. Each time the wood is handled additional breakage and debris is generated that must be periodically cleaned.

Baseline Emission Summary

Baseline condition emissions are the sum of:

- Diesel engine emissions from access and road construction (includes landings),
- Diesel engine emissions from harvesting and handling,
- Diesel engine emissions from transportation,
- Electrical power use (natural gas and/or coal) emissions from chipping,

- Additional harvest debris disposal emissions from combustion,
- Diesel engine emissions from mill yard wood handling and cleanup.

Figure 2 is a simplified baseline process flow diagram showing the key components of the Baseline Condition. Each component of the baseline quantification is described in more detail in Section 4 of this document.

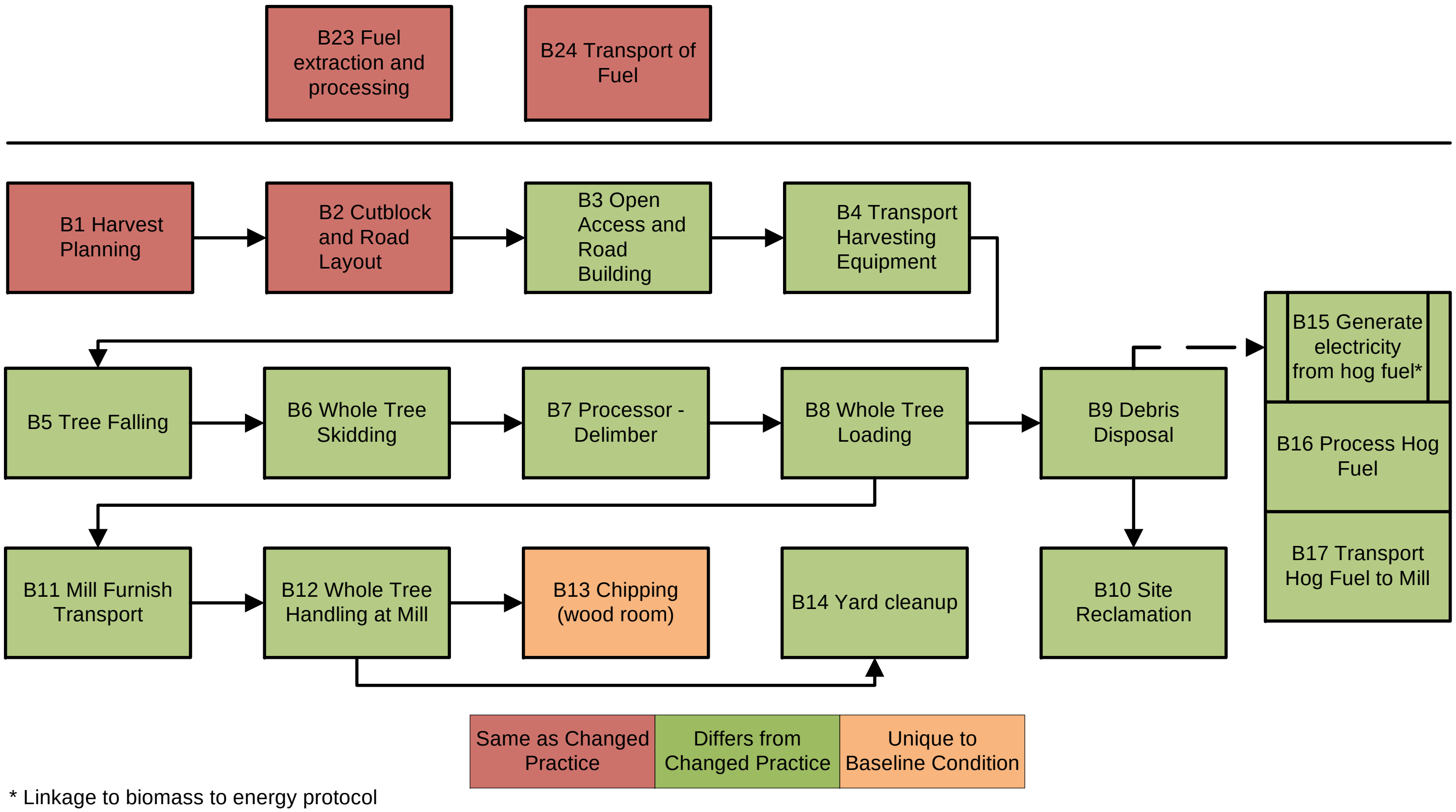


Figure 2: Process Flow Diagram for the Baseline Condition.

2.1 Identification of Baseline Sources and Sinks

Sources and sinks for each action are assessed based on guidance provided by Environment Canada and are classified as follows:

Controlled: The behaviour or operation of a controlled source and/or sink is under the direction and influence of a Project Developer through financial, policy, management, or other instruments.

Related: A related source and/or sink has material and/or energy flows into, out of, or within a project but is not under the reasonable control of the project developer.

Affected: An affected source and/or sink is influenced by the project activity through changes in market demand or supply for projects or services associated with the project.

This protocol quantifies a direct reduction in greenhouse gas emissions from a change in harvest practice. With the exception of electrically powered wood room chipping, all sources and sinks are similar (equipment used, emission factors) to the project condition sources and sinks.

The baseline sources and sinks are defined from discrete actions required to supply mill furnish (Figure 1, Figure 2). These include transportation, harvesting, wood room operations, and debris disposal. The scope of this protocol has been extended to identify a possible link to the biomass to energy (hog fuel) protocol to ensure that double counting of emission offsets does not occur. Figure 3 and Table 3 classify sources and sinks by type (Controlled, Related, Affected) and temporal location (upstream, downstream, or on site).

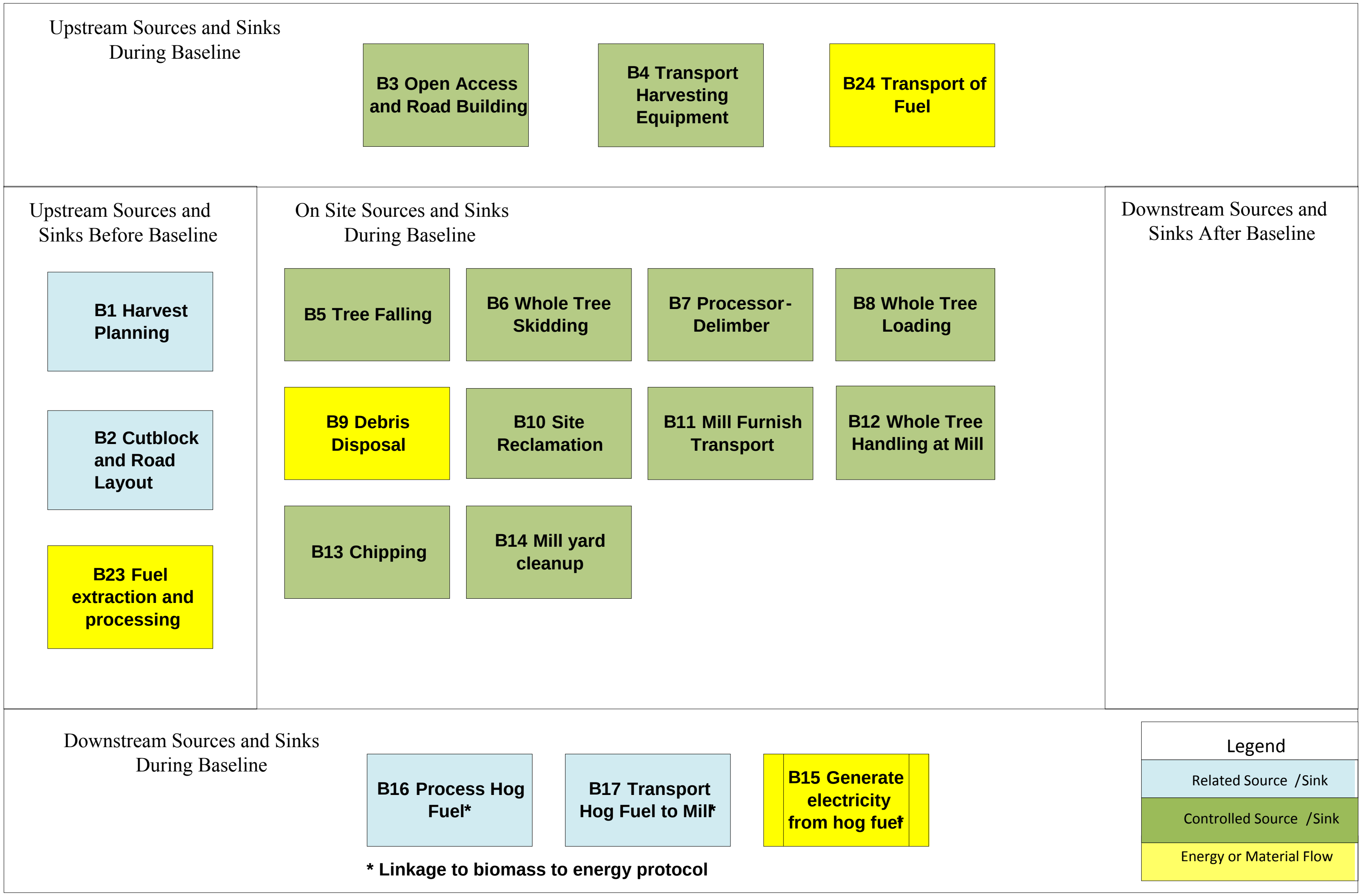


Figure 3: Baseline Sources and Sinks for Forest Harvesting Direct Reduction Protocol.

Table 3: Baseline Sources and Sinks for the Forest Harvesting Direct Reduction Protocol.

Sources/Sinks	Description	Controlled, Affected, Related
Upstream Sources and Sinks Before Project		
B1 Harvest planning	Actions performed for entire FMA according to approved plans for harvest sequencing.	Related
B2 Cutblock and road layout	Actions specific to identified harvest cutblock. Includes map production.	Related
B23 Fuel extraction and processing	Upstream extraction and processing of diesel fuel	Affected
B24 Transport of Fuel	Transportation of diesel fuel for onsite storage and use	Related
Upstream Sources and Sinks During Project		
B3 Open access and road building	Diesel engine emissions from crawler tractors* and graders to open access from the haul road to the cutblock. Includes road clearing, levelling and grading. Also included is construction of landings used for processing, temporary storage, and loading of harvested trees.	Controlled
B4 Transport harvesting equipment	Diesel engine emissions from trucks required to transport harvest equipment to the cutblock.	Controlled
Onsite Sources and Sinks During Project		
B5 Tree falling	Diesel engine emissions from feller-bunchers* used to cut and fell trees according to utilization standards, block design and operating ground rules.	Controlled
B6 Whole tree skidding	Diesel engine emissions from skidders to transport felled whole trees to the landing, and by Butt 'n' top loaders* to pile trees for processing. Skidders use a grapple to grab and move trees laid down by the feller-buncher. Trees are delivered to the landing where they may be repositioned by loaders to facilitate access by the processor*.	Controlled
B7 Processor delimber	Diesel engine emissions from the processor to prepare whole trees for tree length hauling. Processing for tree length includes removing the branches and tops of each tree.	Controlled
B8 Whole tree loading	Diesel engine emissions from Butt 'n' top loaders to load whole trees on trucks for tree length hauling. Loaders take the trees that have had the branches and tops removed by the processor and use a boom to load trees onto waiting trucks.	Controlled
B9 Debris disposal	Amount (weight) of harvest debris burned.	Controlled
B10 Site reclamation	Diesel engine emissions from crawler tractors for block cleanup. Includes piling and redistribution of harvest debris on the cutblock.	Controlled
B11 Mill furnish transport	Diesel engine emissions from trucks for tree length hauling. This includes full cycle emissions from loading at the cutblock to unloading at the mill site, and return.	Controlled
B12 Whole tree handling at mill	Diesel engine emissions from loaders to unload trucks and pile logs for later wood room chipping. Includes additional handling to feed wood room chippers.	Controlled
B13 Chipping	Power use required for operation of centrally located electrically driven chipper.	Controlled

B14 Mill yard cleanup	Diesel engine emissions for crawler tractors for cleanup of the mill yard.	Controlled
Downstream Sources and Sinks During Project		
B15 Electricity generated from hog fuel	Used only for cutblocks where hog fuel is being taken to generate electricity under the biomass to energy protocol.	Energy or material flow
B16 Process hog fuel	Diesel engine emissions from all actions performed to grind and load hog fuel for transport.	Related
B 17 Transport hog fuel	Diesel engine emissions from trucks to haul and unload hog fuel at mill.	Related
Downstream Sources and Sinks After Project		
	None	

*Examples of equipment shown in Appendix A.

3.0 Project Condition

Portable chipping can be conducted in three locations. Portable chipping is typically done in-block (Figure 4a), but may also be undertaken in a satellite yard (Figure 4b) or in the mill yard (Figure 4c). All three portable chipping locations may be used within the same harvest year and the proportion of annual harvest attributable to each form (location) of portable chipping also may change from year to year.

Emissions must be calculated using the total volume of diesel fuel consumed. This requires data on the quantity of diesel fuel used and assumes that all fuel is combusted and generates real greenhouse gas emissions attributable to the project condition. This assumption is necessary because fuel cannot be accurately allocated to different fuel uses such as road construction, harvesting, and processing. Use of total fuel consumed results in a conservative emissions estimate because all fuel use is captured in this protocol. The use of total fuel consumption for emissions calculations **does** capture differences in greenhouse gas emissions attributable to the project including reduced transportation emissions, increased tree utilization, and reduced hauling, but **does not** capture the differences in debris disposal requirements, or if required, use of harvest debris as hog fuel. These must be quantified separately.

In-block portable chipping is when full trees including large limbs and trees below current merchantability standards, cut by a feller-buncher, are chipped. This practice results in:

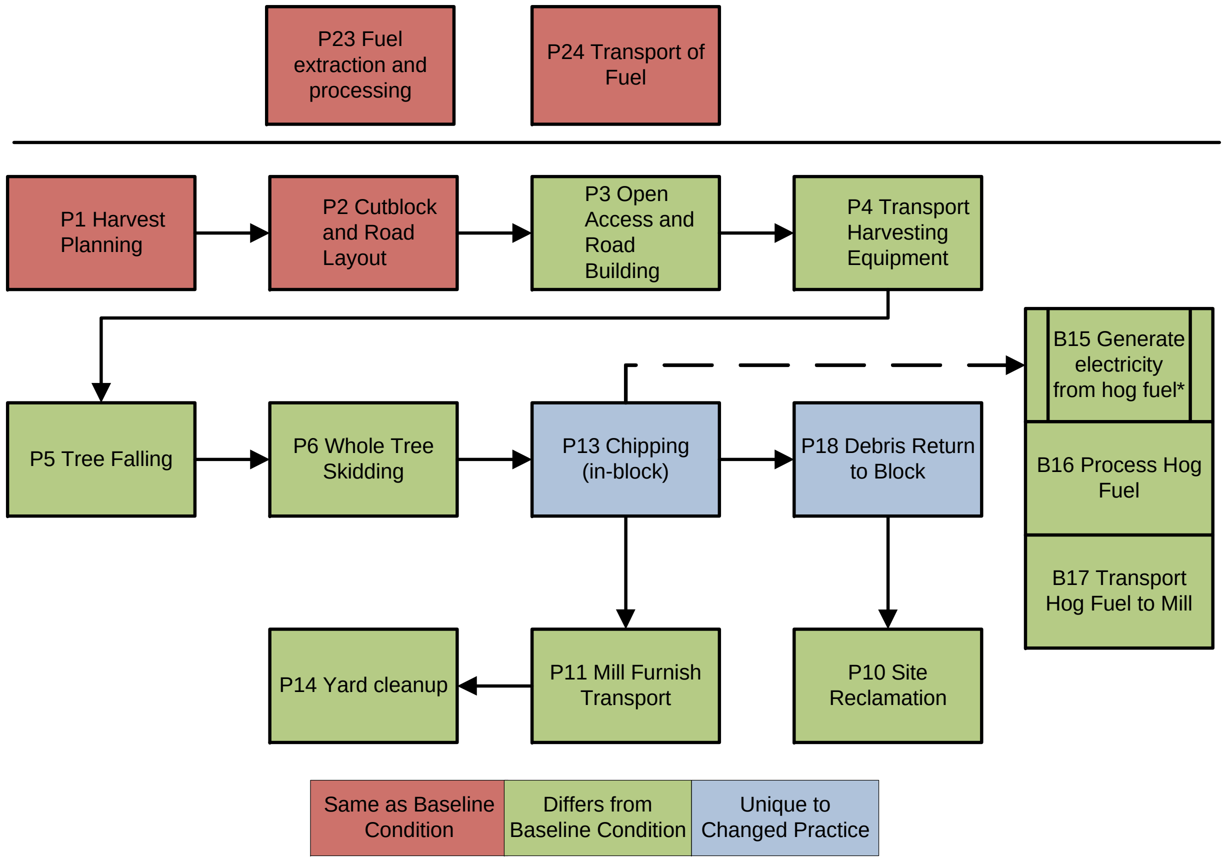
- a significant increase in utilization through increased recovery of chips per unit of cutblock area harvested;
- increased transportation efficiency through increased haul weight per load; and
- a reduction in harvesting debris requiring disposal by debris piling and burning.

Satellite yard portable chipping is primarily used for processing incidental deciduous volume harvested in coniferous or coniferous leading mixedwood cutblocks. In this case, there is less efficient utilization as aspen logs must be hauled by truck to the satellite yard and debris disposal is the same as the baseline condition.

In some cases satellite yard project condition may be composed entirely of incidental and salvage wood. Harvests that only supply incidental and salvage wood to the satellite yard (e.g., from softwood quota holders) are related but uncontrolled emissions and are outside the scope of this protocol. However, once the wood is transported to the satellite yard all activities including handling and chipping must be quantified. This condition will likely result in increased greenhouse gas emissions being quantified, but is necessary to ensure a full and conservative accounting of the total annual harvest volume for the mill operations. Also, if transportation distance for incidental harvest wood increases due to the need for chipping at the satellite yard, then the increased energy for transportation must be included in the project condition emissions. For harvest considered to be in scope, picker trucks, used for transporting recovered wood to the satellite, are also included.

Mill yard portable chipping is the same as the baseline condition except that the portable chipper has replaced the wood room operations. Like satellite yard chipping, it results in reduced utilization due to the requirement to haul logs to the mill yard. Debris disposal is the same as in the baseline condition. Mill yard portable chipping is frequently used for processing wood salvaged from industrial oil & gas development and thus may not always be associated with a harvest. For harvest considered to be in scope, picker trucks, used for transporting recovered wood to the mill, are also included.

Process flow diagrams for the three project conditions are shown in Figures 4a, 4b, and 4c below.



* Linkage to biomass to energy protocol

Figure 4a: Process Flow Diagram for the in-block portable chipping Project Condition.

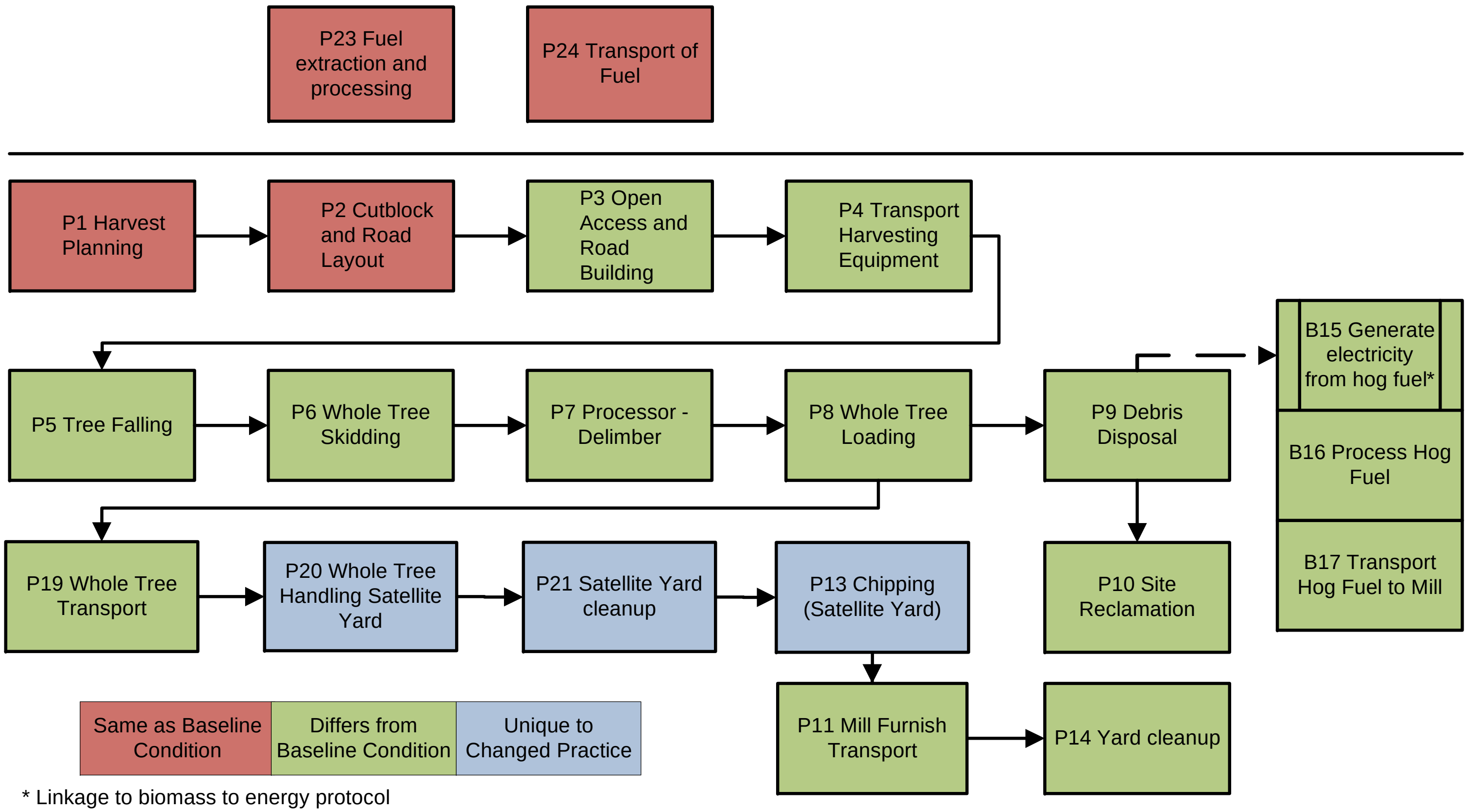


Figure 4b: Process Flow Diagram for the satellite yard portable chipping Project Condition.

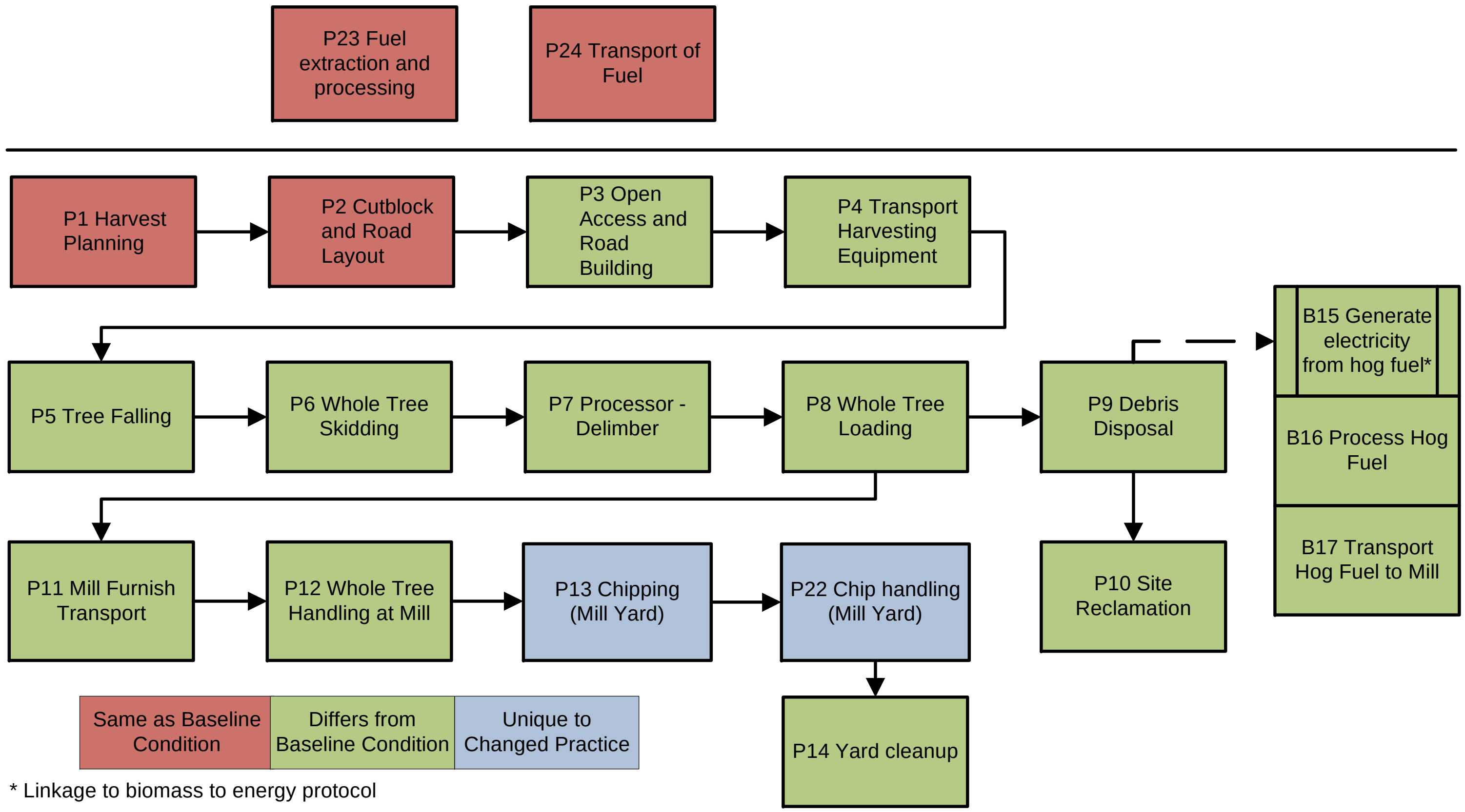


Figure 4c: Process Flow Diagram for the mill yard portable chipping Project Condition.

Note: with the exception of portable chipping replacing electrically powered wood room chipping, the mill yard chipping Project Condition (Figure 4c) is the same as the Baseline Condition (Figure 2).

Harvest Emissions
In Alberta, opening access and road clearing/construction are typically integrated into the harvest operations. Greenhouse gas emissions associated with harvesting are from combustion of diesel fuel used in clearing/construction and harvesting equipment. Total fuel consumption (from records) is used to quantify energy used for harvest.

Project condition energy requirements for in-block chipping are less than for baseline due to reduced wood handling and increased tree utilization efficiency. However, the energy requirements of portable chippers are now included with harvest operations (Appendix A) and therefore total harvest energy consumption may be greater than baseline harvest.

Note: diesel fuel consumption that cannot be portioned out to specific uses and/or vehicles is considered out of scope for this protocol. Uses include harvest, transportation, and cleanup.

Transportation Emissions
Transportation emissions are from combustion of diesel fuel, and efficiencies represent a significant portion of the applicable greenhouse gas emissions reduction. However, transportation emissions vary significantly with haul route and road networks used and can differ considerably between operators and from year to year.

The project condition therefore uses the actual blocks harvested annually for quantification of transportation emissions and compares directly with the projected fuel use under a baseline tree length hauling scenario. This dynamic approach to transportation emissions results in haul routes in most cases being identical between baseline and project conditions, and emissions reflecting only the difference in transportation efficiency (i.e., number of required loads for tree length hauling vs. chip hauling).

Debris Disposal Emissions
Only the use of in-block portable chipping results in a change in harvest debris disposal emissions compared to the baseline condition. For in-block chipping the increased tree utilization results in less harvest debris disposal requirements. In-block portable chipping captures portions of trees (e.g., tops, large branches) that must be removed to facilitate tree length hauling. These portions are typically added to debris piles and burned in the baseline condition. Harvest debris disposal requirements remain unchanged for satellite yard and mill yard project conditions compared to the baseline condition.

Handling and Site Cleanup Emissions
Greenhouse gas emissions associated with handling and clean-up are from combustion of diesel fuel used by equipment. Each time the wood is handled additional breakage and debris is generated that must be periodically cleaned. Therefore, handling and cleanup emissions for the in-block project condition are significantly less than the baseline condition (Appendix A), and handling and cleanup emissions for the mill yard project condition are relatively unchanged compared to the baseline condition.

For the satellite yard project condition additional handling and clean up occur at the satellite yard and not at the mill where handling and cleanup requirements are the same as for the in-block project condition.

3.1 Identification of Project Sources and Sinks

This protocol quantifies a direct and indirect reduction in greenhouse gas emissions resulting from a change in harvest practice. With the exception of portable chipping, all sources and sinks are similar to the baseline condition sources and sinks discussed in section 2 above.

Sources and sinks for the forest harvesting direct reduction protocol were identified based on scientific peer review. This process confirmed that source and sinks in the process flow diagram (Figures 4a, 4b, and 4c) covered the full scope of eligible project activities under this protocol.

Project sources and sinks have been further refined according to the life cycle categories identified in Figure 5. These sources and sinks were then classified as controlled, related, or affected as described in Table 4 below.

The project condition sources and sinks are defined from discrete actions required to supply mill furnish and differ by portable chipping location (Figures 4a, 4b, and 4c). These actions include harvesting, transportation, and debris disposal. The scope of this protocol includes the quantification of biomass to energy (hog fuel) to ensure completeness and prevent potential double counting of emission offsets under this and the biomass to energy protocol.

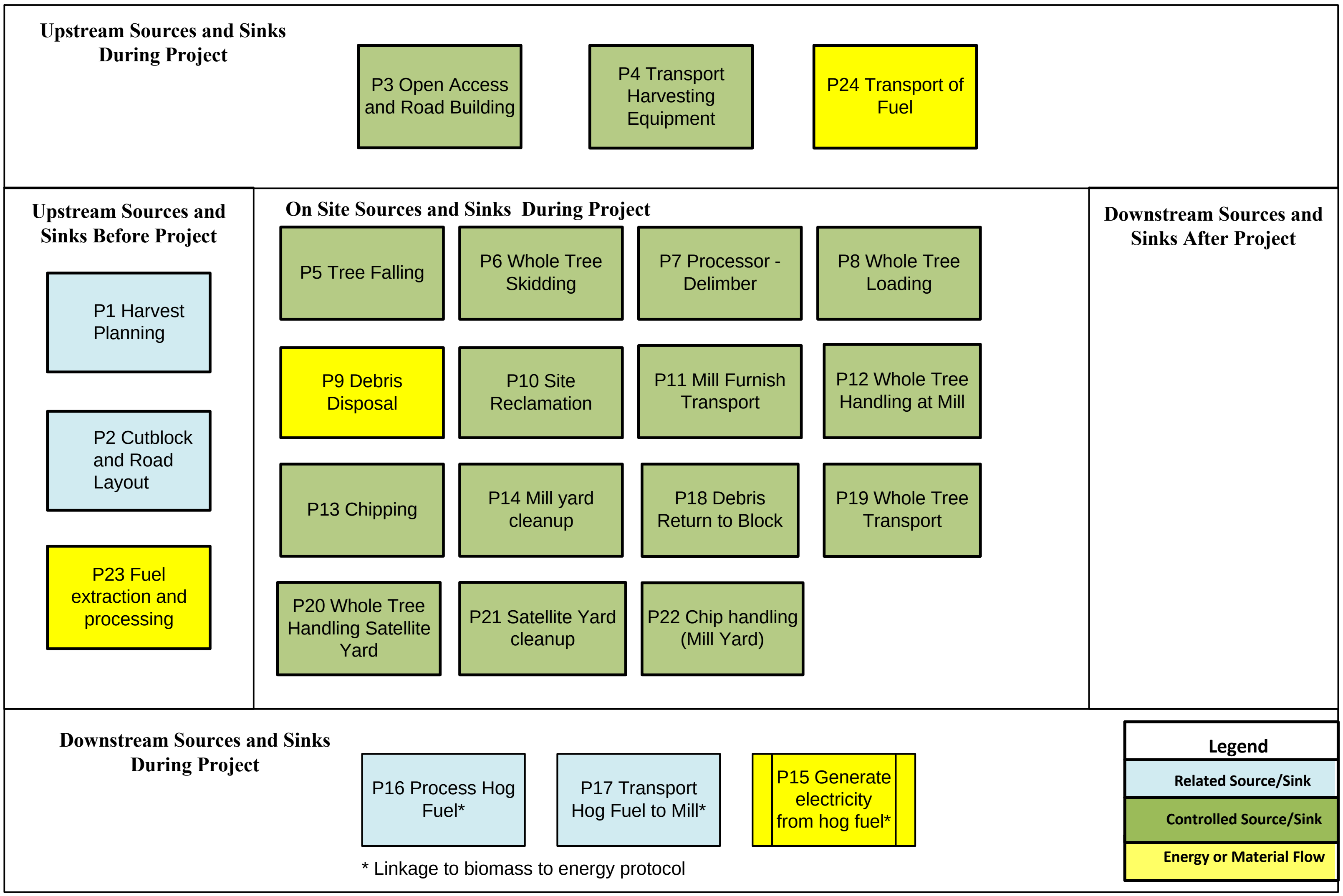


Figure 5: Project Conditions Sources and Sinks for Forest Harvesting Direct Reduction Protocol.

Table 4: Project Condition Sources and Sinks for the Forest Harvesting Direct Reduction Protocol.

Sources/Sinks	Description	Controlled, Affected, Related
Upstream Sources and Sinks Before Project		
P1 Harvest planning	Actions performed for entire Forest Management Area according to approved plans for harvest sequencing.	Related
P2 Cutblock and road layout	Actions specific to identified harvest cutblock. Includes map production.	Related
P23 Fuel extraction and processing	Upstream extraction and processing of diesel fuel.	Affected
P24 Transport of Fuel	Transportation of diesel fuel for onsite storage and use.	Related
Upstream Sources and Sinks During Project		
P3 Open access and road building	Diesel engine emissions from crawler tractors* and graders to open access from the haul road to the cutblock. Includes road clearing, levelling and grading. Also included is construction of landings used for processing, temporary storage, and loading of harvested trees.	Controlled
P4 Transport harvesting equipment	Diesel engine emissions from trucks required to transport harvest equipment to the cutblock.	Controlled
Onsite Sources and Sinks During Project		
P5 Tree falling	Diesel engine emissions from feller-bunchers* used to cut and fell trees according to utilization standards, block design and operating ground rules.	Controlled
P6 Whole tree skidding	Diesel engine emissions from skidders to transport felled whole trees to the landing, and by Butt 'n' top loaders* to pile trees for processing. Skidders use a grapple to grab and move trees laid down by the feller-buncher. Trees are delivered to the landing where they may be repositioned by loaders to facilitate access by the processor*.	Controlled
P7 Processor delimber	Diesel engine emissions from the processor to prepare whole trees for tree length hauling. Processing for tree length includes removing the branches and tops of each tree. Not applicable to in-block chipping Project Condition.	Controlled
P8 Whole tree loading	Diesel engine emissions from Butt 'n' top loaders to load whole trees on trucks for tree length hauling. Loaders take the trees that have had the branches and tops removed by the processor and use a boom to load trees onto waiting trucks. Not applicable to in-block chipping Project Condition.	Controlled
P9 Debris disposal	Amount (weight) of additional harvest debris burned. Not applicable to in-block chipping Project Condition.	Controlled
P10 Site reclamation	Diesel engine emissions from crawler tractors for block cleanup. Includes piling and redistribution of harvest debris on the cutblock.	Controlled
P11 Mill furnish transport	Diesel engine emissions from trucks for tree length hauling. This includes full cycle	Controlled

	emissions from loading to unloading and return.. Mill furnish is chips for in-block and satellite yard chipping Project Conditions, and tree length for mill yard chipping Project Condition.	
P12 Whole tree handling at mill	Diesel engine emissions from loaders to unload trucks and pile logs for later chipping. Includes additional handling to feed portable chippers located in the mill yard. Only applicable to mill yard chipping Project Condition.	Controlled
P13 Chipping	Diesel engine emissions used to power portable chippers that de-bark and chip trees. Chipping is whole trees, including large branches and tops, for in-block Project Condition.	Controlled
P14 Mill yard cleanup	Diesel engine emissions for crawler tractors for cleanup of the mill yard.	Controlled
P18 Debris return to block	Action unique to in-block chipping Project Condition. Diesel engine emission from skidder with modified bucket used to distribute debris from portable chipper back to the block while returning for another load of trees.	Controlled
P19 Whole tree transport	Action unique to satellite yard chipping Project Condition. Diesel engine emissions from trucks for tree length hauling from cutblock to satellite yard. This includes full cycle emissions from loading to unloading and return.	Controlled
P20 Whole tree handling at satellite yard	Diesel engine emissions from Butt'n'top loaders to unload trucks, pile and forward trees to portable chippers located in the satellite yard. Unique to satellite yard chipping Project Condition.	Controlled
P21 Satellite cleanup	Diesel engine emissions from crawler tractors for cleanup. Unique to satellite yard chipping Project Condition.	Controlled
P22 Chip handling mill yard	Diesel engine emissions from crawler tractors at the mill yard used for moving chips. Activity unique to mill yard chipping Project Condition.	Controlled
Downstream Sources and Sinks During Project		
P15 Electricity generated from hog fuel	Used only for cutblocks where hog fuel is being taken to generate electricity under the biomass to energy protocol.	Related. Energy or material flow
P16 Process hog fuel	Actions performed to grind and load hog fuel for transport.	Related
P17 Transport hog fuel	Actions performed by trucks to haul and unload hog fuel at mill.	Related
Downstream Sources and Sinks After Project		
	None	

*Examples of equipment shown in Appendix A

4.0 Quantification

Baseline and project conditions were compared to determine the scope for reductions quantified under this protocol. Sources and sinks were either included or excluded depending on how they were impacted by the project condition. Sources that are not expected to change between baseline and project condition are excluded from the project condition. It is assumed that excluded activities will occur at the same magnitude and emission rate during the baseline and project, and will therefore not be impacted by the project.

Emissions that increase or decrease as a result of the project and associated greenhouse gas emissions must be included as part of the protocol quantification. All sources and sinks identified in Tables 3 and 4 above are listed in Tables 5a, 5b, 5c and 5d below where Table 5a represents the baseline condition, which is then compared against Tables 5b (in-block portable chipping), 5c (satellite yard chipping) and 5d (mill yard chipping) as appropriate to the activity being undertaken. Each source and sink is listed as included or excluded. Justification for these choices is provided.

The following assumptions are used in this protocol for quantification of greenhouse gas emissions using the recommended method. These assumptions are intentionally conservative so that the chance of overestimating emission offsets is reduced, and confidence in the protocol is increased.

1. When total fuel volume is used, all diesel fuel is combusted and produces real greenhouse gas emissions assumed to be within the scope of the protocol.
2. Where manual calculation of transportation hours is used, loaded weight haul speed and fuel use rates will be used in all calculations.
3. All additional harvest debris calculated under this protocol due to differences in tree utilization consisting primarily of ends and large branches is assumed to be disposed of within the block by burning unless hog fuel was taken[3].
4. All additional harvest debris calculated under this protocol due to differences in tree utilization is assumed to be hog fuel where hog fuel was taken or, if unknown, for all cutblocks within an economical hog haul distance to the mill set as 60 kilometres.
5. Known quantity of hog fuel attributable to the in-block project condition must be discounted. This includes increases, if any, in hog fuel realized from additional breakage in satellite yard and mill yard portable chipping.

Note: Additional assumptions specific to the flexibility mechanisms are described in Appendix B.

[3] Hog fuel is assumed to be recoverable at a nominal economic haul distance from the mill site. At distances beyond the nominal economic haul distance, it is assumed to be disposed on site unless records indicate the use of the debris as hog fuel.

Table 5a: Comparison of Sources/Sinks. Baseline Condition.

Identified Sources and Sinks	Baseline (C, R, A)**	Project (C, R, A)**	Include or Exclude from Quantification	Justification for Inclusion/Exclusion
Upstream Sources/Sinks				
B1 Harvest planning	R	N/A	Exclude	No substantive differences between baseline and project condition.
B2 Cutblock and road layout	R	N/A	Exclude	No substantive differences between baseline and project condition.
B23 Fuel extraction and processing	A	N/A	Exclude	No substantive differences between baseline and project condition based on anticipated adoption of portable chipping technology.
B24 Transport of Fuel	R	N/A	Exclude	No substantive differences between baseline and project condition.
Onsite Sources/Sinks				
B3 Open access and road building	C	N/A	**Include**	Fewer log landings built with in-block project condition, but higher grade roads required for chip haulers.
B4 Transport harvesting equipment	C	N/A	**Include**	Additional transport of chippers must be quantified for project condition.
B5 Tree falling	C	N/A	**Include**	Volume gain associated with in-block project condition will result in less feller-buncher activity.
B6 Whole tree skidding	C	N/A	**Include**	Volume gain associated with in-block project condition will result in less skidder activity.
B7 Processor delimber	C	N/A	**Include**	Activity occurs in all but in-block project condition.
B8 Whole tree loading	C	N/A	**Include**	Activity occurs in all but in-block project condition.
B9 Debris disposal	C	N/A	**Include**	Additional debris disposal attributable to baseline condition, satellite yard project condition, and mill yard project condition.
B10 Site reclamation	C	N/A	**Include**	Substantial differences between baseline and in-block project condition.
B11 Mill furnish transport	C	N/A	**Include**	Substantial differences between baseline and project condition. Mill furnish is tree length for baseline and chips for project condition. .
B12 Tree handling at mill	C	N/A	**Include**	Activity unique to baseline condition and mill yard project condition.
B13 Chipping	C	N/A	**Include**	Substantial differences between baseline wood room chipping and project condition using portable chippers.
B14 Mill yard cleanup	C	N/A	**Include**	Substantial differences between baseline and project condition.
Downstream Sources/Sinks				

Identified Sources and Sinks	Baseline (C, R, A)**	Project (C, R, A)**	Include or Exclude from Quantification	Justification for Inclusion/Exclusion
B15 Electricity generated from hog fuel	R	N/A	**Include**	Substantial differences between baseline and in-block project condition. Hog fuel must be netted out to avoid double counting of greenhouse gas emissions.
B16 Process hog fuel	R	N/A	Exclude	Quantified under biomass to energy protocol.
B17 Transport hog fuel	R	N/A	Exclude	Quantified under biomass to energy protocol.
Other				
None				

**Where C is Controlled, R is Related, and A is Affected.

Table 5b: Comparison of Sources/Sinks. In-block Project Condition.

Identified Sources and Sinks	Baseline (C, R, A)**	Project (C, R, A)**	Include or Exclude from Quantification	Justification for Inclusion/Exclusion
Upstream Sources/Sinks				
P1 Harvest planning	N/A	R	Exclude	No substantive differences between baseline and project condition.
P2 Cutblock and road layout	N/A	R	Exclude	No substantive differences between baseline and project condition.
P23 Fuel extraction and processing	N/A	A	Exclude	No substantive differences between baseline and project condition based on anticipated adoption of portable chipping technology.
P24 Transport of Fuel	N/A	R	Exclude	No substantive differences between baseline and project condition.
Onsite Sources/Sinks				
P3 Open access and road building	N/A	C	**Include**	Fewer log landings built with in-block project condition, but higher grade roads required for chip haulers.
P4 Transport harvesting equipment	N/A	C	**Include**	Additional transport of chippers must be quantified for project condition.
P5 Tree falling	N/A	C	**Include**	Volume gain associated with in-block project condition will result in less feller-buncher activity.
P6 Whole tree skidding	N/A	C	**Include**	Volume gain associated with in-block project condition will result in less skidder activity.
P10 Site reclamation	N/A	C	**Include**	Substantial differences between baseline and in-block project condition.

Identified Sources and Sinks	Baseline (C, R, A)**	Project (C, R, A)**	Include or Exclude from Quantification	Justification for Inclusion/Exclusion
P11 Mill furnish transport	N/A	C	**Include**	Substantial differences between baseline and project condition. Mill furnish is tree length for baseline and chips for project condition. .
P13 Chipping	N/A	C	**Include**	Substantial differences between baseline wood room chipping and project condition using portable chippers.
P14 Mill yard cleanup	N/A	C	**Include**	Substantial differences between baseline and project condition.
P18 Debris return to block	N/A	C	**Include**	Activity unique to in-block project condition. Spreading of chip debris by skidder on return trip to block
Downstream Sources/Sinks				
None				
Other				
None				

**Where C is Controlled, R is Related, and A is Affected.

Table 5c: Comparison of Sources/Sinks. Satellite yard Project Condition.

Identified Sources and Sinks	Baseline (C, R, A)**	Project (C, R, A)**	Include or Exclude from Quantification	Justification for Inclusion/Exclusion
Upstream Sources/Sinks				
P1 Harvest planning	N/A	R	Exclude	No substantive differences between baseline and project condition.
P2 Cutblock and road layout	N/A	R	Exclude	No substantive differences between baseline and project condition.
P23 Fuel extraction and processing	N/A	A	Exclude	No substantive differences between baseline and project condition based on anticipated adoption of portable chipping technology.
P24 Transport of Fuel	N/A	R	Exclude	No substantive differences between baseline and project condition.
Onsite Sources/Sinks				
P3 Open access and road building	N/A	C	**Include**	Unchanged from the baseline condition. Differs with in-block project condition.
P4 Transport harvesting equipment	N/A	C	**Include**	Additional transport of chippers must be quantified for project condition.
P5 Tree falling	N/A	C	**Include**	Unchanged from the baseline condition. Differs with in-block project condition.

Identified Sources and Sinks	Baseline (C, R, A)**	Project (C, R, A)**	Include or Exclude from Quantification	Justification for Inclusion/Exclusion
P6 Whole tree skidding	N/A	C	**Include**	Unchanged from the baseline condition. Differs with in-block project condition.
P7 Processor delimber	N/A	C	**Include**	Unchanged from the baseline condition. Activity occurs in all but in-block project condition.
P8 Whole tree loading	N/A	C	**Include**	Unchanged from the baseline condition. Activity occurs in all but in-block project condition.
P9 Debris disposal	N/A	C	**Include**	Additional debris disposal attributable to baseline condition, satellite yard project condition, and mill yard project condition.
P10 Site reclamation	N/A	C	**Include**	Unchanged from the baseline condition. Substantial differences with in-block project condition.
P11 Mill furnish transport	N/A	C	**Include**	Mill furnish is tree length for baseline and mill yard project conditions, and chips for in-block and satellite yard project conditions.
P13 Chipping	N/A	C	**Include**	Substantial differences between baseline wood room chipping and project condition using portable chippers.
P14 Mill yard cleanup	N/A	C	**Include**	Substantial differences between baseline and project condition.
P19 Whole tree transport	N/A	C	**Include**	Activity unique to satellite yard project condition.
P20 Whole tree handling at satellite yard	N/A	C	**Include**	Activity unique to satellite yard project condition.
P21 Satellite yard cleanup	N/A	C	**Include**	Activity unique to satellite yard project condition.
Downstream Sources/Sinks				
P15 Electricity generated from hog fuel	N/A	R	**Include**	Unchanged from baseline condition. Emissions from hog fuel used for electrical co-gen must be netted out to avoid double counting of greenhouse gas emissions.
P16 Process hog fuel	N/A	R	Exclude	Quantified under biomass to energy protocol.
P17 Transport hog fuel	N/A	R	Exclude	Quantified under biomass to energy protocol.
Other				
None				

**Where C is Controlled, R is Related, and A is Affected.

Table 5d: Comparison of Sources/Sinks. Mill yard Project Condition.

Identified Sources and Sinks	Baseline (C, R, A)**	Project (C, R, A)**	Include or Exclude from Quantification	Justification for Inclusion/Exclusion
Upstream Sources/Sinks				
P1 Harvest planning	N/A	R	Exclude	No substantive differences between baseline and project condition.
P2 Cutblock and road layout	N/A	R	Exclude	No substantive differences between baseline and project condition.
P23 Fuel extraction and processing	N/A	A	Exclude	No substantive differences between baseline and project condition based on anticipated adoption of portable chipping technology.
P24 Transport of Fuel	N/A	R	Exclude	No substantive differences between baseline and project condition.
Onsite Sources/Sinks				
P3 Open access and road building	N/A	C	**Include**	Unchanged from the baseline condition. Differs with in-block project condition.
P4 Transport harvesting equipment	N/A	C	**Include**	Unchanged from the baseline condition.
P5 Tree falling	N/A	C	**Include**	Unchanged from the baseline condition.
P6 Whole tree skidding	N/A	C	**Include**	Unchanged from the baseline condition.
P7 Processor delimber	N/A	C	**Include**	Unchanged from the baseline condition.
P8 Whole tree loading	N/A	C	**Include**	Unchanged from the baseline condition.
P9 Debris disposal	N/A	C	**Include**	Additional debris disposal attributable to baseline condition, satellite yard project condition, and mill yard project condition.
P10 Site reclamation	N/A	C	**Include**	Unchanged from the baseline condition. Substantial differences with in-block project condition.
P11 Mill furnish transport	N/A	C	**Include**	Unchanged, mill furnish is tree length for baseline and mill yard conditions, chips for in-block and satellite yard project condition.
P12 Whole tree handling at mill	N/A	C	**Include**	Activity unique to baseline condition and mill yard project condition.
P13 Chipping	N/A	C	**Include**	Substantial differences between baseline wood room chipping and project condition using portable chippers.
P14 Mill yard cleanup	N/A	C	**Include**	Substantial differences between baseline and project condition.
P22 Chip handling mill yard	N/A	C	**Include**	Activity unique to mill yard project condition.
Downstream Sources/Sinks				

Identified Sources and Sinks	**Baseline (C, R, A)****	**Project (C, R, A)****	**Include or Exclude from Quantification**	**Justification for Inclusion/Exclusion**
P15 Electricity generated from hog fuel	N/A	R	**Include**	Unchanged from baseline condition. Emissions from hog fuel used for electrical co-generation must be netted out to avoid double counting of greenhouse gas emissions.
B16/P16 Process hog fuel	N/A	R	Exclude	Quantified under biomass to energy protocol.
B17/P17 Transport hog fuel	N/A	R	Exclude	Quantified under biomass to energy protocol.
Other				
None				

**Where C is Controlled, R is Related, and A is Affected.

4.1 Quantification Methodology

The general quantification approach for greenhouse gas emissions quantification under this protocol is shown below. Each equation is described and broken down in greater detail under individual subheadings, and where required, emissions factors[4] are provided.

1. Compression Ignition Engine Diesel (CIE-D) emissions (g/L) from Heavy Duty Diesel Vehicles (**EF** $_{HDDV}$) or from off-road vehicles (**EF** $_{off\text{-}road}$).[5]
2. Harvesting debris (**EF** $_{Wood}$) and/or waste wood emissions (g/kg) from combustion.[5,6]
3. Electrical power generation (**EF** $_{Power}$) emissions (g/kWh) in Alberta.[7]
4. Natural gas (**EF** $_{Natural\ gas}$) emissions (g/m^3) from Alberta-produced gas.[5]
5. Spent pulping liquor (**EF** $_{Pulp\ liquor}$) industrial combustion emissions.[5]
6. Wood fuel (**EF** $_{Wood\ fuel}$) industrial combustion emissions.[5]

$$\text{Emission Reduction} = \text{Emissions}_{Baseline} - \text{Emissions}_{Project}$$

$$\text{Emissions}_{Baseline} = \text{Emissions}_{Harvest} + \text{Emissions}_{Transportation} + \text{Emissions}_{Wood\ room} + \text{Emissions}_{Debris\ disposal} + \text{Emissions}_{Handling\ \&\ cleanup}$$

$$\text{Emissions}_{Project} = \Sigma\text{Emissions}_{In\text{-}block} + \Sigma\text{Emissions}_{Satellite\ yard} + \Sigma\text{Emissions}_{Mill\ yard}$$

$$\text{Emissions}_{In\text{-}block} = \text{Emissions}_{Harvest} + \text{Emissions}_{Transportation} + \text{Emissions}_{Handling\ \&\ cleanup}$$

$$\text{Emissions}_{Satellite\ yard} = \text{Emissions}_{harvest} + \text{Emissions}_{Transportation} + \text{Emissions}_{Debris\ disposal} + \text{Emissions}_{Handling\ \&\ cleanup}$$

$$\text{Emissions}_{Mill\ yard} = \text{Emissions}_{harvest} + \text{Emissions}_{Transportation} + \text{Emissions}_{Debris\ disposal} + \text{Emissions}_{Handling\ \&\ cleanup}$$

[4] CO_2e emission factors are sum of CO_2, CH_4 and N_2O emissions.
[5] National Inventory Report: Greenhouse Gas Sources and Sinks in Canada.
[6] Biogenic CO_2 emissions are no longer reported. Available from past NIR reports.
[7] Environment Canada (http://www.ec.gc.ca/ges-ghg/).

To ensure that the baseline is up to date and captures technological improvements, greenhouse gas quantification under this protocol may be performed in one-year increments to a maximum of five years. Harvest operations do not coincide with a calendar year and typically occur in the fall and winter. Quantification **must** therefore use a timber year (May to April) to ensure full accounting and to eliminate overlap between quantification done for sequential timber years.

4.2 Baseline Condition Quantification

Baseline condition greenhouse gas emissions are from the combustion of diesel fuel, open air combustion of harvest debris, and electrical energy use by wood room chipper operation. The same emission factors must be applied to both the baseline and project conditions in all cases. This ensures that any emission offsets quantified by this protocol are not a result of general improvements in technology associated with harvesting or other equipment operations.

One efficiency factor and three emission intensity factors are required for baseline quantification and are as follows:

1. Harvest emissions per m^3 harvested from comparison harvest(s).
2. Wood room energy (kW) required per m^3 chipped from historic records.
3. Additional wood handling and cleanup emissions per m^3 from historic records.
4. Tree utilization efficiency factor calculated using methodology described in Appendix C.

<u>Baseline Emissions Harvest [B3, B4, B5, B6, B7, B8, B10]</u>

Standard industry practice in Alberta is that the same group (e.g., contractor) is responsible for all aspects of harvest including: opening access to the harvest block, building roads and landings (B3), transporting equipment (B4), felling trees (B5), skidding (B6), processing trees for transport (B7), loading trees (B8), and block cleanup (B10).

Before quantification can begin, baseline harvest emissions must be generalized to tonnes CO_2 e per m^3 harvested to allow application to varying annual levels of harvest. Emissions generated from ongoing baseline harvests (whole tree harvest with tree length haul) can be used as a comparison per unit of harvest with the project condition. Emissions must be quantified from diesel engine emissions for all aspects of full tree harvest.

$$\textbf{Emissions}_{\textbf{Harvest}} = \textbf{m}^3 \textbf{ Harvested}_{\textbf{Project}} \textbf{ X Harvest emissions per m}^3$$

Where:

$$\textbf{m}^3 \textbf{ Harvested}_{\textbf{Project}} = \textbf{total project harvest for the year being quantified}$$

Harvest emissions per m^3 =
ΣCIE-D emissions $_{Comparison}$ / m^3 Harvested $_{Comparison}$

CIE-D emissions $_{Comparison}$ = diesel emissions from the comparison harvest(s)

m^3 Harvested $_{Comparison\ harvest}$ =
volume harvested from the comparison harvest(s)

CIE-D emissions = diesel fuel used (L) X EF $_{off\text{-}road}$

The equations provided here are generalized. It is the project developer's responsibility to maintain records for the comparison harvest(s) including a description of the data and its distribution.

Baseline Emissions Transportation [B11]

In order to perform the required calculations, it is necessary to first determine the log truck transport hours. A spatially explicit GIS-based sustainable forest management planning model such as Patchworks™ or similar model that includes sophisticated and flexible transportation modeling can be used for annual transportation emission quantification. This calculation can be performed using L/hour or L/km fuel consumption values. If manual calculation of transport hours is being used, a per-load haul weight or volume (m^3) of chip equivalent is used along with an average loaded haul speed[8]. Hours are multiplied by two (2) to account for the total travel distance (i.e., the full travel cycle). Fuel used is then summed by harvest block, groups of blocks (dispositions) or annually from the total hours required to transport the harvest.

Emissions $_{Transportation}$ = Litres of Fuel $_{transportation}$ X EF $_{HDDV}$

Where:

Litres of Fuel $_{transportation}$ = Hours X Fuel Use (L/hour)

Hours = ((m^3 harvested - (m^3 salvage + m^3 incidental))/45 m^3) X ((Haul distance (km) /Average speed (kph))*2)

If manual calculations are being used, operation specific fuel efficiency of the truck manufacturer's loaded fuel efficiency in L per hour may be used. The average haul speed depends on the road network, road quality and loading and unloading times. The average speed will be operator specific. Haul speeds are normally contained in operational ground and/or safety rules. Justification for the speed selected must be provided.

[8] Loaded haul speeds are used to ensure conservativeness in the calculations.

The per-load chip equivalent haul volume of 45 m^3 is a conservative estimate for standard tree length haul and may vary by operator. If a number other than 45 m^3 is being used, justification must be provided.

Baseline Emissions Wood Room (chipping) [B13]

Wood room calculations must be calculated on a per-m^3 of harvest basis where annual emissions associated with wood room chipping are calculated from the total energy (kW) that would have been required to power wood room chipping based on annual total volume chipped for each offset quantification year. Total volume chipped is sum of harvest, incidental and salvage volume processed by the portable chippers.

$$\textbf{Energy Required } (kW_{\text{wood room}}) = kW_{\text{wood room}} \textbf{ per } m^3 \times \textbf{Total Volume } m^3$$

Power is supplied to the mill from three potential emission sources:

1. on-site power generated from biomass fuelled co-gen facility (wood fuel and/or pulping liquor);
2. on-site power generated from natural gas consumption in a co-gen facility; and
3. power generated for the Alberta power grid.

Wood room green house gas emissions must be allocated proportionately using the appropriate emission factors for each source. The CO_2 emissions from combustion of renewable biomass for power generation cannot be included in offset calculations because these emissions are assumed to be biogenic, and only the CH_4 and N_2O emissions are quantified.

When the power generated at the co-gen facility from biomass combustion is sufficient to meet mill demand then the wood room greenhouse gas emissions are calculated entirely from CH_4 and N_2O emissions from combustion of hog fuel wood ($EF_{\text{Wood fuel}}$) and pulping liquor ($EF_{\text{Pulp liquor}}$).

When power generation at the co-gen facility does not meet mill demand, makeup power is required. In those years where makeup power is required, the percentage of make-up power from the Alberta grid (%Grid) and from natural gas (%NG) must also be used to quantify emissions. The percentages for fuel types must sum to 100, and can be obtained from annual specified gas compliance reports. Wood room chipping emissions are calculated as:

$$\begin{aligned} \textbf{Emissions}_{\text{wood room}} = &(\%Grid \times kW_{\text{wood room}} \times EF_{\text{Power}}) \\ &+ (\%NG \times kW_{\text{wood room}} \times EF_{\text{Natural gas}}) \\ &+ (\%Wood\ Fuel \times kW_{\text{wood room}} \times EF_{\text{Wood Fuel}}) \\ &+ (\%Pulp\ liquor \times kW_{\text{wood room}} \times EF_{\text{Pulp liquor}}) \end{aligned}$$

Where:

$$\%Grid + \%NG + \%Wood\ Fuel + \%Pulp\ liquor = 100$$

$$kW_{\text{wood room}} = kW_{\text{wood room}} \textbf{ per } m^3 \times \textbf{Harvest } m^3$$

$kW_{wood\ room}$ per m^3 = kW required per m^3 chipped from historic records

Harvest m^3 = Harvest volume for the year being quantified

Baseline Emissions Debris Disposal [B9, B15]

The difference in debris biomass must be calculated in order to account for differences in emissions attributable to debris disposal between the baseline condition and in-block chipping project condition. The difference in debris biomass represents the difference in tree utilization efficiency between full tree harvesting and in-block chipping. This calculation applies to satellite yard and mill yard project conditions that also use full tree harvesting and tree length hauling. The debris difference is calculated as a proportion of the tonnes harvested less the incidental and salvaged tonnes estimated directly from scaled weight and/or volume numbers.

Initial debris biomass weight (Wt_{debris}) =
(Tonnes harvested - (Tonnes salvage + Tonnes incidental)) X increased utilization proportion

The increased utilization will vary based on the condition of the harvested stand and the harvesting operations employed. Appendix C provides a description of factors that must be considered to determine the increased utilization proportion of the tree, which is composed of large branches, ends, and harvest of smaller trees that would otherwise go to debris and/or hog fuel depending on presence of a biomass-fuelled electrical co-gen facility and proximity to the mill. Additional debris biomass not transported to the mill as hog fuel is disposed of by in-block burning.

For quantification where no hog fuel harvest occurs, the calculation of emissions from debris disposal is the weight of debris multiplied by the emission factor for burning of waste wood (EF_{Wood}):

$$Emissions_{Debris\ disposal} = Wt_{debris} \times EF_{Wood}$$

Biomass-fuelled electrical co-gen facilities located at the mill are common in the forest industry. These facilities are powered by a variety of biomass sources including hog fuel derived from harvest debris. Where hog fuel harvest takes place, calculations **must** assume that 100 per cent of the debris biomass calculated from differences in tree utilization efficiency is used for hog fuel if it is within the nominal economical hog hauling distance to the mill. **These emissions must be discounted from the baseline emissions.**

If realized hog (the amount of hog taken from each harvest block) is known, this number can be used for offset quantification purposes. In this case, the realized hog **must** be discounted and only the difference between realized and additional debris biomass weight (Wt debris) is used for calculating offsets. Calculations can be done on a per cutblock basis or from total annual volumes. Because harvest debris disposal for the baseline, satellite yard, and mill yard conditions are the same, only those blocks where in-block chipping occurred need to be quantified.

$$\textbf{Emissions}_{\textbf{Debris disposal}} = \Sigma\textbf{Emissions}_{\textbf{no hog}} + \Sigma\textbf{Emissions}_{\textbf{hog}}$$

Where:

$$\textbf{Emissions}_{\textbf{no hog}} = \textbf{Wt}_{\textbf{no hog}} \textbf{ X EF}_{\textbf{Wood}}$$

$$\textbf{Emissions}_{\textbf{hog}} = (\textbf{Wt}_{\textbf{hog}} - \textbf{realized hog}) \textbf{ X EF}_{\textbf{Wood}}$$

Realized hog is the actual weight of hog fuel (from records) provided to the co-gen facility. The subscripts "hog" and "no hog" are used to indicate where hog fuel was or was not harvested. This is typically determined based on a nominal economical hog fuel haul distance from the mill. The emission factor EF_{Wood} is the combustion of waste wood.

If hog fuel is taken that is not quantified under the biomass to energy protocol or reported as part of facility (mill) emissions, then emissions from processing (B16) and transporting (B17) of hog fuel must also be quantified and accrued to the baseline and project conditions.

Handling & Cleanup [B12, B14]

Emissions associated with additional wood handling and cleanup are from diesel fuel combustion, and are calculated from total fuel consumption multiplied by the emission factor for off road vehicles. Use of total fuel consumption was chosen as it captures all activities and equipment types and thus provides the most robust and accurate measure of emissions. Under the baseline condition, handling and cleanup emissions are emissions associated with the unloading, moving, piling, and cleanup of wood in the mill yard performed by a variety of equipment including Wagners, loaders, tractors, and graders.

$$\textbf{Emissions}_{\textbf{Handling \& Cleanup}} = \textbf{Diesel fuel use (L) X EF}_{\textbf{off-road}}$$

Historical comparison records may be used to determine a fuel use per m^3 of harvest if the baseline condition is no longer being practiced (i.e., portable chipping has replaced wood room chipping). Handling and cleanup emissions would be quantified by multiplying by the fuel use per m^3 of harvest by the annual harvest for the year being quantified.

$$\textbf{Emissions}_{\textbf{Handling \& Cleanup}} = \textbf{m}^3 \textbf{ Harvest}_{\textbf{Project}} \textbf{ X Handling\&Cleanup emissions per m}^3$$

Where:

$$\textbf{m}^3 \textbf{ Harvested}_{\textbf{Project}} = \textbf{total project harvest for the year being quantified}$$

Handling & Cleanup emissions per m^3 =
ΣCIE-D emissions $_{Comparison}$ / m^3 Harvested $_{Comparison}$

CIE-D emissions $_{Comparison}$ = diesel (CIE-D) emissions from the comparison

m^3 Harvested $_{Comparison}$ =
harvest volume handled during the comparison period

CIE-D emissions = diesel fuel used (L) X EF $_{off\text{-}road}$

The equations provided here are generalized. It is the project developer's responsibility to maintain records for the comparison harvest(s) including a description of the data and its distribution.

4.3 In-Block Project Condition Quantification

All in-block project condition emissions are from consumption of diesel fuel.

Emissions $_{In\text{-}block}$=
Emissions $_{Harvest}$ + Emissions $_{Transportation}$ + Emissions $_{Handling\ \&\ cleanup}$

Note: The differences in harvest debris and/or hog fuel volume are accrued to the baseline condition and are **not** included in the project condition calculations. All other differences between in-block chipping and the baseline condition including road and landing building, equipment transport, and portable chipper use are captured in the total fuel consumption for the project. Mill furnish transportation must be calculated separately and added to the project condition.

Emissions Harvest [P3, P4, P5, P6, P10, P13, P18]

Emissions associated with diesel engines are calculated from total fuel consumption. Use of total fuel consumption was chosen as it captures all activities and equipment types and therefore provides the most robust and accurate measure of emissions for the project. Total fuel use is obtained from records, but may also be calculated using equipment type and hours of operation as described in Appendix B.

Standard industry practice is that the same group (e.g., contractor) is responsible for all aspects of harvest including: opening access to the harvest block, building roads and landings (P3), transporting equipment (P4), felling trees (P5), skidding (P6), site cleanup (P10), operation of portable chippers (P13), and returning unusable debris from the chippers to the block (P18).

Emissions $_{Harvest}$ = Diesel fuel use (L) X EF $_{off\text{-}road}$

Transportation (in-block chipping) [P11]

In order to perform the required calculations, it is necessary to first determine the log truck transport hours. A spatially explicit GIS-based sustainable forest management planning model such as Patchworks™ or similar model that includes sophisticated and flexible transportation modeling can be used for annual transportation emission quantification. This calculation can be performed using L/hour or L/km fuel consumption values. If manual calculation of transport hours is being used, a per-load haul weight or volume (m^3) of chips is used along with an average loaded haul speed[9]. Hours are multiplied by two (2) to account for the total travel distance (i.e., the full travel cycle). Fuel used is then summed by harvest blocks, groups of blocks (dispositions) or annually from the total hours required to transport the harvest.

$$\textbf{Emissions}_{\textbf{Transportation}} = \textbf{Fuel}_{\textbf{transportation}} \textbf{ X EF}_{\textbf{HDDV}}$$

Where:

$$\textbf{Fuel}_{\textbf{transportation}} = \textbf{Hours X Fuel Use (L/hour)}$$

$$\textbf{Hours} = ((\textbf{m}^3 \textbf{ harvested} - (\textbf{m}^3 \textbf{ salvage} + \textbf{m}^3 \textbf{ incidental}))/60.5\ \textbf{m}^3) \textbf{ X } ((\textbf{Haul distance (km)} / \textbf{Average speed (km/h)})*2)$$

If manual calculations are being used, the truck manufacturer's loaded fuel efficiency in L per hour may be used. The average haul speed depends on the road network, road quality and loading and unloading times. The average speed will be operator specific. Haul speeds are normally contained in operational ground and/or safety rules. Justification for the speed selected must be provided.

The per-load chip equivalent haul volume of 60.5 m^3 is a conservative estimate for standard B-train configuration chip haul and may vary by operator. If a number other than 60.5 m^3 is being used, justification must be provided.

Handling & Cleanup [P14]

Emissions associated with additional wood handling and cleanup are from diesel fuel combustion, and are calculated from total fuel consumption multiplied by the emission factor for off road vehicles. Use of total fuel consumption was chosen as it captures all activities and equipment types and therefore provides the most robust and accurate measure of emissions for the project.

Under the in-block chipping project condition, handling and cleanup emissions are emissions associated with the unloading, moving, piling, and cleanup of wood chips in the mill yard.

$$\textbf{Emissions}_{\textbf{Handling \& Cleanup}} = \textbf{Diesel fuel use (L) X EF}_{\textbf{off-road}}$$

[9] Loaded haul speeds are used to ensure conservativeness in the calculations.

4.4 Satellite Yard Project Condition Quantification

The satellite yard project condition includes four components:

$$\textbf{Emissions}_{\text{Satellite yard}} = \textbf{Emissions}_{\text{harvest}} + \textbf{Emissions}_{\text{Transportation}} + \textbf{Emissions}_{\text{Debris disposal}} + \textbf{Emissions}_{\text{Handling \& cleanup}}$$

Additional transportation requirements (P19), wood handling at the satellite yard (P20), and satellite yard cleanup (P21) are the only calculations unique to the satellite yard project condition.

Emissions Harvest [P3, P4, P5, P6, P7, P8, P10, P13, P20, P21]

Emissions associated with harvest are from diesel engines and are calculated from total fuel consumption. Total fuel consumed is from records, but may also be calculated using equipment type and hours of operation as described in Appendix B. Standard Alberta industry practice is that the same group (e.g., contractor) is responsible for all aspects of harvest including: opening access to the harvest block, building roads and landings (P3), transporting equipment (P4), felling trees (P5), skidding (P6), processing trees for transport (P7), loading trees for transport (P8), site cleanup (P10), operation of portable chippers (P13), wood handling at the satellite yard (P20), and satellite yard cleanup (P21).

$$\textbf{Emissions}_{\text{CIE-D}} = \textbf{Diesel fuel use (L) X EF}_{\text{off-road}}$$

The satellite yard project condition may not always be associated with a harvest, but instead be composed of incidental and salvage wood from other sources (e.g., oil and gas development and softwood quota holders). When not associated with a harvest, harvest emissions P3, P4, P5, P6, P7, P8, and P10 are excluded.

Transportation (satellite yard chipping) [P19, P11]

In order to perform the required calculations, it is necessary to first determine the log truck transport hours. A spatially explicit GIS-based sustainable forest management planning model such as Patchworks™ or similar model that includes sophisticated and flexible transportation modeling can be used for annual transportation emission quantification. This calculation can be performed using L/hour or L/km fuel consumption values.

Satellite yard chipping requires two transportation calculations. The first is tree length haul from the harvest block to the satellite yard (P19), and the second is transportation of chips from the satellite yard to the mill (P11). If manual calculation of transport hours is being used, a per-load haul weight or volume (m^3) of chip equivalent is used along with an average loaded haul speed[10]. Average haul speed based on loaded haul speeds must also be determined for each portion (block to satellite yard, and satellite yard to mill).

[10] Loaded haul speeds are used to ensure conservativeness in the calculations.

Hours are multiplied by two (2) to account for the total travel distance (i.e., the full travel cycle). Fuel used is then summed by harvest blocks, groups of blocks (dispositions) or annually from the total hours required to transport the harvest to the satellite yard, and fuel is also summed for transport from the satellite yard to the mill.

The satellite yard project condition must include all chip hauling including incidental and salvage wood (e.g., softwood quota holder, oil & gas development) from all sources within the scope of the project.

$$\textbf{Emissions}_{\textbf{Transportation}} = \textbf{Fuel}_{\textbf{transportation}} \textbf{ X EF}_{\textbf{HDDV}}$$

Where:

$$\textbf{Fuel}_{\textbf{transportation}} = (\textbf{Hours}_{\textbf{tree length}} + \textbf{Hours}_{\textbf{chips}}) \textbf{ X Fuel Use (L/hour)}$$

$$\textbf{Hours}_{\textbf{tree length}} = ((\textbf{m}^3 \textbf{ harvested - (m}^3 \textbf{ salvage + m}^3 \textbf{ incidental))/45 m}^3) \textbf{ X ((Haul distance (km) /Average speed (kph))*2)}$$

$$\textbf{Hours}_{\textbf{chips}} = (\textbf{Yard Volume m}^3 \textbf{ / 60.5 m3)*((Haul distance (km) /Average speed}_{\textbf{chips}} \textbf{ (kph))*2)}$$

Yard Volume m^3 = volume of wood chipped at the satellite yard, including incidental and salvaged wood within project scope.

If manual calculations are being used, the truck manufacturer's loaded fuel efficiency in L per hour may be used. The average haul speed depends on the road network, road quality and loading and unloading times. The average speed will be operator specific. Haul speeds are normally contained in operational ground and/or safety rules. Justification for the speed selected must be provided.

The per-load chip equivalent haul volume of 45 m^3 for tree length and 60.5 m^3 for standard B-train configuration chip haul are conservative estimates and may vary by operator. If a number other than 45 m^3 or 60.5 m^3 is being used, justification must be provided.

Debris disposal [P9, P15]

These operating conditions are unchanged from the baseline condition and are quantified the same way. The initial difference in debris biomass must be calculated in order to account for differences in emissions attributable to debris disposal between full tree harvest with and without in-block chipping. The difference in debris biomass represents the difference in tree utilization efficiency and also is applied to satellite yard and mill yard project calculations.

Note: Debris disposal can be excluded where individual harvest block records are being used to locate and quantify only those blocks where in-block chipping occurred.

Exclusion is possible because harvest debris disposal for the baseline, satellite yard, and mill yard conditions are the same.

Handling & Cleanup [P14]

Emissions associated with additional wood handling and cleanup result from diesel engine use and are calculated from total fuel consumption multiplied by the emission factor for off road vehicles. Under the satellite yard chipping project condition, handling and cleanup emissions are emissions associated with the unloading, moving, piling, and cleanup of wood chips in the mill yard.

$$\textbf{Emissions}_{\textbf{Handling \& Cleanup}} = \textbf{Diesel fuel use (L) X EF}_{\textbf{off-road}}$$

Note: handling and cleanup in the satellite yard (P20, P21) are included in with harvest emissions.

4.5 Mill Yard Project Condition Quantification

Mill yard portable chipping is very similar to the baseline condition with the exception of the replacement of electrically powered wood room chipping with portable chippers located in the mill yard, and chip handling at the mill (P22). The mill yard Project Condition includes four components:

$$\textbf{Emissions}_{\textbf{Mill yard}} = \textbf{Emissions}_{\textbf{Harvest}} + \textbf{Emissions}_{\textbf{Transportation}} + \textbf{Emissions}_{\textbf{Debris disposal}} + \textbf{Emissions}_{\textbf{Handling \& cleanup}}$$

Emissions Harvest [P3, P4, P5, P6, P7, P8, P10, P13, P22]

Emissions associated with diesel engines are calculated from total fuel consumption. Standard industry practice in Alberta is that the same group (e.g., contractor) is responsible for all aspects of harvest including: opening access to the harvest block, building roads and landings (P3), transporting equipment (P4), felling trees (P5), skidding (P6), processing trees for transport (P7), loading trees for transport (P8), site cleanup (P10), operation of portable chippers (P13), chip handling at the mill yard (P22).

$$\textbf{Emissions}_{\textbf{Harvest}} = \textbf{Diesel fuel use (L) X EF}_{\textbf{off-road}}$$

Transportation (Mill yard Chipping) [P11]

Calculation of transportation for the mill yard project condition is the same tree length haul as described for the baseline condition (B11).

Debris disposal [P9, P15]

Calculation of debris disposal is identical to the baseline (B9, B15) and satellite yard conditions.

Note: Debris disposal can be excluded where individual harvest block records are being used to locate and quantify only those blocks where in-block chipping occurred. Exclusion is possible because harvest debris disposal for the baseline, satellite yard, and mill yard conditions are the same.

Handling & Cleanup [P12, P14]

Calculation of wood handling and cleanup emissions is from whole tree handling at the mill yard (P12) and mill yard cleanup (P14). Emissions are the sum of diesel fuel used, from records, multiplied by the emission factor for off road vehicles.

$$\textbf{Emissions}_{\textbf{Handling \& cleanup}} = \textbf{Diesel fuel use (L) X EF}_{\textbf{off-road}}$$

Table 6: Quantification Methodology

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify measurement or estimation and frequency
Baseline Condition						
Source/Sink B5, B6, B7, B8, B10	Emissions $_{Harvest}$ = m^3 Harvested $_{Project}$ X Harvest emissions per m^3 Harvest emissions per m^3 = ΣCIE-D emissions $_{Comparison\ harvest}$ / m^3 Harvested $_{Comparison\ harvest}$ CIE-D emissions = Σ diesel fuel used (L) X EF $_{off\text{-}road}$					
	units of harvest	Volume of harvest (m^3)	Measured	From scale and/or block records.	Once. Reviewed annually.	Must be repeated if Baseline Condition (full tree harvest with tree length hauling) technology changes, substantial improvements occur, or forest utilization standards change..
	Diesel fuel consumed; CIE-D	Diesel fuel consumed (L)	Measured or estimated	From records, measured directly. May also be estimated from equipment type and hours of use.	Once. Reviewed annually	Must be repeated if Baseline Condition (full tree harvest with tree length hauling) technology changes or substantial improvements occur.
	EF $_{off\text{-}road}$	CO_2e (g/L)	Estimated	From Environment Canada reference documents	Annually	Must use most current emission factor for off-road Diesel Vehicles. National Inventory Report (NIR): Greenhouse Gas Sources and Sinks in Canada.
Source/Sink B11	Emissions $_{Transportation}$ = Fuel $_{transportation}$ X EF $_{HDDV}$; Fuel $_{transportation}$ = Hours X Fuel Use (L/hour) Hours = ((m^3 harvested - (m^3 salvage + m^3 incidental))/chip equivalent m^3) X ((Haul distance (km) /Average speed (kph))*2)					
	EF $_{HDDV}$	CO_2e (g/L)	Estimated	From Environment Canada reference documents	Annually	Must use most current emission factor for Heavy Duty Diesel Vehicles. National Inventory Report (NIR): Greenhouse Gas Sources and Sinks in Canada.
	m^3 harvested	m^3	Measured	From scale and/or block records	Annually	Required for every block or groups of blocks in which an offset is to be quantified.
	m^3 salvage	m^3	Measured	From scale and/or block records	Annually	Required for every block or group of blocks in which an offset is to be quantified. Must be deducted as salvage tonnes are out of scope.
	m^3incidental	m^3	Measured	From scale and/or block records	Annually	Required for every block or group of blocks in which an offset is to be quantified. Must be deducted as salvage tonnes are out of scope.

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify measurement or estimation and frequency
	chip equivalent m^3	m^3	Estimated	Determined based on haul m^3 measured in chip equivalents. Operator specific.	Annually	For manual calculation of transport hours, a per-load tree length haul of 45 m^3 of chip equivalent is used for tree length transport. The per-load haul of 45 m^3 for tree length hauling is a conservative estimate based on the protocol Initiating Entities hauling configuration, and may vary by operator.
	Haul distance	km	Measured	GIS-based program and/or maps	Annually	Transportation distance must be calculated using the same harvest blocks as the Project Condition to ensure differences are attributable to differences in efficiency and not in road network and/or road quality.
	Average speed	kph	Estimated	Estimated from GIS based program or measured.	Annually	Average haul speed must be calculated using the same harvest blocks as the Project Condition to ensure differences are attributable to differences in efficiency and not in road network and/or road quality. Average speed must include loading and unloading wait times.
	Fuel Use	L/hour	Estimated	From operation specific information or truck manufacturers loaded fuel use rate information	N/A	Must use most recent manufacturer specific information.
Source/Sink B13	$kW_{wood\ room} = kW_{wood\ room}$ per m^3 x Harvest m^3 $Emissions_{wood\ room} = (\%Grid \times kW_{wood\ room} \times EF_{Power}) + (\%NG \times kW_{wood\ room} \times EF_{Natural\ gas}) + (\%Wood\ Fuel \times kW_{wood\ room} \times EF_{Wood\ Fuel}) + (\%Pulp\ liquor \times kW_{wood\ room} \times EF_{Pulp\ liquor})$					
	$kW_{wood\ room}$ per m^3	kW; m^3	Measured	From electrical use (kW) and volume chipped (m^3) records	Once (Historical)	The electrical power required to operate wood room chipper for each unit of harvest. Can be calculated using annual numbers and therefore will capture the range of log quality and size.
	%Grid	None	Measured	Percentage of facility power from Alberta electrical grid.	Annually	Calculated from annual records of facility power use. Note that %Grid + %NG + %Wood Fuel + %Pulp liquor must sum to 100.

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify measurement or estimation and frequency
	%NG	None	Measured	Percentage of facility power from Alberta produced natural gas consumed in onsite co-gen facility.	Annually	Calculated from annual records of facility power use. Note that %Grid + %NG + %Wood Fuel + %Pulp liquor must sum to 100.
	%Wood Fuel	None	Measured	Percentage of facility power from hog wood fuel consumed in onsite co-gen facility.	Annually	Calculated from annual records of facility power use. Note that %Grid + %NG + %Wood Fuel + %Pulp liquor must sum to 100.
	%Pulp liquor	None	Measured	Percentage of facility power from spent pulping liquor consumed in onsite co-gen facility.	Annually	Calculated from annual records of facility power use. Note that %Grid + %NG + %Wood Fuel + %Pulp liquor must sum to 100.
	EF_{Power}	CO_2e (g/kWh)	Estimated	From Environment Canada reference documents	Annually	Must use most current emission factor for power generated in Alberta. National Inventory Report (NIR): Greenhouse Gas Sources and Sinks in Canada.
	$EF_{Natural\ Gas}$	CO_2e (g/m^3)	Estimated	From Environment Canada reference documents	Annually	Must use most current emission factor for power generated in Alberta. National Inventory Report (NIR): Greenhouse Gas Sources and Sinks in Canada.
	$EF_{Wood\ Fuel}$	CO_2e (g/kg)	Estimated	From Environment Canada reference documents	Annually	Must use most current emission factor for power generated in Alberta. National Inventory Report (NIR): Greenhouse Gas Sources and Sinks in Canada
	$EF_{Pulp\ liquor}$	CO_2e (g/kg)	Estimated	From Environment Canada reference documents	Annually	Must use most current emission factor for power generated in Alberta. National Inventory Report (NIR): Greenhouse Gas Sources and Sinks in Canada
Source/Sink B9, B15	Initial debris biomass weight (Wt) = (Tonnes harvested - (Tonnes salvage + Tonnes incidental)) x increased utilization proportion $Emissions_{Debris\ disposal} = Emissions_{no\ hog} + Emissions_{hog}$ $Emissions_{no\ hog} = Wt_{no\ hog} \times EF_{Wood}$ $Emissions_{hog} = (Wt_{hog} – realized\ hog) \times EF_{Wood}$					
	Tonnes harvested	Tonnes	Measured	Scale	Annually	Must use most accurate harvest numbers in all calculations.
	Tonnes salvage	Tonnes	Measured	Scale or load estimate	Annually	Required to ensure no overestimation of harvest occurs.

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify measurement or estimation and frequency
	Tonnes incidental	Tonnes	Measured	Scale or load estimate	Annually	Required to ensure no overestimation of harvest occurs.
	increased utilization proportion	Proportion	Estimated	Derived from replicated study and corrected for expected harvest stand condition (tree size and density)	Periodic	Properly implemented replicated study that includes the range of stand conditions need not be repeated unless technological or operational change occurs. Results from the study may require periodic correction (adjustment) when stand conditions change. Assessed from approved harvest plans and forest inventory data.
	EF_{Wood}	CO_2e (g/kg)	Estimated	From IPCC, Environment Canada, or other recognized reference documents	Annually	Must use most current emission factor for waste wood burning.
	$Wt_{no\ hog}$	Tonnes	Measured, Estimated	Scale or derived from economical hog fuel haul distance from the mill	Annually	Harvest tonnes from harvest blocks where hog fuel harvesting did not occur. Required to ensure no double accounting of GHG emissions.
	Wt_{hog}	Tonnes	Measured, Estimated	Scale or derived from economical hog fuel haul distance from the mill	Annually	Harvest tonnes from harvest blocks where hog fuel harvesting did occur. Required to ensure no double accounting of GHG emissions.
	realized hog	Tonnes	Measured	Scale	Annually	Required to discount hog fuel used for energy production. Tonnes from harvest blocks where hog fuel harvesting did occur.
Source/Sink B12, B14	$Emissions_{Handling\ \&\ cleanup}$ = Diesel fuel use (L) X $EF_{off\text{-}road}$					
	Diesel fuel use	Litres (L)	Estimated	From records or calculated on a unit basis	Annually	Required for annual offset quantification.
	$EF_{off\text{-}road}$	CO_2e (g/L)	Estimated	From Environment Canada reference documents	Annually	Must use most current emission factor for off-road Diesel Vehicles. National Inventory Report (NIR): Greenhouse Gas Sources and Sinks in Canada.
Project Condition						
Source/Sink P3, P4, P5, P6, P7, P8,	$Emissions_{Harvest}$ = Diesel fuel use (L) X $EF_{off\text{-}road}$					
	Diesel fuel use	Litres (L)	Estimated/ Measured	From records or calculated on a unit basis	Annually	Required for annual offset quantification.

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify measurement or estimation and frequency
P10, P12, P13, P18, P20, P21, P22	$EF_{off\text{-}road}$	CO_2e (g/L)	Estimated	From Environment Canada reference documents	Annually	Must use most current emission factor for off-road Diesel Vehicles. National Inventory Report (NIR): Greenhouse Gas Sources and Sinks in Canada.
Source/Sink P11, P19	$Emissions_{Transportation} = Fuel_{transportation} \times EF_{HDDV}$; $Fuel_{transportation}$ = (Hours tree length + Hours chip) X Fuel Use (L/hour) Hours chips = (Yard Volume m^3 / 60.5 m^3)*((Haul distance (km) /Average speed chips (kph))*2) Yard Volume m^3 = volume of wood chipped at the satellite yard, including incidental and salvaged wood within project scope. Hours tree length = ((m^3 harvested - (m^3 salvage + m^3 incidental))/(chip equivalent m^3))*((Haul distance(km) /Average speed(kph))*2)					
	EF_{HDDV}	CO_2e (g/L)	Estimated	From Environment Canada reference documents	Annually	Must use most current emission factor for Heavy Duty Diesel Vehicles. National Inventory Report (NIR): Greenhouse Gas Sources and Sinks in Canada.
	Fuel Use	L/hour	Estimated	From truck manufacturers loaded fuel use rate information	N/A	Must use most recent manufacturer specific information.
	m^3harvested	m^3	Measured	Scale	Annually	Must use most accurate harvest numbers in all calculations
	m^3salvage	m^3	Measured	Scale or load estimate	Annually	Required to ensure no overestimation of harvest occurs.
	m^3incidental	m^3	Measured	Scale or load estimate	Annually	Required to ensure no overestimation of harvest occurs.
	Chip equivalent m^3	m^3	Estimated	Determined based on haul weight measured in chip equivalents. Operator specific.	Annually	For manual calculation of transport hours, a per-load tree length haul of 45 m^3 of chip equivalent is used for tree length transport, and 60.5 m3 per load is used for chip haul. The per-load chip equivalent haul volume of 45 m^3 for tree length and 60.5 m^3 for standard B-train configuration chip haul are conservative estimates and may vary by operator. If a number other than 45 m^3 or 60.5 m^3 is being used, justification must be provided.

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify measurement or estimation and frequency
	Haul distance	km	Measured	GIS-based program and/or maps	Annually	Transportation distance must be calculated using the same harvest blocks as the Baseline Condition to ensure differences are attributable to differences in efficiency and not in road network and/or road quality.
	Average speed	kph	Estimated	Estimated from GIS-based program or measured.	Annually	Average haul speed must be calculated using the same harvest blocks as the Baseline Condition to ensure differences are attributable to differences in efficiency and not in road network and/or road quality. Average speed must include loading and unloading wait times.
Source/Sink P9, P15	Initial debris biomass weight (Wt) = (Tonnes harvested - (Tonnes salvage + Tonnes incidental)) x increased utilization proportion $Emissions_{Debris\ disposal} = Emissions_{no\ hog} + Emissions_{hog}$ $Emissions_{no\ hog} = Wt_{no\ hog} \times EF_{Wood}$ $Emissions_{hog} = (Wt_{hog} - realized\ hog) \times EF_{Wood}$					
	Tonnes harvested	Tonnes	Measured	Scale	Annually	Must use most accurate harvest numbers in all calculations.
	Tonnes salvage	Tonnes	Measured	Scale or per-load estimate	Annually	Required to ensure no overestimation of harvest occurs.
	Tonnes incidental	Tonnes	Measured	Scale or per-load estimate	Annually	Required to ensure no overestimation of harvest occurs.
	Increased utilization proportion	Proportion	Estimated	Derived from replicated study and corrected for expected harvest stand condition (tree size and density)	Periodic	Properly implemented inventory study that includes the entire range of merchantable stand conditions need not be repeated unless technological or operational change occurs. Results from the study may require periodic correction (adjustment) when stand conditions change, and the most recent factor should be used. Assessed from approved harvest plans and forest inventory data.
	EF_{Wood}	CO_2e (g/kg)	Estimated	From IPCC, Environment Canada, or other recognized reference documents	Annually	Must use most current emission factor for waste wood burning.

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify measurement or estimation and frequency
	$Wt_{no\ hog}$	Tonnes	Measured or Estimated	Scale or derived from economical hog fuel haul distance from the mill	Annually	Harvest tonnes from harvest blocks where hog fuel harvesting did not occur. Required to ensure no double accounting of GHG emissions.
	Wt_{hog}	Tonnes	Measured or Estimated	Scale or derived from economical hog fuel haul distance from the mill	Annually	Harvest tonnes from harvest blocks where hog fuel harvesting did occur. Required to ensure no double accounting of GHG emissions.
	Realized hog	Tonnes	Measured	Scale	Annually	Required to discount hog fuel used for energy production. Tonnes from harvest blocks where hog fuel harvesting did occur.
Source/Sink P 14	$Emissions_{Handling\ \&\ cleanup}$ = Diesel fuel use (L) X $EF_{off\text{-}road}$					
	Diesel fuel use	Litres (L)	Estimated/ Measured	From records or calculated on a unit basis	Annually	Required for annual offset quantification.
	$EF_{off\text{-}road}$	CO_2e (g/L)	Estimated	From Environment Canada reference documents	Annually	Must use most current emission factor for off-road Diesel Vehicles. National Inventory Report (NIR): Greenhouse Gas Sources and Sinks in Canada.

5.0 Data Management

Data quality management must be of sufficient quality to fulfill the quantification requirements and be substantiated by actual records for the purpose of verification and for any subsequent government audits.

The project developer shall establish and apply quality management procedures to manage data and information. Written procedures must be established for each measurement task outlining responsibility, timing and record location requirements. The greater the rigour of the management system for the data, the more easily verification/audit will be conducted for the project.

5.1 Project Documentation

Minimum documentation required for this protocol includes:

Project Eligibility documentation

- Time and location when project began and activities occurred,
    - Actions taken after January 1, 2002.
    - Occur after January 1, 2002.
    - In Alberta.
- Industry business as usual comparison,
- Clearly established ownership
- Project not required by law.

Project Quantification Documentation

- Location and volume (amount) of harvest (GIS spatial data)
- Method of harvest (GIS spatial data)
- Transportation distance; manual calculation or GIS model also used for Baseline
- Average haul speeds; manual calculation or GIS model also used for Baseline
- Haul weights; also used for Baseline
- Hog fuel location (by cutblock or by economical haul distance; GIS spatial data)
- Diesel fuel consumed in harvesting, transportation, site reclamation

Baseline Condition Documentation

- Energy required (kW) for wood room chipping (kW per m^3 chipped)
- Energy (total kW) produced in co-gen facility
        - From biomass
        - From natural gas
- Energy required (total kW) by mill
- Diesel fuel use per unit of harvest (m^3) from comparable baseline or historical harvest
- Tree utilization efficiency difference relative to in-block project condition. Required to calculate additional harvest debris for baseline condition (also

required for satellite and mill yard project conditions); from replicated study and/or Alberta Sustainable Resource Development (ASRD) scale factor
- Hog fuel location (by harvest block or by nominal economical haul distance)

All GIS spatial data must be in ESRI Arc GIS or compatible formats.

5.2 Record Keeping

Alberta Environment requires that project developers maintain appropriate supporting information for the project, including all raw data for the project for a period of 7 years after the end of the project crediting period. Where the project developer is different from the person implementing the activity, as in the case of an aggregated project, the individual projects and the aggregator must both maintain sufficient records to support the offset project. The project developer must keep the information listed below in addition to any other supporting records and disclose all information to the verifier and/or government auditor upon request.

Record-Keeping Requirements:

- Raw baseline data, e.g., full tree harvest fuel use (comparison harvest), wood room chipper energy (historical), transportation fuel use (model output),
- A record of all adjustments made to raw baseline data with justifications,
- Metering equipment specifications (model number, serial number, manufacturer's calibration procedures),
- A record of changes in static factors along with all calculations for non-routine adjustments,
- All calculations of greenhouse gas emissions/reductions and emission factors,
- Measurement equipment maintenance activity logs,
- Measurement equipment calibration records,
- Initial and annual verification records and audit results.

In order to support the third party verification and the potential supplemental government audit, the project developer must put in place a system that meets the following criteria:

- All records must be kept in areas that are easily located,
- All records must be legible, dated and revised as needed,
- All records must be maintained in an orderly manner,
- All documents must be retained for 7 years after the project crediting period,
- Electronic and paper documentation are both satisfactory,
- Copies of records should be stored in two locations to prevent loss of data.

Note: Attestations are not considered sufficient evidence that an activity has occurred and will not be accepted by Alberta Environment as proof that the activity took place.

5.3 Quality Assurance/Quality Control Considerations

Quality Assurance/Quality Control can also be applied to add confidence that all measurements and calculations have been made correctly. These include, but are not limited to:

- Ensuring that the changes to harvest operations continue to function as planned and achieve greenhouse gas reductions,
- Ensuring that the measurement and calculation system and greenhouse gas reduction reporting remains in place and accurate,
- Checking the validity of all data before it is processed, including emission factors, static factors, and acquired data,
- Performing recalculations of quantification procedures to reduce the possibility of mathematical errors,
- Storing the data in its raw form so it can be retrieved for verification,
- Protecting records of data and documentation by keeping both a hard and soft copy of all documents,
- Recording and explaining any adjustment made to raw data in the associated report and files,
- A contingency plan for potential data loss.

5.4 Liability

Offset projects must be implemented according to the approved protocol and in accordance with government regulations. Alberta Environment reserves the right to audit Offset credits and associated projects submitted to Alberta Environment for compliance under the *Specified Gas Emitters Regulation* and may request corrections based on audit findings.

6.0 References

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Appendix A:

Example of Baseline and Project Condition Harvests

Baseline equipment

1. Feller-buncher
2. Skidder
3. Processor delimber
4. Butt 'n' top loader loading truck for tree length transport
5. Crawler tractor
6. Wagner transporter

Project condition

1. Feller-buncher
2. Skidder
3. Portable chipper
4. Chip transporter

Baseline Harvest Condition

In-block Project Condition

Provided by Daishowa-Marubeni International Ltd.

Appendix B:

Quantification for Flexibility Mechanisms

Flexibility Mechanism 1: Calculating Fuel Use by Hours and Equipment Type

Total diesel fuel consumed should be used for greenhouse gas emission quantifications if available. Alternatively, project developers may quantify emissions based on hours and equipment type. The equipment listed in the examples below was used by the initiating entity at the time of preparation of this document. Other equipment types or variations (e.g., wheeled instead of tracked) would be calculated in the same manner by determining hours of operation and fuel use per hour of operation. Both methods are conservative estimates because fuel use rates used are not discounted for idling or downtime, and/or all fuel is assumed to be consumed within the scope of the protocol. The best method of quantification will ultimately depend on the data quality. Where available, the volume of total fuel consumed can be used as a reference check for emissions based on equipment type and hours of operation.

Road building and maintenance quantification (CIE-D) [B3, P3]

Determine number and size of crawler tractors and graders devoted to road construction and maintenance (CR, G).
Determine hour of operation for per crawler tractor and grader per season devoted to road construction and maintenance (H_{CR}, H_G)
Determine fuel use per hour of operation (D_{CR1}, D_{CR2}, D_G)
Determine fuel use – $FU_R = \sum_{i=0}^{m} CR \ X \ Hcr \ X \ Dcr + \sum_{i=0}^{m} G \ X \ Hg \ X \ Dg$
Determine CO_2e Emissions – $E_R = FU_R \ X \ EF_{HDDV}$ g CO_2/L diesel

Harvest operations emission quantification

Tree falling emission quantification (CIE-D) [B5, P5]
- Determine number of feller-bunchers required (FB)
- Determine hours of operation per feller-buncher per season (H_{FB})
- Determine fuel use (L) per hour of operation (D_{FB})
- Determine feller-buncher fuel use – $FU_{FB} = \sum_{i=0}^{m} FB \ X \ Hfb \ X \ D \ fb$
- Determine CO_2e Emissions – $E_{FB} = FU_{FB} \ X \ EF_{HDDV}$ g CO_2/L diesel

Skidding emission quantification (CIE-D) [B6, P6]
- Determine number and size of skidders required (Sk)
- Determine hours of operation per skidder per season (H_{Sk})
- Determine fuel use (L) per hour of operation (D_{Sk})
- Determine skidder fuel use – $FU_{Sk} = \sum_{i=0}^{m} Sk \ X \ Hsk \ X \ Dsk$
- Determine CO_2e Emissions – $E_{Sk} = FU_S \ X \ EF_{HDDV}$ g CO_2/L diesel

Pile trees in block quantification (CIE-D) [B7, P7]
- Determine number of loaders (Butt'n'top loader) required (Bw)
- Determine hours of operation per loader per season (H_{bw})
- Determine fuel use (L) per hour of operation (D_{bw})
- Determine loader fuel use – $FU_{bw} = \sum_{i=0}^{m} Bw \ X \ Hbw \ X \ Dbw$
- Determine CO_2e Emissions – $E_{bw} = FU_{bw} \ X \ EF_{HDDV}$ g CO_2/L diesel

In-block log processing quantification (CIE-D) [B7, P7]
- Determine number of processors required (Pr)
- Determine hours of operation per processor per season (H_{Pr})
- Determine fuel use (L) per hour of operation (D_{Pr})
- Determine processor fuel use – $FU_{Pr} = \sum_{i=0}^{n} Pr \ X \ Hpr \ X \ Dpr$
- Determine CO_2e Emissions – $E_{Pr} = FU_{Pr}$ X EF $_{HDDV}$ g CO_2/L diesel

Block clean-up quantification (CIE-D) [B10, P10]
- Determine number and size of crawler tractors used for block clean-up (Cl)
- Determine hour of operation per crawler tractor per season devoted to cleanup
- Determine fuel use per hour of operation (D_{Cl1}, D_{Cl2},...)
- Determine fuel use – $FU_{BC} = \sum_{i=0}^{n} Cl \ X \ Hcl \ X \ Dcl$

Debris disposal quantification (wood combustion) [B9, P9]
- Determine weight of additional debris biomass – Wt = (Tonnes harvested - (Tonnes salvage + Tonnes incidental)) x increased utilization proportion
- Determine additional debris burned (SB) – SB = Wt – Tonnes Hog
- Determine CO_2e emissions – E_{SB} = SB X EF $_{Wood}$ kg CO_2/tonne

Transportation quantification

Tree loading quantification (CIE-D) [B8, P8,]
- Determine number of loaders (Butt 'n' top loader) required (Bwx)
- Determine hours of operation per loader per season (H_{bwx})
- Determine fuel use (L) per hour of operation (D_{bwx})
- Determine loader fuel use – $FU_{bw} = \sum_{i=0}^{n} Bwx \ X \ Hbwx \ X \ Dbwx$
- Determine CO_2e Emissions – $E_{bwx} = FU_{bwx}$ X EF $_{HDDV}$ g CO_2/L diesel

Mill Furnish whole tree trucking quantification (CIE-D) [B11, P11, P19]
- Determine hours haul (HH) per load – km / average haul speed kph
  - Determine average haul distance total cycle i.e. round trip (km)
  - Determine total tonnes harvested (TH)
  - Determine waiting time (WT) per load
- Determine total loads hauled – LD = TH/Chip equivalent tonnes/load
- Determine truck fuel use (L) per hour hauling (D)
- Determine truck fuel use (L) per hour waiting (W)
- Determine truck fuel use – $FU_{Tx} = \sum_{i=0}^{n} LD \ X \ HH \ X \ D + \sum_{i=0}^{n} LD \ X \ WT \ X \ W$
- Determine CO_2e Emissions – $E_T = FU_{Tx}$ X CIE-D g CO_2/L diesel

Unloading whole tree quantification (CIE-D) [B12, P12]
- Determine number of Butt 'n' top loaders (By)
- Determine hours of operation per Butt'n'top loader per season (H_{By})
- Determine fuel use (L) per hour of operation (D_{By})
- Determine loader fuel use – $FU_{By} = \sum_{i=0}^{n} By \ X \ HBy \ X \ DBy$
- Determine CO_2e Emissions – $E_{By} = FU_{By}$ X EF $_{HDDV}$ g CO_2/L diesel

Mill yard quantification

Wood handling quantification (CIE-D) [P12]
- Determine number of wheel loaders (Wl), Butt'n'top (By), and "Wagner" (Wa) required

Determine hours of operation per processor per season (H_{WL},H_{By},H_{Wa})
Determine fuel use (L) per hour of operation (D_{WL},D_{By},D_{Wa})
Determine wood handling fuel use – $FU_{Wl} = \sum_{i=0}^{n} Wl \ X \ Hwl \ X \ Dwl$
Determine wood handling fuel use – $FU_{By} = \sum_{i=0}^{n} By \ X \ HBy \ X \ DBy$
Determine wood handling fuel use – $FU_{Wa} = \sum_{i=0}^{n} Wa \ X \ Hwa \ X \ Dwa$
Determine CO_2e Emissions – $E_{Wl} = FU_{Wl}$ X EF $_{HDDV}$ g CO_2/L diesel
Determine CO_2e Emissions – $E_{By} = FU_{By}$ X EF $_{HDDV}$ g CO_2/L diesel
Determine CO_2e Emissions – $E_{Wa} = FU_{Wa}$ X EF $_{HDDV}$ g CO_2/L diesel
Total wood yard handling Emissions is sum of Wl, By, Wa emissions

Yard clean up quantification (CIE-D) [B14, P14]

Determine number and size of crawler tractors used for wood yard clean-up (Cm)
Determine hour of operation per crawler tractor per season devoted to clean-up
Determine fuel use per hour of operation (D_{Cm1}, D_{Cm2},...)
Determine fuel use – $FU_{cm} = \sum_{i=0}^{n} Cm \ X \ Hcm \ X \ Dcm$
Determine CO_2e Emissions – $E_{Cm} = FU_{Cm}$ X EF $_{HDDV}$ g CO_2/L diesel

Wood room chipping quantification – [B13]

Determine CO_2e Emissions – EWr = kW used X EF $_{Power}$ CO_2e per kW

The following equations differ from the baseline and/or are unique to the project condition. All other required equations remain the same as baseline and are not repeated. Calculation of greenhouse gas emissions from reduced hog volume for in-block chipping within economical hog fuel haul distance of the mill are shown in Section 4 of this document.

Portable chipping quantification (CIE-D) – in-block, satellite yard, mill yard chipping [P13]

Determine number of portable chippers required per season (Ch)
Determine hours of operation per chipper per season (H_{Ch})
Determine fuel use (L) per hour of operation (D_{Ch})
Determine in-block chipper fuel use $FU_{Ch} = \sum_{i=0}^{n} Ch \ X \ Hch \ X \ Dch$
Determine CO_2e Emissions – $E_{Ch} = FU_{Ch}$ X EF $_{HDDV}$ g CO_2/L diesel

Chip Mill Furnish trucking quantification (CIE-D) – in-block, satellite yard chipping [P11]

Determine hours haul (HH) per load – km / average haul speed kph
Determine average haul distance total cycle i.e. round trip (km)
Determine total tonnes harvested (TH)
Determine waiting time (WT) per load
Determine total loads hauled – LD = TH/tonnes of chips/load
Determine truck fuel use (L) per hour hauling (D)
Determine truck fuel use (L) per hour waiting (W)
Determine truck fuel use – $FU_{Tx} = \sum_{i=0}^{n} LD \ X \ HH \ X \ D + \sum_{i=0}^{n} LD \ X \ WT \ X \ W$

Determine CO_2e Emissions – $E_T = FU_{Tx}$ X EF $_{HDDV}$ g CO_2/L diesel

In-Block chipping debris returns to block (CIE-D) [P18]

Determine number and size of skidder used to return debris to block (Sk)
Determine hour of operation per crawler tractor per season devoted to clean-up (H_{Sk})
Determine fuel use per hour of operation (D_{Sk1}, D_{Sk2},...)
Determine fuel use – $FU_{Sk} = \sum_{i=0}^{n} Sk\ X\ HSk\ X\ DSk$
Determine CO_2e Emissions – $E_{Sk} = FU_{Sk}$ X EF $_{HDDV}$ g CO_2/L diesel

Satellite yard chipping quantification (CIE-D)

Wood handling quantification (CIE-D) [P20]

Determine number of wheel loaders (Wl) and Butt'n'top (By) required
Determine hours of operation per processor per season (H_{WL}, H_{By})
Determine fuel use (L) per hour of operation (D_{WL}, D_{By})
Determine wood handling fuel use – $FU_{Wl} = \sum_{i=0}^{n} Wl\ X\ Hwl\ X\ Dwl$
Determine wood handling fuel use – $FU_{By} = \sum_{i=0}^{n} By\ X\ HBy\ X\ DBy$
Determine CO_2e Emissions – $E_{Wl} = FU_{Wl}$ X EF $_{HDDV}$ g CO_2/L diesel
Determine CO_2e Emissions – $E_{By} = FU_{By}$ X EF $_{HDDV}$ g CO_2/L diesel
Total wood yard handling Emissions is sum of Wl and By emissions

Satellite yard clean up quantification (CIE-D) [P21]

Determine number and size of crawler tractors used for wood yard clean-up (Cm)
Determine hour of operation per crawler tractor per season devoted to cleanup
Determine fuel use per hour of operation (D_{Cm1}, D_{Cm2},...)
Determine fuel use – $FU_{cm} = \sum_{i=0}^{n} Cm\ X\ Hcm\ X\ Dcm$
Determine CO_2e Emissions – $E_{Cm} = FU_{Cm}$ X EF $_{HDDV}$ g CO_2/L diesel

Mill yard chipping quantification

Mill yard wood handling quantification (CIE-D) [P12]

Determine number of wheel loaders (Wl) and Butt'n'top (By) required
Determine hours of operation per processor per season (H_{WL},H_{By},H_{Wa})
Determine fuel use (L) per hour of operation (D_{WL},D_{By},D_{Wa})
Determine wood handling fuel use – $FU_{Wl} = \sum_{i=0}^{n} Wl\ X\ Hwl\ X\ Dwl$
Determine wood handling fuel use – $FU_{By} = \sum_{i=0}^{n} By\ X\ HBy\ X\ DBy$
Determine CO_2e Emissions – $E_{Wl} = FU_{Wl}$ X EF $_{HDDV}$ g CO_2/L diesel
Determine CO_2e Emissions – $E_{By} = FU_{By}$ X EF $_{HDDV}$ g CO_2/L diesel
Total wood yard handling Emissions is sum of Wl and By emissions

Mill yard chip handling quantification (CIE-D) [P22]

Determine number and size of crawler tractors (Cm) used
Determine hour of operation per crawler tractor per season devoted to cleanup
Determine fuel use per hour of operation (D_{Cm1}, D_{Cm2},...)
Determine fuel use – $FU_{cm} = \sum_{i=0}^{n} Cm\ X\ Hcm\ X\ Dcm$
Determine CO_2e Emissions – $E_{Cm} = FU_{Cm}$ X EF $_{HDDV}$ g CO_2/L diesel
Determine number of wheel loaders (Wl) used

Determine hours of operation per processor per season (H_{Wl})
Determine fuel use (L) per hour of operation (D_{Wl})
Determine chip handling fuel use – $FU_{Wl} = \sum_{i=0}^{m} Wl \, X \, Hwl \, X \, Dwl$
Determine CO_2e Emissions – $E_{Wl} = FU_{Wl}$ X EF $_{HDDV}$ g CO_2/L diesel
Total wood yard handling Emissions is sum of Cu and Wl Emissions.

Flexibility Mechanism 2: Reduced Debris Volume Quantification

All of the calculations in this document, including the alternative quantification method described above, apply the emissions due to additional debris disposal requirements to the baseline condition and to satellite yard and mill yard project conditions that use the same harvest practice, [B9, P9].

Reductions in harvest debris attributable to blocks greater than the nominal economic hog fuel haul distance from the mill would assume in-block disposal and are subtracted from the in-block chipping project emissions. Reductions in harvest debris volume within economic hog fuel haul distance from the mill must be assumed to be hog, and would have to be discounted to avoid double counting where it is already quantified under the biomass to energy protocol. Discounting in this case is calculated based on the amount of non-renewable fuel that is required to produce an equivalent amount of power as the reduction in hog fuel. **This approach requires co-implementation of the biomass to energy protocol**.

Annual emission reductions are determined annually using the following formula where a positive number indicates an increase in greenhouse gas emissions for the year and a negative number indicates a reduction:

Emission Reduction = Emissions Baseline – Emissions Project

Three emission components make up the baseline condition. These are emissions attributable to harvesting, electrically powered wood room chippers, and mill furnish transportation. Baseline emissions attributable to harvesting will be determined in the same manner as for the preferred approach by quantifying harvesting CIE-D emissions from several sources where full tree hardwood harvesting is being practiced on a similar land base. Emissions attributable to wood chipping and mill furnish transportation would also be determined in the same manner as the preferred quantification method.

Emissions Baseline $_{year}$ =
((Harvesting + Chipping) x Harvest $_{year}$) + Transportation $_{year}$

Project emissions are the sum of emissions associated with all three current harvesting scenarios:

Emissions $_{Project\ year}$ =

$$\textit{Emissions}_{\text{Mill Yard Chipping}} + \textit{Emissions}_{\text{Satellite Yard Chipping}} + \textit{Emissions}_{\text{In-block Chipping}}$$

In-block project emissions include adjustments for the reduction in harvesting debris volume attributable to the increased efficiency of in-block portable chipping technology.

$$\textit{Emissions}_{\text{In-block Chipping}} = \textbf{Sum of all CIE-D emissions – (Reduced debris emissions)}$$

$$\textit{Emissions}_{\text{Satellite Yard Chipping}} = \textbf{Sum of all CIE-D emissions}$$

$$\textit{Emissions}_{\text{Mill Yard Chipping}} = \textbf{Sum of all CIE-D emissions}$$

Included in the CIE-D emissions for all three forms of project conditions is the calculation of mill furnish transportation emissions. This is determined in the same manner as baseline transportation emissions except that a per-load weight of 42 tonnes of chips will be used.

In order to ensure that no double counting of emission offsets occurs due to the operation of the biomass-fired electrical co-generation facility, the amount of electricity (kW) generated per unit (m^3) of hog fuel must be used. Thus, for harvesting within an economical hog fuel haul distance from the mill, the reduction in greenhouse gas emissions due to increased tree use efficiency (see Appendix C) will be discounted by the total kilowatts (kW) of electricity produced from hog fuel that is used to replace electricity from the Alberta power grid, or from natural gas used to supplement biomass used in the co-gen facility. Therefore, for harvesting within an economical hog fuel haul distance from mill the calculations for tonnes of greenhouse gas CO_2e emission from reduced debris volume are;

1. Determine reduced debris volume (RSvol) based on mill furnish scale numbers (conservatively assumed to be 100% hog fuel)

   RSvol = ((increased utilization proportion X harvest m^3)

2. Determine the kg of reduced debris (RSkg) using aspen density[11] (kg per m^3).

   RSkg = RSvol X Aspen density (kg/m^3)

3. Determine the tonnes of reduced debris greenhouse gas emissions in CO_2e ($RSTCO_2e$)

   EF_{wood} = kg of CO_2e per kg of wood burned

   $RSTCO_2e$ = (RSkg X EF_{wood})/1000 kg per tonne

[11] Aspen density numbers are available nationally from Forestry Canada but may also be available locally from scale numbers. Values typically range from 370 to 410 kg/m^3 oven dry weight.

4. Determine the kW of electricity that would have been generated by consumption of the reduced debris volume (RSvol) in the Co-gen facility (Bf $kW_{co\text{-}gen}$)

   HfkW= kW generated in co-gen facility per m^3 of hog fuel

   Bf $kW_{co\text{-}gen}$ = RSvol X HfkW

5. Determine the tonnes of greenhouse gas emissions in CO_2e ($kWTCO_2e$) that must be discounted to avoid double counting of emission reductions. This is based on the displacement of electricity from the Alberta power grid, or generated from natural gas in the co-gen facility.

   EF_{Power} = kg CO_2e per kW in Alberta

   $kWTCO_2e$ = (Bf kWco-gen X EF_{Power})/1000 kg per tonne

If natural gas was used to generate power in the co-gen facility rather than electricity from the Alberta power grid, then kg CO_2e per m^3 of natural gas ($EF_{Natural\ gas}$) required to produce a kW of power is used.

6. Finally, determine the reduced greenhouse gas emissions for in-block chipping harvests within an economical hog fuel haul distance from the mill (RE_{hog}).

   RE_{hog} = $RSTCO_2e$ - $kWTCO_2e$

No discounting of reduced emissions is required for harvesting beyond an economical hog fuel haul distance because none of the reduced debris volume is being used as hog fuel. Calculations of emission reductions due to reduced debris volume are then simplified as follows:

1. Determine reduced debris volume (RSvol) based on mill furnish scale numbers
   RSvol = ((increased utilization proportion X harvest m^3)
2. Determine the kg of reduced debris (RSkg) using aspen wood density (kg/m^3).
   **RSkg = RSvol X aspen density (kg/m^3) **
3. Finally, determine the reduced greenhouse gas emissions (RE) for in-block chipping harvests where no hog fuel was taken.
   EF_{wood} = kg of CO_2e per kg of wood burned
   RE= (RSkg X EF_{Wood})/1000 kg per tonne

The amount of kilowatts generated per cubic meter of hog fuel burned in the co-gen facility (HFkW) would need to be determined from records or calculated from manufacturers' specifications. The calculations would require adjusting for typical hog fuel feed rates, fuel moisture, hog fuel heat content, as well as co-gen efficiency and operating conditions (e.g., temperature, pressure).

The total annual greenhouse gas emissions for the in-block chipping project condition used to calculate offsets relative to the baseline condition would then be:

$Emissions_{In\text{-}block\ Chipping}$ = Sum of all CIE-D emissions – (RE_{hog} + RE)

All other calculations for CIE-D emissions would remain the same as the preferred method of quantification already described.

Note: Because harvest debris disposal and hog fuel amount for the baseline, satellite yard, and mill yard conditions are the same, quantification of harvest debris disposal and hog fuel is only required for those harvest blocks where in-block chipping occurs and all other blocks may be excluded. Exclusion is only possible where individual harvest block records are being used to locate and quantify only those blocks where in-block chipping occurred.

Table A1: Quantification Methodology for Flexibility Mechanism.

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify measurement or estimation and frequency
Project Condition. Flexibility mechanism Modification of the in-block Project Condition to reflect reduced debris volume						
Source/Sink P9, P15	RSvol = ((increased utilization proportion X harvest m^3) RSkg = RSvol X Aspen density (kg/m^3) $RSTCO_2e$ = (RSkg X EF_{Wood})/1000 kg per tonne Bf $kW_{co\text{-}gen}$ = RSvol X HfkW $kWTCO_2e$ = (Bf kWco-gen X EF_{Power})/1000 kg per tonne RE_{hog} = $RSTCO_2e$ - $kWTCO_2e$ RE = (RSkg X EF_{Wood})/1000 kg per tonne Reduced debris emissions = RE_{hog} + RE					
	Increased utilization proportion	Proportion	Estimated	Derived from replicated study and corrected for expected harvest stand condition (tree size and density)	Periodic	Properly implemented replicated study that includes the range of stand conditions need not be repeated unless technological or operational change occurs. Results from the study may require periodic correction (adjustment) when stand conditions change. Assessed from approved harvest plans and forest inventory data.
	Harvest	Volume m^3	Measured	Scale. Calculated from scale weights	Annually	Must use most accurate harvest numbers in all calculations.
	Aspen density	kg/m^3	Estimated	From published sources or operator specific values.	Periodic Reviewed annually	Aspen density numbers are available nationally from Forestry Canada but may also be available locally from scale numbers. Values typically range from 370 to 410 kg/m^3 oven dry weight.
	EF_{Wood}	CO_2e (g/kg)	Estimated	From IPCC, Environment Canada, or other recognized reference documents	Annually	Must use most current emission factor for waste wood burning.

Source/Sink	Parameter / Variable	Unit	Measured/ Estimated	Method	Frequency	Justify measurement or estimation and frequency
	HfkW	kW/m^3	Estimated	From records and/or manufacturers specifications	Once; Reviewed annually	The kW generated in co-gen facility per m^3 of hog fuel does not need to be recalculated unless technological change or modification results in increased efficiency.
	EF_{Power}	CO_2e (g/kwh)	Estimated	From Environment Canada reference documents	Annually	Must use most current emission factor for power generated in Alberta. National Inventory Report (NIR): Greenhouse Gas Sources and Sinks in Canada.
	RE_{hog}	CO_2e	Estimated	Calculated	Annually	Harvest debris emissions from cutblocks where hog fuel harvesting did occur. Required to ensure no double accounting of GHG emissions.
	RE	CO_2e	Estimated	Calculated	Annually	Harvest debris emissions from cutblocks where hog fuel harvesting did not occur. Required to ensure no double accounting of GHG emissions.

Appendix C:

Increased Tree Utilization Description

The application of portable chipping technology results in a significant increase in tree utilization compared to full tree harvest with tree length hauling. According to portable chipper manufacturers, this is typically estimated to be in the range of 20 per cent or more due to the inclusion of large branches, ends, tops, and smaller diameter trees. This is reflected in a difference in harvest debris generated for each unit of harvest. Because efficiency will vary by operator and stand condition (e.g., tree size, condition, density) the **increased utilization proportion** must be determined for each application of this protocol.

Calculation of increased tree utilization following implementation of portable chipping technology is required by regulators (i.e., Alberta Sustainable Resource Development (ASRD)) to ensure application of an appropriate scaling factor, which must be applied to avoid unwarranted annual allowable cut (AAC) drawdown and the application of appropriate stumpage fees. The scaling factor calculation requires a replicated study to determine utilization differences from known harvest volumes. The replicated study must include the range of stand conditions (particularly tree sizes) that may be harvested. The range in stand conditions is required because the efficiency of portable chipping will vary by tree size, age and density. Once determined the utilization efficiency value (scaling factor) must then be corrected (adjusted) to reflect the yield strata (tree size and density) that will be harvested.