QUANTIFICATION PROTOCOL FOR LOW-RETENTION, WATER-POWERED ELECTRICITY GENERATION AS RUN-OF-RIVER OR ON AN EXISTING RESERVOIR

Submitted to:

Alberta Environment

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Note to User:

This protocol is intended to apply to run-of-river water powered electricity generation projects and some water powered electricity generation projects on existing reservoirs. Eligibility criteria, applicable project and baseline conditions, and definitions are outlined herein. The project types covered under this protocol are acknowledged to be a sub-set of the possible water powered electricity generation projects. Other protocols may be developed to cover additional water powered electricity generation project types.

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1.0 Project and Methodology Scope and Description

1.1 Protocol Scope and Description

This protocol is applicable to the quantification of reductions in greenhouse gas (GHG) emissions resulting from the implementation of facilities that convert the potential energy of river flow into low retention, water-powered electricity generation as run-of-river or on an existing reservoir. Henceforth, these facilities will be referred to as 'run-of-river hydro' and as 'existing reservoir hydro' electricity generation projects, respectively. The protocol quantifies the emission reductions based on the generation of an equivalent quantity of electricity from fossil fuel based sources, either at grid-connected or off-grid facilities.

This quantification protocol is written for the run-of-river hydro or existing reservoir hydro electricity generation project operator or project proponent. Some familiarity with, or general understanding of, the operation of these types of hydro electric facilities and associated practices, is expected.

Protocol Approach

Under the project condition, run-of-river hydro or existing reservoir hydro electricity generation facilities energize either loads connected to the electrical utility grid or to off-grid loads. **FIGURE 1.1** offers a process flow diagram for a typical project.

The baseline condition includes the generation of electricity by other facilities linked to the electrical loads to cover the net generation capacity of the low retention, hydro electric facility. **FIGURE 1.2** offers a process flow diagram for a typical baseline configuration.

This protocol serves as a generic 'recipe' for project proponents to follow in order to meet the measurement, monitoring and GHG quantification requirements for reductions due to low retention, water-powered electricity generation and usage.

The boundary of this protocol encompasses the production storage, conversion and management of electrical energy upstream of its input to grid-connected loads or to off-grid loads.

Protocol Applicability

To demonstrate that a project meets the requirements under this protocol, the project proponent must supply sufficient evidence to demonstrate that:

1. The metering of net electricity production must be made at a point downstream of both generation and any storage system, typically to where generated electricity is connected to its loads; and
2. The quantification of reductions achieved by the project is based on actual measurement and monitoring (except where indicated in this protocol) as indicated by the proper application of this protocol.

FIGURE 1.1: Process Flow Diagram for Project Condition

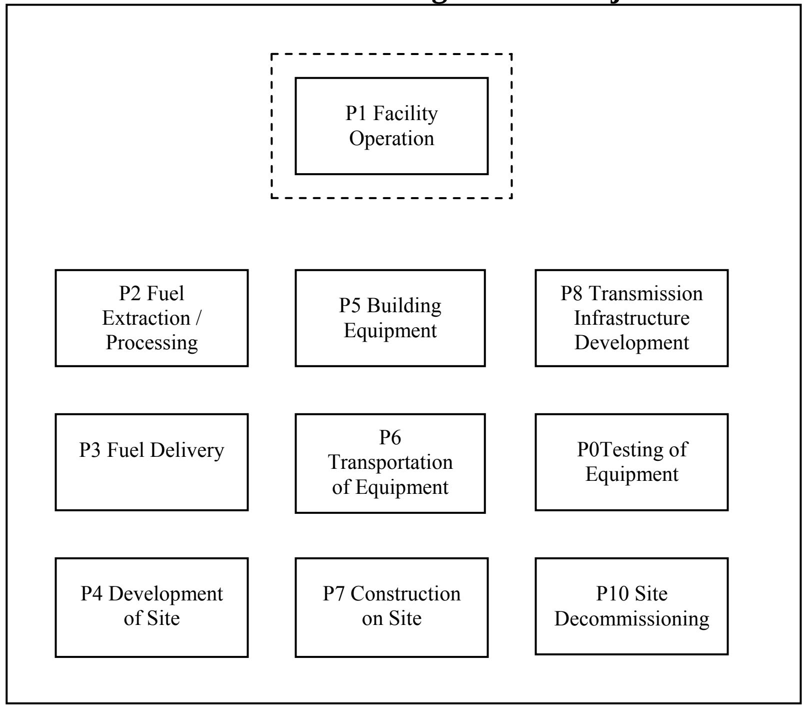
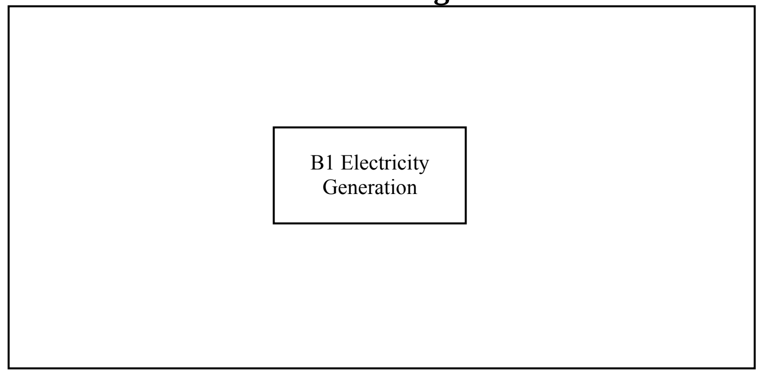


FIGURE 1.2: Process Flow Diagram for Baseline Condition



It is important to understand that GHG emission reductions are one of many environmental benefits associated with renewable low retention electricity generation. The aggregation of the environmental benefits of one megawatt-hour of renewable electricity generation are commonly referred to as 'green tags' and traded as Renewable Energy Certificates (RECs). To avoid the 'double counting' of the environmental benefits bundled in RECs and emission offsets, the electricity generation to which any traded RECs are associated with should not be included in the quantification of GHG offsets from an eligible project. REC's may also be converted to offsets by developing an offset project plan and applying this protocol.

Protocol Flexibility

Flexibility in applying the quantification protocol is provided to project developers by:

1. For projects with a dedicated end-user of some or all of the electricity generation, where the run of river power facility is connected by a dedicated line to that facility, site specific electricity generation emission factors, reflecting the source of generation displaced under the project condition, may be substituted for the generic grid emission factors indicated in this protocol document. Guidance on the selection of appropriate emission factors is contained in Appendix A. The methodology for generation of these emission factors must be sufficiently robust as to ensure reasonable accuracy.

If flexibility provisions have been applied, the proponent must describe the provisions used, and justify their application through a detailed methodology, calculations, and all supporting documentation.

1.2 Glossary of New Terms

Electricity Grid: Infrastructure that brings power from the plant to the end users through high-voltage transmission systems which carry electricity from the power plants and transmit it hundreds of miles away, and lower-voltage distribution systems which draw electricity from the transmission lines and distribute it to individual customers.

Low retention, Hydro Electric Facility:

A facility that uses a mechanical method to capture and convert the potential energy of water into electricity. Specific to this protocol, this includes facilities where the head pond or reservoir is not for storage (i.e. less than 48-hour retention time in any head pond) maintained upstream of the facility. Also, this includes facilities implemented at an existing reservoir where a water control device is already operating on the same waterway. In such cases, termed *existing reservoir hydro*, there should either be no change in the volume and/or operating characteristics of the reservoir, or no functional control of the water control device on the reservoir (i.e. direct government control of reservoir or water control device).

2.0 Quantification Development and Justification

The following sections outline the quantification development and justification.

2.1 Identification of Sources and Sinks (SS's) for the Project

SS's were identified for the project by reviewing the seed document, other protocols and project configurations. This process confirmed that the SS's in the process flow diagrams covered the full scope of eligible project activities under the protocol.

Based on the process flow diagrams provided in **FIGURE 1.1**, the project SS's were organized into life cycle categories in **FIGURE 2.1**. Descriptions of each of the SS's and their classification as controlled, related or affected are provided in **TABLE 2.1.**

FIGURE 2.1: Project Element Life Cycle Chart

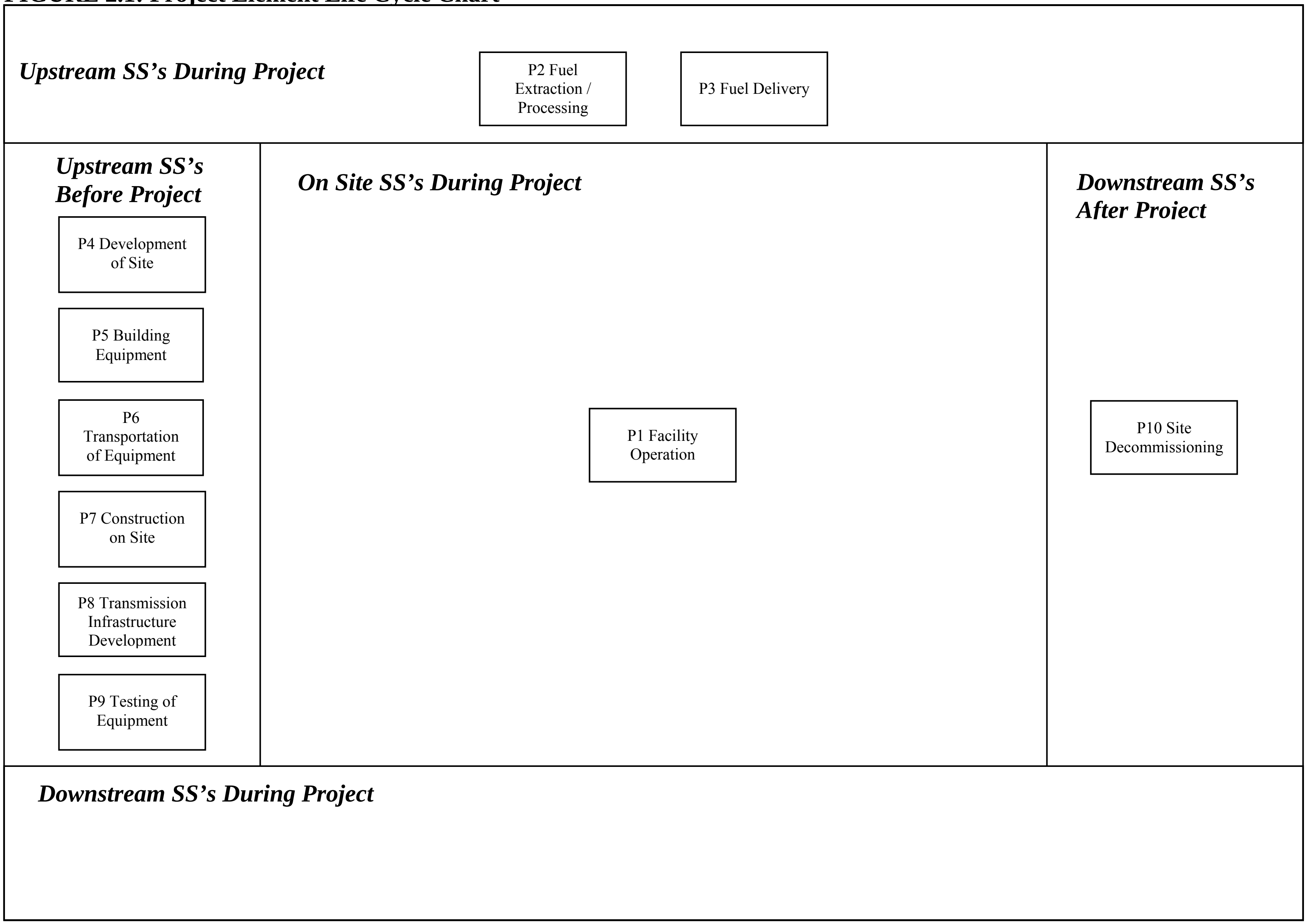


TABLE 2.1: Project SS's

1. SS	2. Description	3. Controlled, Related or Affected
Upstream SS's during Project Operation		
P2 Fuel Extraction and Processing	Each of the fuels used throughout the on-site component of the project will need to sourced and processed. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on-site SS's are considered under this SS. Volumes and types of fuels are the important characteristics to be tracked.	Related
P3 Fuel Delivery	Each of the fuels used throughout the on-site component of the project will need to be transported to the site. This may include shipments by tanker or by pipeline, resulting in the emissions of greenhouse gases. It is reasonable to exclude fuel sourced by taking equipment to an existing commercial fuelling station as the fuel used to take the equipment to the site is captured under other SS's and there is no other delivery.	Related
Onsite SS's during Project Operation		
P1 Facility Operation	Greenhouse gas emissions may occur that are associated with the operation and maintenance of the overall run of river power generation facility. This may include running vehicles and operating buildings on the site. Quantities and types of the fuels used would need to be tracked.	Controlled
Downstream SS's during Baseline Operation		
None		
Other		
P4 Development of Site	The site may need to be developed. This could include civil infrastructure such as access to electricity, gas and water supply, as well as sewer etc. This may also include clearing, grading, building access roads, etc. There will also need to be some building of structures for the facility such as storage areas, storm water drainage, offices, vent stacks, firefighting water storage lagoons, etc., as well as structures to enclose, support and house the equipment. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to develop the site such as graders, backhoes, trenching machines, etc.	Related
P5 Building Equipment	Equipment may need to be built either on-site or off-site. This includes all of the components of the storage, handling, processing, combustion, air quality control, and system control and safety systems. These may be sourced as pre-made standard equipment or custom built to specification. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment for the extraction of the raw materials, processing, fabricating and assembly.	Related
P6 Transportation of Equipment	Equipment built off-site and the materials to build equipment on-site, will all need to be delivered to the site. Transportation may be completed by train, truck, by some combination, or even by courier. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels to power the equipment delivering the equipment to the site.	Related

P7 Construction on Site	The process of construction at the site will require a variety of heavy equipment, smaller power tools, cranes and generators. The operation of this equipment will have associated greenhouse gas emission from the use of fossil fuels and electricity.	Related
P8 Transmission Infrastructure Development	Electricity transmission infrastructure will need to be developed and installed in order to transmit power from the generating station to the grid. The installation of this equipment will have associated greenhouse gas emissions as a result of the use of fossil fuels to power the installation equipment and land clearing activities.	Related
P9 Testing of Equipment	Equipment may need to be tested to ensure that it is operational. This may result in running the equipment using test anaerobic digestion fuels or fossil fuels in order to ensure that the equipment runs properly. These activities will result in greenhouse gas emissions associated with the combustion of fossil fuels and the use of electricity.	Related
P10 Site Decommissioning	Once the facility is no longer operational, the site may need to be decommissioned. This may involve the disassembly of the equipment, demolition of on-site structures, disposal of some materials, environmental restoration, re-grading, planting or seeding, and transportation of materials off-site. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to decommission the site.	Related

2.2 Identification of Baseline

The baseline condition for projects applying this protocol is defined as the electricity that would have otherwise been generated using fossil fuel based sources.

The approach to quantifying the baseline will be calculation based on the applicable emissions factor covering an equivalent quantity of electricity. The baseline scenario for this protocol is dynamic as the amount of electricity produced will change.

The baseline condition is defined, including the relevant SS's and processes, as shown in **FIGURE 1.2**. More detail on each of these SS's is provided in Section 2.3, below.

2.3 Identification of SS's for the Baseline

Based on the process flow diagrams provided in **FIGURE 1.2**, the project SS's were organized into life cycle categories in **FIGURE 2.2**. Descriptions of each of the SS's and their classification as either 'controlled', 'related' or 'affected' is provided in **TABLE 2.2.**

FIGURE 2.2: Baseline Element Life Cycle Chart

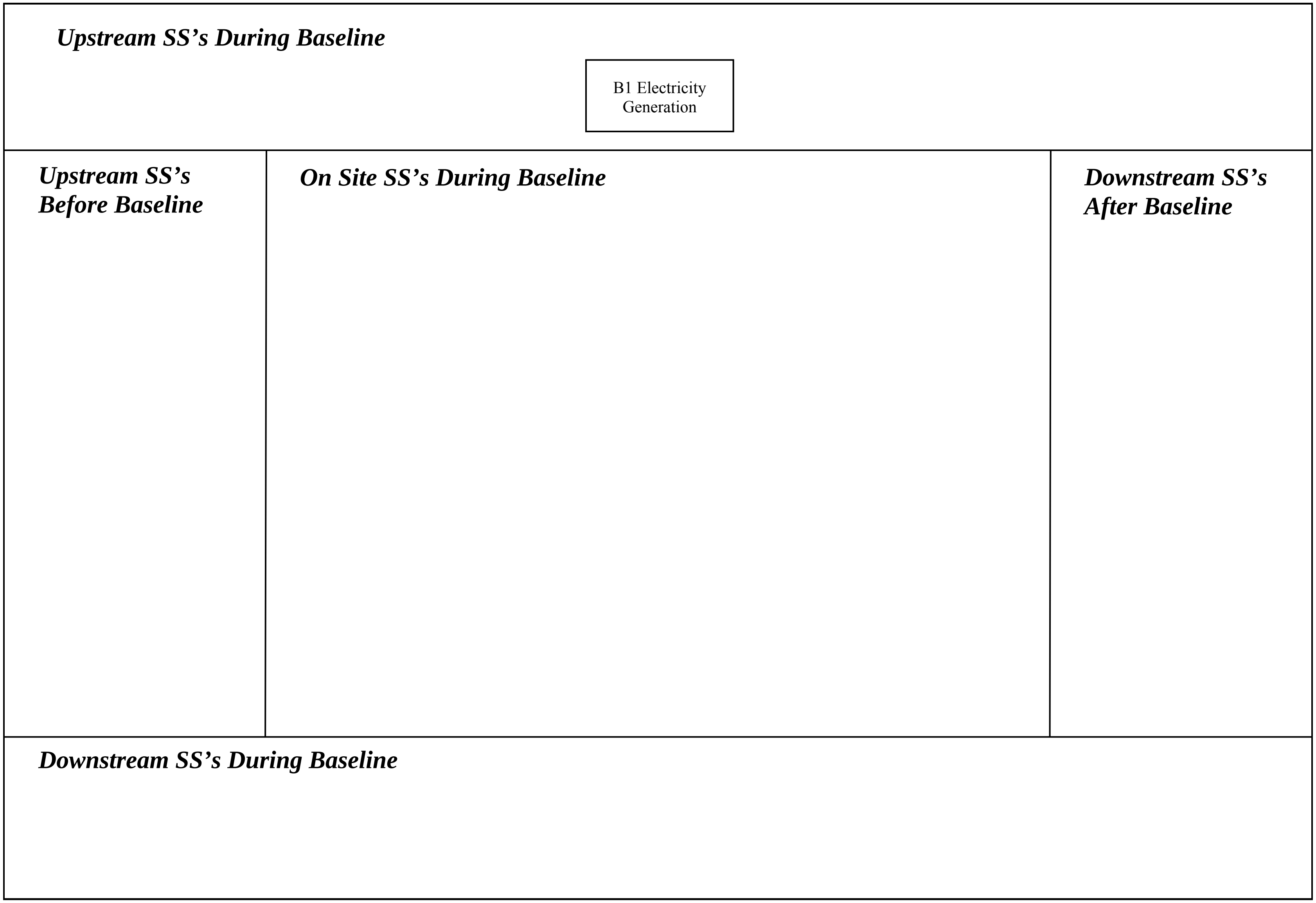


TABLE 2.2: Baseline SS's

1. SS	**2. Description**	**3. Controlled, Related or Affected**
Upstream SS's during Baseline Operation		
B1 Electricity Generation	Electricity will be produced off-site to match the electricity being produced by the run of river power generation facility. This electricity will be produced at an emission's intensity as deemed appropriate by the Program Authority. Measurement of the net quantity of electricity produced by the facility will need to be tracked to quantify this SS. Measurement must occur downstream of any electricity storage and transmission systems at the point where the electricity is tied into the electricity grid to account for on-site losses and parasitic loads.	Controlled
Onsite SS's during Baseline Operation		
	None	
Downstream SS's during Baseline Operation		
	None	
Other		
	None	

2.4 Selection of Relevant Project and Baseline SS's

Each of the SS's from the project and baseline condition were compared and evaluated as to their relevancy using the guidance provided in Annex VI of the "Guide to Quantification Methodologies and Protocols: Draft", dated March 2006 (Environment Canada). The justification for the exclusion or conditions upon which SS's may be excluded is provided in **TABLE 2.3** below. All other SS's listed previously are included.

TABLE 2.3: Comparison of SS's

1. Identified SS	2. Baseline (C, R, A)	3. Project (C, R, A)	4. Include or Exclude from Quantification	5. Justification for Exclusion
Upstream SS's				
B1 Electricity Generation	Controlled	N/A	Include	N/A
P2 Fuel Extraction and Processing	N/A	Related	Include	N/A
P3 Fuel Delivery	N/A	Related	Exclude	Excluded as the emissions from transportation are negligible and likely greater under the baseline condition.
Onsite SS's				
P1 Facility Operation	N/A	Controlled	Include	N/A
Downstream SS's				
None				
Other				
P4 Development of Site	N/A	Related	Exclude	Emissions from site development are not material given the long project life, and the minimal site development typically required.
P5 Building Equipment	N/A	Related	Exclude	Emissions from building equipment are not material given the long project life, and the minimal building equipment typically required.
P6 Transportation of Equipment	N/A	Related	Exclude	Emissions from transportation of equipment are not material given the long project life, and the minimal transportation of equipment typically required.
P7 Construction on Site	N/A	Related	Exclude	Emissions from construction on site are not material given the long project life, and the minimal construction on site typically required.
P8 Transmission Infrastructure Development	N/A	Related	Exclude	Emissions from transmission infrastructure development are not material given the long project life, and the minimal transmission infrastructure development typically required.
P9 Testing of Equipment	N/A	Related	Exclude	Emissions from testing of equipment are not material given the long project life, and the minimal testing of equipment typically required.
P10 Site Decommissioning	N/A	Related	Exclude	Emissions from decommissioning are not material given the long project life, and the minimal decommissioning typically required.

2.5 Quantification of Reductions, Removals and Reversals of Relevant SS's

2.5.1 Quantification Approaches

Quantification of the reductions, removals and reversals of relevant SS's for each of the greenhouse gases will be completed using the methodologies outlined in **TABLE 2.4**, below. A listing of relevant emission factors is provided in **Appendix A**. These calculation methodologies serve to complete the following three equations for calculating the emission reductions from the comparison of the baseline and project conditions.

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

$$\text{Emissions}_{\text{Baseline}} = \text{Emissions}_{\text{Electricity Generation}}$$

$$\text{Emissions}_{\text{Project}} = \text{Emissions}_{\text{Facility Operation}} + \text{Emissions}_{\text{Fuel Extraction and Processing}}$$

Where:

$\text{Emissions}_{\text{Baseline}}$ = sum of the emissions under the baseline condition.
$\text{Emissions}_{\text{Electricity Generation}}$ = emissions under SS B1 Electricity Generation

$\text{Emissions}_{\text{Project}}$ = sum of the emissions under the project condition.
$\text{Emissions}_{\text{Facility Operation}}$ = emissions under SS P1 Facility Operation
$\text{Emissions}_{\text{Fuel Extraction and Processing}}$ = emissions under SS P2 Fuel Extraction and Processing

TABLE 2.4: Quantification Procedures

1.0 Project / Baseline SS	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Method	6. Frequency	7. Justify measurement or estimation and frequency
Project SS's						
P1 Facility Operation	$Emissions_{Facility\ Operation} = \sum (Vol.\ Fuel_i * EF\ Fuel_{i\ CO2})\ ;\ \sum (Vol.\ Fuel_i * EF\ Fuel_{i\ CH4})\ ;\ \sum (Vol.\ Fuel_i * EF\ Fuel_{i\ N2O})$					
	Emissions $_{Facility\ Operation}$	kg of CO_2 ; CH_4 ; N_2O	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel and electricity use on site is likely aggregated for each of these SS's.
	Volume of Each Type of Fuel / Vol Fuel $_i$	L, m^3 or other	Measured	Direct metering or reconciliation of volume in storage (including volumes received).	Continuous metering or monthly reconciliation.	Both methods are standard practise. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	CO_2 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CO2}$	Kg CO_2 per L, m^3 or other	Estimated	From Environment Canada reference documents. (Appendix A)	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH_4 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CH4}$	kg CH_4 per L, m^3 or other	Estimated	From Environment Canada reference documents. (Appendix A)	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N_20 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ N2O}$	kg N2O per L, m^3 or other	Estimated	From Environment Canada reference documents. (Appendix A)	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
P2 Fuel Extraction and Processing	$Emissions_{Fuel\ Extraction\ /\ Processing} = \sum (Vol.\ Fuel_i * EF\ Fuel_{i\ CO2})\ ;\ \sum (Vol.\ Fuel_i * EF\ Fuel_{i\ CH4})\ ;\ \sum (Vol.\ Fuel_i * EF\ Fuel_{i\ N2O})$					
	Emissions $_{Fuel\ Extraction\ /\ Processing}$	kg of CO2e	N/A	N/A	N/A	Quantity being calculated.

	Volume of Each Type of Fuel Combusted for P1 / Vol $_{Fuel\ i}$	m^3	Measured	Direct metering or reconciliation of volume in storage (including volumes received).	Continuous metering or monthly reconciliation.	Both methods are standard practice. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	CO_2 Emissions Factor for Each Type of Fuel Production and Processing / EF Fuel $_{i\ CO2}$	kg CO_2 per m^3	Estimated	From Environment Canada reference documents. (Appendix A)	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH_4 Emissions Factor for Each Type of Fuel Including Production and Processing / EF Fuel $_{i\ CH4}$	kg CH_4 per m^3	Estimated	From Environment Canada reference documents. (Appendix A)	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N_20 Emissions Factor for Each Type of Fuel Including Production and Processing / EF Fuel $_{i\ N2O}$	kg N2O per m^3	Estimated	From Environment Canada reference documents. (Appendix A)	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
Baseline SS's						
B1 Electricity Generation	Emissions $_{Electricity\ Generation}$ = Electricity * EF $_{Elec}$					
	Emissions $_{Electricity}$	kg of CO2e	N/A	N/A	N/A	Quantity being calculated.
	Incremental Electricity Exported from the Project Site / Electricity	kWh	Measured	Direct metering	Continuous metering	Continuous direct metering represents the industry practice and the highest level of detail.
	Emissions Factor for Electricity / EF $_{Elec}$	kg of CO2e per kWh	Estimated	From Alberta Environment Offset Project Guidance Document	Annual	Reference values adjusted periodically.

2.5.2. Contingent Data Approaches

Contingent means for calculating or estimating the required data for the equations outlined in section 2.5.1 are summarized in **TABLE 2.5**, below.

2.6 Management of Data Quality

In general, data quality management must include sufficient data capture such that the mass and energy balances may be easily performed with the need for minimal assumptions and use of contingency procedures. The data should be of sufficient quality to fulfill the quantification requirements and be substantiated by company records for the purpose of verification.

The project proponent shall establish and apply quality management procedures to manage data and information. Written procedures should 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 an audit will be to conduct for the project.

2.6.1 Record Keeping

Record keeping practises should include:

a. Electronic recording of values of logged primary parameters for each measurement interval;
b. Printing of monthly back-up hard copies of all logged data;
c. Written logs of operations and maintenance of the project system including notation of all shut-downs, start-ups and process adjustments;
d. Retention of copies of logs and all logged data for a period of 7 years; and
e. Keeping all records available for review by a verification body.

2.6.2 Quality Assurance/Quality Control (QA/QC)

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

a Protecting monitoring equipment (sealed meters and data loggers);
b Protecting records of monitored data (hard copy and electronic storage);
c Checking data integrity on a regular and periodic basis (manual assessment, comparing redundant metered data, and detection of outstanding data/records);
d Comparing current estimates with previous estimates as a 'reality check';
e Provide sufficient training to operators to perform maintenance and calibration of monitoring devices;
f Establish minimum experience and requirements for operators in charge of project and monitoring; and
g Performing recalculations to make sure no mathematical errors have been made.

TABLE 2.5: Contingent Data Collection Procedures

1. Project / Baseline SS	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Contingency Method	6. Frequency	7. Justify measurement or estimation and frequency
Project SS's						
P1 Facility Operation	Volume of Each Type of Fuel for Unit Operation / Vol. Fuel $_i$	L / m^3 / other	Measured	Reconciliation of volume of fuel purchased within given time period.	Monthly	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
P2 Fuel Extraction and Processing	Volume of Each Type of Fuel / Vol. Fuel $_i$	L / m^3 / other	Estimated	Reconciliation of volume of fuel purchased within given time period.	Monthly	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.
Baseline SS's						
B1 Electricity Generation	Incremental Electricity Exported from the Project Site / Electricity	kWh	Measured	Reconciliation with electricity sales records.	Monthly	Provides reasonable estimate of the parameter, when the more accurate and precise method cannot be used.

APPENDIX A:

Relevant Emission Factors

Table A1: Emission Intensity of Fuel Extraction and Production (Diesel, Natural Gas, and Gasoline)

Diesel		
Production		
Emissions Factor (CO_2)	0.138	kg CO_2 per Litre
Emissions Factor (CH_4)	0.0109	kg CH_4 per Litre
Emissions Factor (N_2O)	0.000004	kg N_2O per Litre
Natural Gas		
Extraction		
Emissions Factor (CO_2)	0.043	kg CO_2 per m^3
Emissions Factor (CH_4)	0.0023	kg CH_4 per m^3
Emissions Factor (N_2O)	0.000004	kg N_2O per m^3
Processing		
Emissions Factor (CO_2)	0.090	kg CO_2 per m^3
Emissions Factor (CH_4)	0.0003	kg CH_4 per m^3
Emissions Factor (N_2O)	0.000003	kg N_2O per m^3
Gasoline		
Production		
Emissions Factor (CO_2)	0.138	kg CO_2 per Litre
Emissions Factor (CH_4)	0.0109	kg CH_4 per Litre
Emissions Factor (N_2O)	0.000004	kg N_2O per Litre

Table A2: Emission Factors for Natural Gas and NGL's

Source	**Emission Factors**		
	CO_2	**CH_4**	**N_2O**
	g/m^3	**g/m^3**	**g/m^3**
Natural Gas			
Electric Utilities	1891	0.49	0.049
Industrial	1891	0.037	0.033
Producer Consumption	2389	6.5	0.06
Pipelines	1891	1.9	0.05
Cement	1891	0.037	0.034
Manufacturing Industries	1891	0.037	0.033
Residential, Construction, Commercial/Institutional, Agriculture	1891	0.037	0.035
	g/L	**g/L**	**g/L**
Propane			
Residential	1510	0.027	0.108
All Other Uses	1510	0.024	0.108
Ethane	976	N/A	N/A
Butane	1730	0.024	0.108

Table A3: Emission Factors for Refined Petroleum Products

Source	Emission Factors (g/L)		
	CO_2	CH_4	N_2O
Light Fuel Oil			
Electric Utilities	2830	0.18	0.031
Industrial	2830	0.006	0.031
Producer Consumption	2830	0.006	0.031
Residential	2830	0.026	0.006
Forestry, Construction, Public Administration, and Commercial/Institutional	2830	0.026	0.031
Heavy Fuel Oil			
Electric Utilities	3080	0.034	0.064
Industrial	3080	0.12	0.064
Producer Consumption	3080	0.12	0.064
Residential, Forestry, Construction, Public Administration, and Commercial/Institutional	3080	0.057	0.064
Kerosene			
Electric Utilities	2550	0.006	0.031
Industrial	2550	0.006	0.031
Producer Consumption	2550	0.006	0.031
Residential	2550	0.026	0.006
Forestry, Construction, Public Administration, and Commercial/ Institutional	2550	0.026	0.031
Diesel	2730	0.133	0.4