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**QUANTIFICATION PROTOCOL FOR PUMP SYSTEM CONVERSION TO
REDUCE GREENHOUSE GAS EMISSIONS**

Public Review Version

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1 **1.0. Project and Methodology Scope and Description**

2 This quantification protocol is written for the gas and/or oil operator or any operator in
3 the oil and gas industry where natural gas or electricity is used to power pumps for fluid
4 displacement. Some familiarity with, or understanding of, the operation of gas and/or oil
5 operations is assumed.

6 The opportunity for generating carbon offsets with this protocol arises from the direct and
7 indirect reduction of greenhouse gas emissions resulting from converting high GHG
8 intensive pumps to low/no GHG intensive pumps. In this protocol, the project developer
9 will install, update or retrofit pumps and/or the power source for these pumps at a facility
10 to reduce GHG emissions.

11 It must be stated that this protocol does not stipulate a process change but rather a change
12 in the type of pumps used and consequently the elimination or reduction of greenhouse
13 gases. It is assumed that the new pump configuration will eliminate or reduce these
14 greenhouse gases.

15 **1.1. Protocol Scope and Description**

16 This protocol serves as a generic ‘recipe’ for project proponents to follow in order to
17 meet the measurement, monitoring, and greenhouse gas quantification requirements for
18 reductions resulting from converting high GHG intensive pumps to low/no GHG
19 intensive pumps. Once this conversion has occurred, greenhouse gas emission will have
20 decreased considerably. Replacement of end-of-life pumps is also considered in the scope
21 of this protocol. The intent of this inclusion is to stimulate project developers to convert
22 to low/no GHG intensive pumps. A process flow diagram for a typical project converting
23 high GHG intensive pumps to low/no GHG intensive pumps is shown in **FIGURE 0.1**.

24 **Protocol Approach:**

25 The general protocol approach requires the calculation of greenhouse gas emissions from
26 manufactures’ technical specifications for high GHG intensive pumps and low/no GHG
27 intensive pumps and metered quantities in the project. The manufacturer’s technical
28 specifications are used to determine a pump-specific Pump Displacement Factor (PDF),
29 which allows for a high degree of project accuracy.

30 The baseline condition has been identified as the use of high GHG intensive pump
31 systems at a facility prior to conversion to low/no GHG intensive pump systems. A
32 process flow diagram for the baseline condition prior to converting high GHG intensive
33 pumps to low/no GHG intensive pumps is shown in **FIGURE 0.2**. Baseline emissions
34 likely stem from one of more of the following: electricity generation used to power
35 pumps, vented natural gas, and fuel extraction and processing of fossil fuels used in the
36 baseline.

37 Metered quantities of either electricity or fluid displaced in the project condition are
38 applied to pump-specific PDFs to estimate baseline emissions. Examples of how to
39 determine these PDFs for gas powered pumps is shown in **APPENDIX A**. High GHG

1 intensive pump systems are typically powered by natural gas, which is sourced from the
2 fuel supply for the facility, or by on-grid or off-grid electricity.

3 The project condition has been identified as the use of low/no GHG intensive pump
4 systems at a facility after the conversion. Similarly to the methodology used to calculate
5 baseline emissions, project emissions are calculated using PDFs from manufactures'
6 technical specifications. This requires the project developer to meter either the electricity
7 consumed or the fluid displaced in the new pump system.

8 Low/no GHG intensive pump systems are powered by natural gas, typically sourced from
9 the fuel supply for the facility and recaptured downstream, or by on-grid or off-grid
10 electricity. As such, project emission likely stem from one of the following: electricity
11 generation used to power pumps and fuel extraction and processing.

12 **Protocol Applicability:**

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

- 15 1. The conversion to low/no GHG intensive pumps displaces the same type of fluid
16 and provides the same level of services (i.e. functional equivalence) as the high
17 GHG intensive pumps as demonstrated by unit operational performance data,
18 and/or facility process flow diagrams and/or other equipment technical
19 specifications.
- 20 2. The project is a conversion from high GHG intensive pumps to low/no GHG
21 intensive pumps systems, which includes end-of-life replacements, and not
22 facilities originally constructed to use low/no GHG intensive pump systems. This
23 may be demonstrated by facility process flow diagrams and/or accounting records,
24 work orders, invoices or other vendor/third party documentation/evidence.

25 End-of-life replacements must demonstrate that there is a clear intent to increase
26 environmental performance. The pump system replacement must go beyond
27 replacing the end-of-life pump system with one of similar service. For example, if a
28 facility has a pump of type "A" which wears out and is subsequently replaced with
29 another pump type "A" (or if pump type "A" is not available, then a pump of
30 similar level of service, i.e. pump type "B"), this replacement would not qualify.
31 However, if the new pump system is installed such that it enhances environmental
32 performance (i.e. pump type "C"), it can qualify under this protocol. Furthermore,
33 if pump type "A" is no longer available, then the baseline would be set using pump
34 type "B".

35 For further clarity, a summary of available options is described in TABLE 2.1
36 where:

- 37 • "A" represents an existing end-of life pump;

- 1 • “B” represents the next best available pump. B is intended to represent a
- 2 pump or pump system that provides as close to the same level of service as
- 3 type A regardless of environmental performance. This scenario is intended
- 4 to represent cases where pump type A is no longer available in the market;
- 5 and
- 6 • “C” represents any pump or pumping system with environmental
- 7 performance better than pump “A” or “B”.

8 **TABLE 0.1: Evaluation Criteria/Baseline Selection for Pump End-of-life Options**

Option	Conversion Type	Is type A available?	Baseline calculated using* :
1	A→A	Yes	Does not qualify for offsets
2	A→B	Yes	Does not qualify for offsets
3	A→B	No	Does not qualify for offsets
4	A→C	No	B
5	A→C	Yes	A

9 *This column refers to the manufacturer’s technical specifications used to calculate
 10 the baseline in Section 2.5 of this document.

- 11 3. The project must meet the requirements for offset eligibility as specified in the
 12 applicable regulation and guidance documents for the Alberta Offset System. [Of
 13 particular note:
- 14 a. [The date of equipment installation, operating parameter changes or process
 15 reconfiguration are initiated or have effect on the project on or after January 1,
 16 2002 as indicated by facility records;]
- 17 b. [The project may generate emission reduction offsets for a period of 8 years
 18 unless an extension is granted by Alberta Environment, as indicated by facility and
 19 offset records. Additional credit duration periods require a reassessment of the
 20 baseline condition; and,]
- 21 c. [Ownership of the emission reduction offsets must be established as indicated by
 22 facility records.]
- 23 d. [An emission reduction or removal can only be used once to create an emission
 24 offsets in Alberta’s Offsets System. Alberta Environment tracks all verified
 25 emission offsets from projects that are used for compliance and will randomly audit
 26 submitted verification and compliance reports to ensure that activities are unique in
 27 the Alberta system. A public Offset Registry will further support the objectives of
 28 this criterion.]

29 **Protocol Flexibility:**

30 The protocol is applicable to any kind of pump conversion program intended to
 31 reduce/eliminate greenhouse gas emissions. Given the diversity of pumps operated in the
 32 oil and gas industry, the following flexibility mechanisms have been put in place:

- 1 1. Site specific emissions factors may be substituted for the generic emission factors
2 indicated in this protocol document. The methodology for generation of these
3 emission factors must be sufficiently robust to ensure accuracy.
- 4 2. This protocol establishes greenhouse gas emissions for the project conditions based
5 on metered electricity. Flexibility is given to the project developer to measure
6 displaced fluids or electricity. The project developer should therefore be cautious
7 when establishing the PDF for fluid-based metering. Refer to **APPENDIX A** for
8 details.
- 9 3. This Flexibility Mechanism allows the project developer to establish baseline
10 volumes of fluids displaced on a site-specific basis using historical data. Historical
11 records at the facility before implementation of the conversion include purchase
12 bills, purchase invoices, metered quantities etc. This baseline is applicable to
13 conversion projects that, for example have an associated optimization program.
14 These types of projects would potentially have lower volumes in the project
15 condition and as a result would underestimate the claimable offsets under the
16 methodology in section 2.5. **APPENDIX B – Explanation on Adjustment of**
17 **Baseline** provides a detailed explanation on how these quantities are quantified.
- 18 4. Retroactive credits are accepted under this protocol for projects that were
19 implemented before the creation of this protocol. The claim is based on an adjusted
20 baseline including:
 - 21 ▪ Annual electricity displacement factors;
 - 22 ▪ Volumes of fluids displaced; and
 - 23 ▪ Commissioning or decommissioning of devices.
- 24 Documentation must be provided in order to establish retroactive credits. These
25 may include electricity bills, purchase orders or invoices for displaced fluids,
26 purchase orders or invoices for high GHG and low/no GHG intensive pump
27 systems installed at the facility. Emissions are quantified in the same manner as
28 emissions in section 2.5.
- 29 5. Pump system conversion can take place at single or multiple sites. As such, the
30 protocol allows for flexibility in aggregating offsets from multiple projects.

31 If applicable, the proponent must indicate and justify why flexibility provisions have
32 been used.

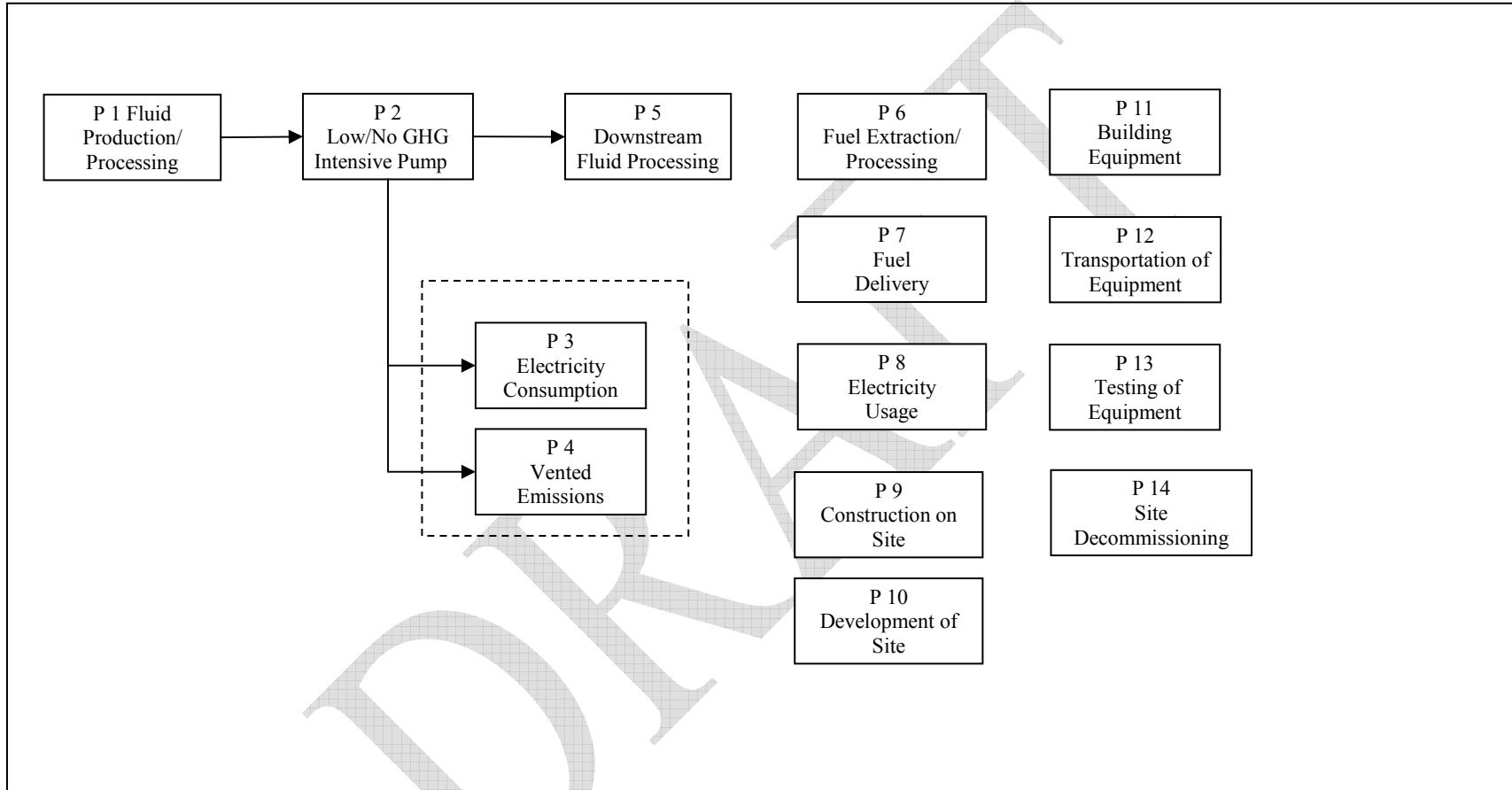
33 1.2. Glossary of New Terms

Functional Equivalence	The project and the baseline should provide the same function and quality of products or services. This type of comparison requires a common metric or unit of measurement (such as flow rate) for comparison between the Project and Baseline activity (Refer to the Guidance Document for the Alberta Offset System) The functional equivalence in this protocol is volume
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	of fluid displaced, measured in terms of volume displaced or electricity consumption.
High GHG Intensive Pump	Any pump that uses pressurized natural gas to power a pump to displace a fluid. This natural gas is subsequently vented to the atmosphere. The pump may also run on electricity.
Low/No GHG Intensive Pump	Any pump that uses electricity to power a pump to displace a fluid or recaptures natural gas. Electricity may come from renewable or non-renewable sources.
Pump	A pump is an apparatus used to move or displace fluids, such as gases, liquids or slurries.
Pump System	A pump and accessories such as power source, cables, etc...

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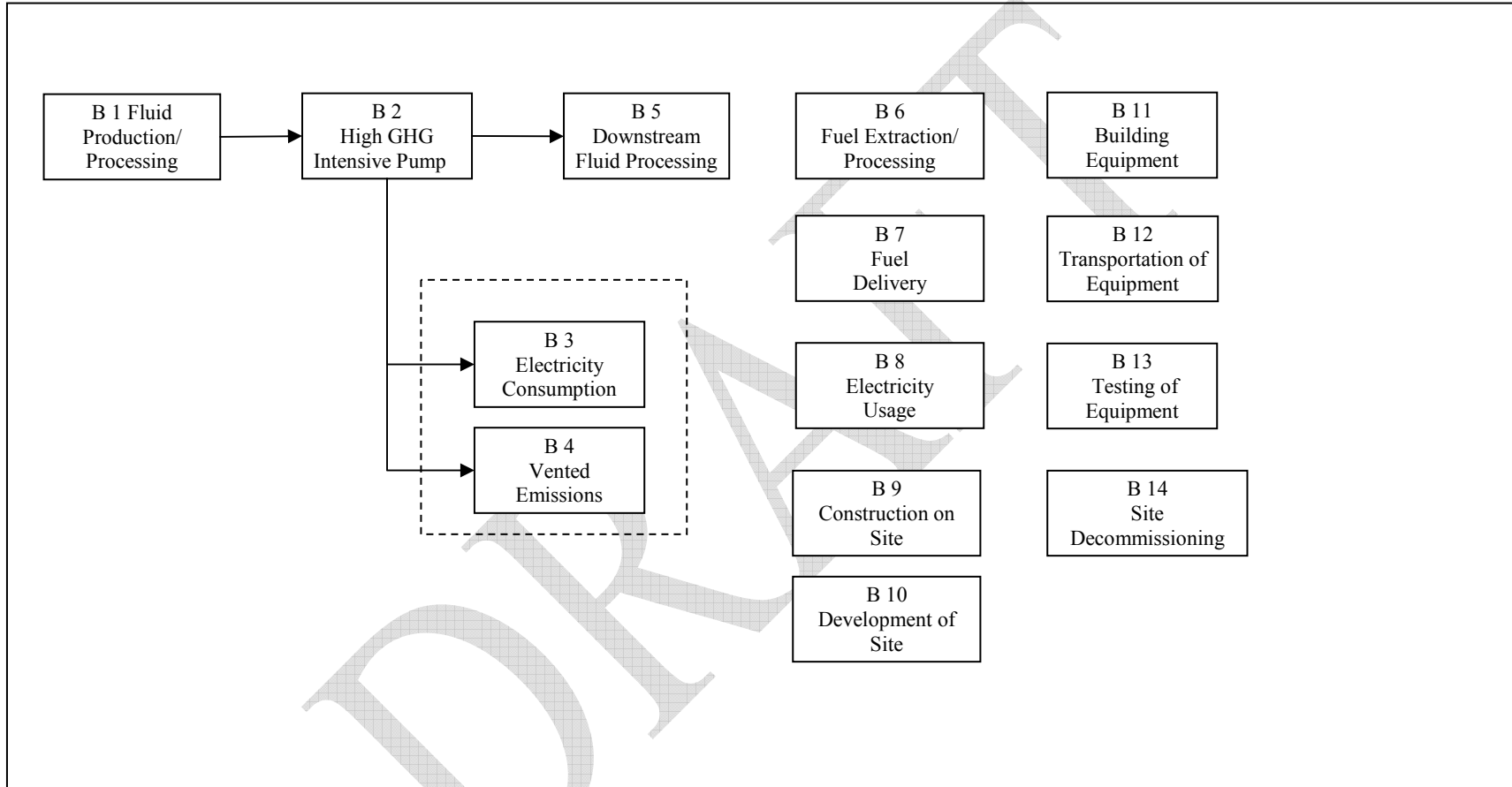
1 **FIGURE 0.1: Process Flow Diagram for Project Condition**



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1 **FIGURE 0.2: Process Flow Diagram for Baseline Condition**

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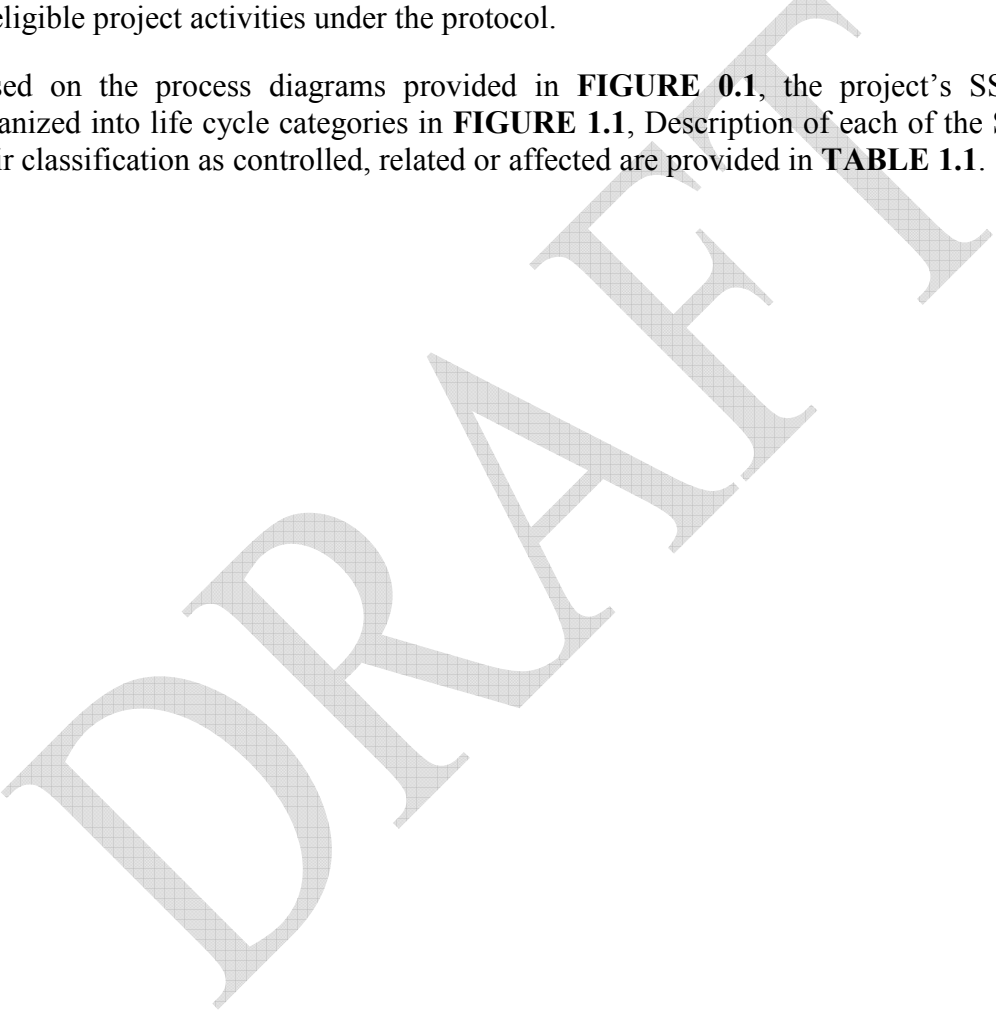
2.0. Quantification Development and Justification

The following sections outline the quantification development and justifications.

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

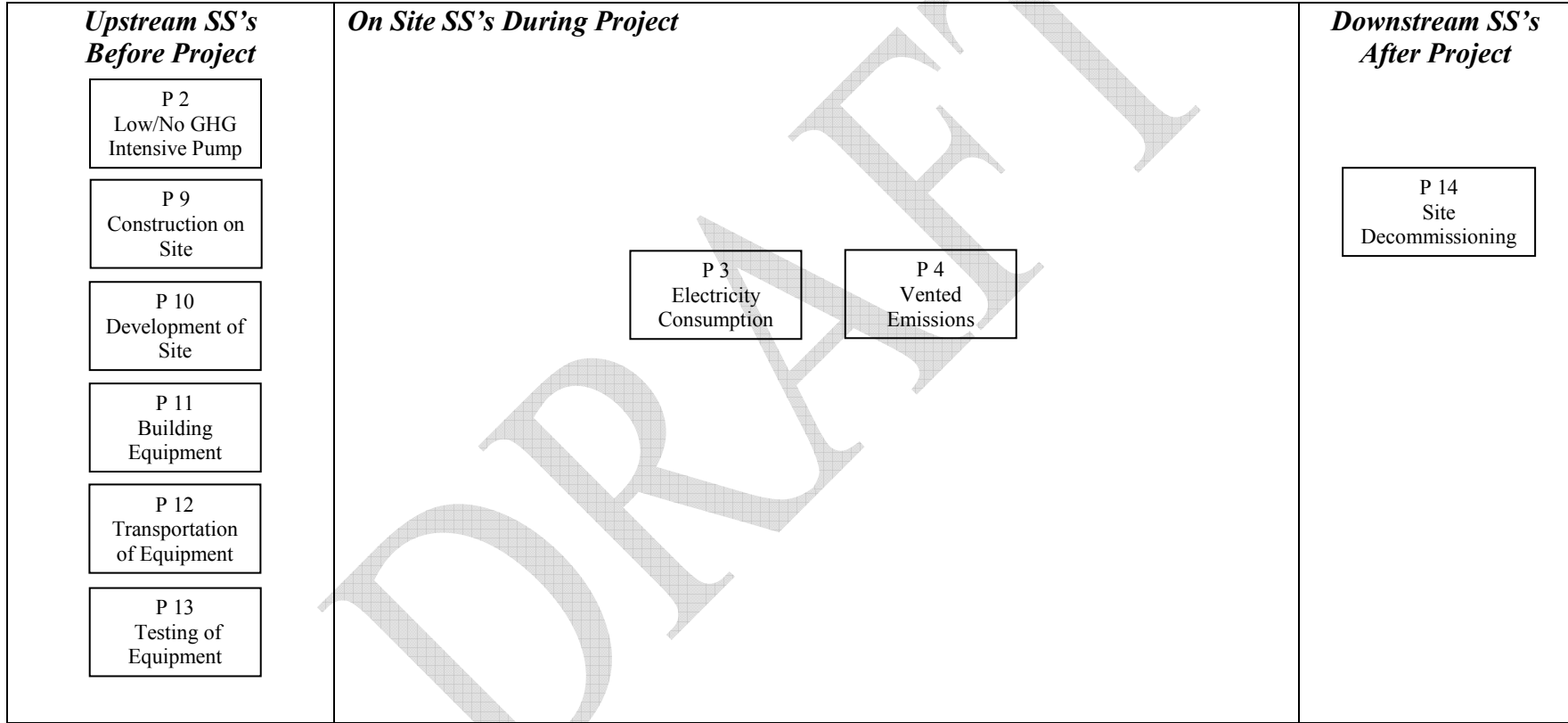
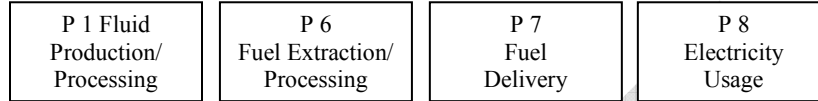
SS's were identified for the project by reviewing the seed documents and relevant process flow diagrams pertaining to the operation of natural gas processing facilities. This process confirmed that the SS's in the process flow diagrams covered the full scope of eligible project activities under the protocol.

Based on the process diagrams provided in **FIGURE 0.1**, the project's SS's were organized into life cycle categories in **FIGURE 1.1**, Description of each of the SS's and their classification as controlled, related or affected are provided in **TABLE 1.1**.

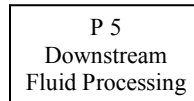


1 **FIGURE 1.1: Project Element Life Cycle Chart**

Upstream SS's During Project



Downstream SS's During Project



1 **TABLE 1.1: Project SS's**

1. SS	2. Description	3. Controlled, Related or Affected
Upstream SS's during Project Operation		
P 1 Fluid Production/Processing	Each of the fluids displaced throughout the project will need to be sourced and processed. Types and quantities of fluids used would need to be tracked. This will allow for the calculation of greenhouse gas emissions from the various processes involved in the production, refinement, and storage of the fluids.	Related
P 6 Fuel Extraction/ Processing	Each of the fuels used throughout the project will need to be sourced and processed. This will allow for the calculation of 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 SS's in this project are considered in this SS. Types and quantities of fuels used would need to be tracked.	Related
P 7 Fuel Delivery	Each of the fuels used throughout 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 gas. 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
P 8 Electricity Usage	Electricity may be required for operating the facility. This power may be sourced either from internal generation, connected facilities or the local electricity grid. Metering of electricity may be netted in terms of the power going to and from the grid. Quantity and source of the power are the important characteristics to be tracked as they directly relate to the quantity of greenhouse gas emissions. Electricity for pump system is taken into account in activity P3.	Related
Onsite SS's during Project Operation		
P 3 Electricity Consumption	Electricity may be required for operating the pumps or re-pressurizing the captured fuel gas. This power may be sourced either from internal generation, connected facilities or the local electricity grid. Metering of electricity may be netted in terms of the power going to and from the grid. Quantity and source of the power are the important characteristics to be tracked as they directly relate to the quantity of greenhouse gas emissions.	Controlled
P 4 Vented Emissions	Some pump systems use natural gas from the facility's fuel supply. Once the natural gas has powered the pump, it is left to vent to the atmosphere. Vented emissions in the project can be captured and reintroduced to the pipe network. Quantity and gas composition of the natural gas are important characteristics to be tracked as they directly relate to the quantity of greenhouse gas emissions avoided.	Controlled
Downstream SS's during Project Operation		
Other		

P 2 Low/No GHG Intensive Pump	The low/no GHG intensive pump system and accessories such as power supply and assembly need to be manufactured by a specialized company. Quantity and source of the power are the important characteristics to be tracked as they directly relate to the quantity of greenhouse gas emissions.	Related
P 9 Construction on Site	The process of construction at the site may require a variety of heavy equipment, smaller power tools, cranes, and generators. The operation of this equipment will have associated greenhouse gas emissions from the use of fossil fuels and electricity.	Related
P 10 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. 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
P 11 Building of 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, 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, fabrication and assembly.	Related
P 12 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, barge, or 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
P 13 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
P 14 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
P 5 Downstream Fluid Processing	Each of the displaced fluids throughout the project may need to be processed downstream. Types and quantities of fluids used would need to be tracked. This will allow for the calculation of greenhouse gas emissions from the various processes involved in the production, refinement, and storage of the fluids downstream.	Related

1 **2.2. Identification of Baseline**

2 **2.2.1. Identification and Assessment of Baseline Scenarios**

3 An assessment of potential baseline scenarios was performed based on section 2.5.2
4 Baseline Conditions from Alberta Carbon Offset Solutions’ “Offset Credit Project
5 Guidance Document”. Preference was given to baseline candidates that portrayed
6 accuracy and conservativeness. Baselines were also defined as either static or dynamic
7 depending on the characteristics of each one. **TABLE 1.2** summarizes the baseline
8 candidates and the reason they were accepted or rejected.

9 **2.2.2. Selection of Baseline Scenario**

10 A comparison-based baseline was chosen because of accuracy and consistency. The
11 protocol relies on manufacturer’s technical specifications combined with site-specific
12 continuously metered quantities to establish the baseline. PDFs established using
13 manufacturers’ technical specifications provide an accurate baseline estimation because
14 they are established under controlled conditions.

15 The type and volume of fluid displaced in the baseline is assumed to be the same as in the
16 project condition as required by design purposes or by facility operations. As such, the
17 conversion is a change in the way the fluid is displaced and not the volume of fluid
18 displaced. This allows a relationship to be established between the project condition and
19 baseline condition based on type and volume of fluid displaced. PDFs from the baseline
20 and project are applied to measured quantities in the project to calculate emissions from
21 the project itself and the baseline.

22 The baseline condition is defined, including the relevant SS’s and processes, as shown in
23 **FIGURE 0.2**. More detail on each of these SS’s is provided in the following section,
24 section 2.3.

25 **2.3. Identification of SS’s for the Baseline**

26 Based on the process diagrams provided in **FIGURE 0.2**, the project’s SS’s were
27 organized into life cycle categories in **FIGURE 1.2**. Description of each of the SS’s and
28 their classification as ‘controlled’, ‘related’ or ‘affected’ are provided in **TABLE 1.3**.

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1 **TABLE 1.2: Assessment of Possible Baseline Scenarios**

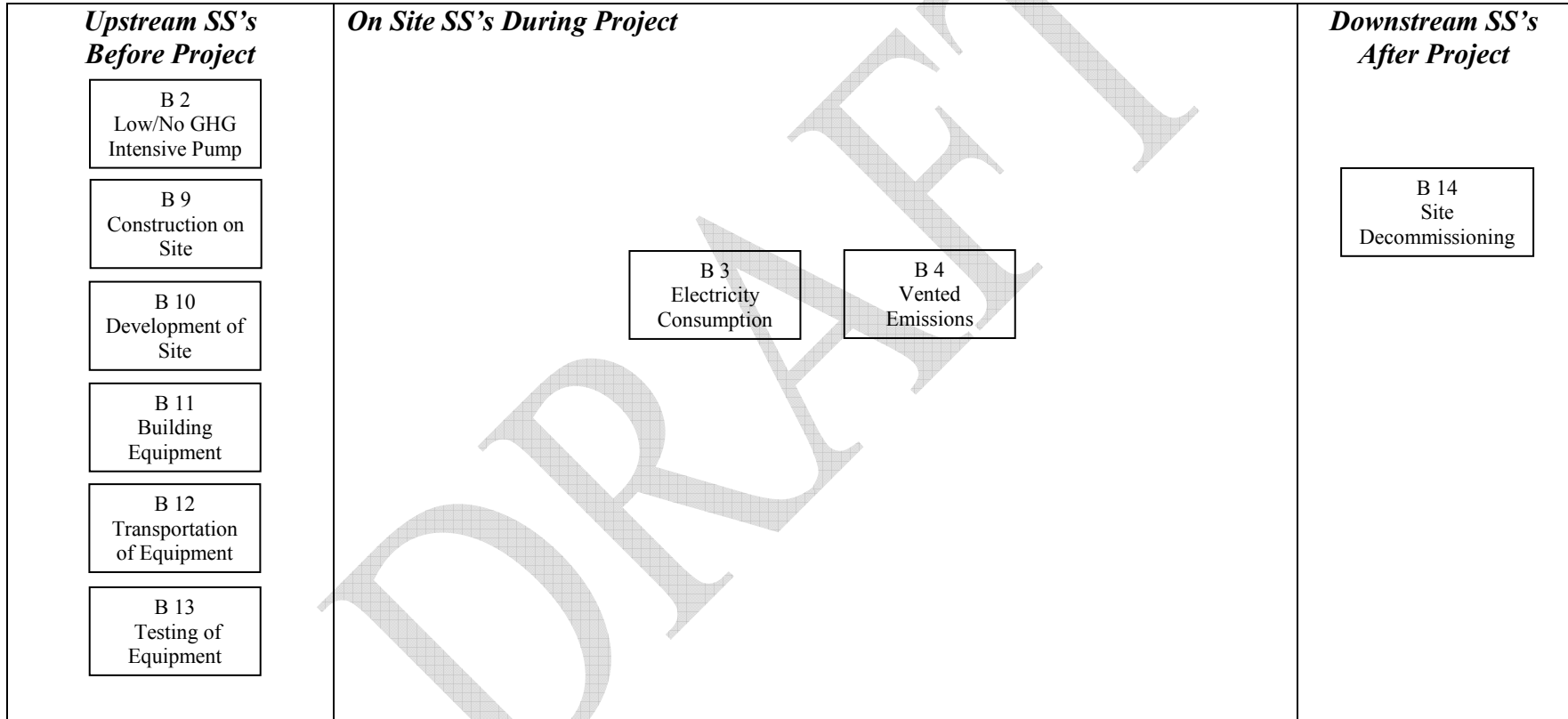
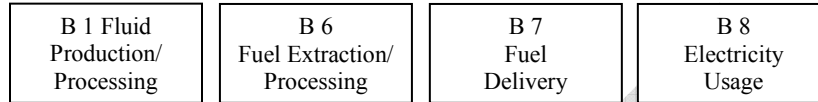
1. Baseline Options	2. Description	3. Static / Dynamic Baseline	4. Accept or Reject and Justify
Historic Benchmark:	Baseline emissions are constructed using historical records from site-specific operations. <i>(Typically site-specific and can be constructed to reflect reductions in a base period (such as the average emissions of the previous three years).)</i>	Static/ Dynamic	Reject- Historic benchmark, although accurate, is not practical because records may not exist as to how much fluid was displaced. Moreover, if they do exist, accounting and data records may be cumbersome to procure or process.
Performance Standard:	Greenhouse gas emissions can be established by accepted emission factors. <i>(Assumes the typical emissions profile for the industry or sector is a reasonable representation of the baseline.)</i>	Static/ Dynamic	Accept- Emission factors from accredited sources can be used to establish emissions. In general, the oil and gas industry has developed accurate emissions factors for reporting purposes for various types of pumps.
Comparison-based:	Emissions can be taken from a control group and compared to the project using manufacturer emission rates. <i>(Actual measurements of parameters from a control group to compare with the project.)</i>	Static/ Dynamic	Accept-Measuring emissions from a control group to establish a baseline will provide an accurate approach. These emissions factor are established by testing control groups and reported in the manufacturer’s technical specifications for a given pump. Priority is given to this approach.
Projection-Based:	Emissions can be used to project past/future emission reductions using mathematical models. <i>(Projections of reductions in the future)</i>	Static/ Dynamic	Reject-The nature of this protocol involves diverse categories of pumps, so each type may require a particular mathematical model. This would be a

	<i>can use a variety of techniques, from simple straight-line growth assumptions to complex models.)</i>		cumbersome and impractical approach to establish the baseline.
Adjusted Baseline:	Emissions from an established baseline can be adjusted to reflect a baseline from another project <i>(Takes into account current practice levels of a particular project and specified that the same baseline is used for all projects of a certain type, regardless of historical practices.)</i>	Static/ Dynamic	Accept-This approach will be necessary if flexibility mechanisms are used.
Other (Explain):		N/A	Rejected-No other baseline is available.

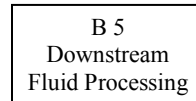
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1 **FIGURE 1.2: Baseline Element Life Cycle Chart**

Upstream SS's During Project



Downstream SS's During Project



1 **TABLE 1.3: Baseline SS's**

1. SS	2. Description	3. Controlled, Related or Affected
Upstream SS's during Project Operation		
B 1 Fluid Production/Processing	Each of the fluids displaced throughout the project will need to be sourced and processed. This will allow for the calculation of greenhouse gas emissions from the various processes involved in the production, refinement, and storage of the fluids. Types and quantities of fluids used would need to be tracked.	Related
B 6 Fuel Extraction/ Processing	Each of the fuels used throughout the project will need to be sourced and processed. This will allow for the calculation of 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 SS's in this project are considered in this SS. Types and quantities of fuels used would need to be tracked.	Related
B 7 Fuel Delivery	Each of the fuels used throughout 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 gas. 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
B 8 Electricity Usage	Electricity may be required for operating the facility. This power may be sourced either from internal generation, connected facilities or the local electricity grid. Metering of electricity may be netted in terms of the power going to and from the grid. Quantity and source of the power are the important characteristics to be tracked as they directly relate to the quantity of greenhouse gas emissions. Electricity for pump system is taken into account in activity P3.	Related
Onsite SS's during Project Operation		
B 3 Electricity Consumption	Electricity may be required for operating the pumps. This power may be sourced either from internal generation, connected facilities or the local electricity grid. Metering of electricity may be netted in terms of the power going to and from the grid. Quantity and source of the power are the important characteristics to be tracked as they directly relate to the quantity of greenhouse gas emissions.	Controlled
B 4 Vented Emissions	Some pump systems use natural gas from the facility's fuel supply. Once the natural gas has powered the pump, it is left to vent to the atmosphere in the baseline condition. Quantity and gas composition of the natural gas are important characteristics to be tracked as they directly relate to the quantity of greenhouse gas emissions vented to the atmosphere.	Controlled
Downstream SS's during Project Operation		
Other		
B 2 High GHG Intensive	The high GHG intensive pump system and accessories such as power supply and assembly need	Related

Pump	to be manufactured by a specialized company. Quantity and source of the power are the important characteristics to be tracked as they directly relate to the quantity of greenhouse gas emissions.	
B 9 Construction on Site	The process of construction at the site may require a variety of heavy equipment, smaller power tools, cranes, and generators. The operation of this equipment will have associated greenhouse gas emissions from the use of fossil fuels and electricity.	Related
B 10 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. 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
B 11 Building of 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, 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, fabrication and assembly.	Related
B 12 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, barge, or 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
B 13 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
B 14 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
B 5 Downstream Fluid Processing	Each of the displaced fluids throughout the project may need to be processed downstream. Types and quantities of fluids used would need to be tracked. This will allow for the calculation of greenhouse gas emissions from the various processes involved in the production, refinement, and storage of the fluids downstream.	Related

1 **2.4. Selection of Relevant Project and Baseline SS's**

2 Each of the SS's from the project and baseline condition were compared and evaluated as
3 to their relevancy using the guidance provided in Annex VI of the "Guide to
4 Quantification Methodologies and Protocols: Draft", dated March 2006 (Environment
5 Canada). The justification for the exclusion or conditions upon which SS's may be
6 excluded is provided in **TABLE 1.4**, below. All other SS's listed previously are included.

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1 **TABLE 1.4: 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				
P 1 Fluid Production/Processing	N/A	Related	Excluded	Excluded as fluid production/processing is not impacted by the implementation of the project and as such the baseline and the project conditions will be functionally equivalent.
B 1 Fluid Production/Processing	Related	N/A	Excluded	
P 6 Fuel Extraction/Processing	N/A	Related	Included	N/A
B 6 Fuel Extraction/Processing	Related	N/A	Included	N/A
P 7 Fuel Delivery	N/A	Related	Excluded	Excluded as the fuel delivery is not impacted by the implementation of the project and as such the baseline and the project conditions will be functionally equivalent.
B 7 Fuel Delivery	Related	N/A	Excluded	
P 8 Electricity Usage	N/A	Related	Excluded	Excluded as electricity usage is not impacted by the implementation of the project and as such the baseline and the project conditions will be functionally equivalent.
B 8 Electricity Usage	Related	N/A	Excluded	
Onsite SS's				
P 3 Electricity Consumption	N/A	Controlled	Included	N/A
P 4 Vented Emissions	N/A	Controlled	Included	N/A
B 3 Electricity Consumption	Controlled	N/A	Included	N/A
B 4 Vented Emissions	Controlled	N/A	Included	N/A
Downstream SS's				
P 5 Downstream Fluid Processing	N/A	Related	Excluded	Excluded as downstream fluid processing is not impacted by the implementation of the project and as such the baseline and the project conditions will be functionally equivalent.
P 5 Downstream Fluid Processing	Related	N/A	Excluded	
Other				
P 2 Low/No Intensive Pump	N/A	Related	Excluded	Emissions from low/no GHG intensive pump are not material given the long project life and the minimal time required for construction of pumps and accessories.

B 2 High GHG Intensive Pump	Related	N/A	Excluded	Emissions from high GHG intensive pump are not material given the long project life and the minimal time required for construction of pumps and accessories.
P 9 Construction on Site	N/A	Related	Excluded	Emissions from construction on site are not material given the long project life and the minimal construction on site typically required.
B 9 Construction on Site	Related	N/A	Excluded	Emissions from construction on site are not material for the baseline condition given the minimal construction on site typically required.
P 10 Development of Site	N/A	Related	Excluded	Emissions from development of site are not material given the long project life and the minimal development of site typically required.
B 10 Development of Site	Related	N/A	Excluded	Emissions from development of site are not material for the baseline condition given the minimal development of site typically required.
P 11 Building of Equipment	N/A	Related	Excluded	Emissions from building of equipment are not material given the long project life and the minimal building equipment typically required.
B 11 Building of Equipment	Related	N/A	Excluded	Emissions from building of equipment are not material for the baseline given the minimal building equipment typically required.
P 12 Transportation of Equipment	N/A	Related	Excluded	Emissions from transportation of equipment are not material given the long project life and the minimal transportation of equipment typically required.
B 12 Transportation of Equipment	Related	N/A	Excluded	Emissions from transportation of equipment are not material for the baseline given the minimal transportation of equipment typically required.
P 13 Testing of Equipment	N/A	Related	Excluded	Emissions from testing of equipment are not material given the long project life and the minimal testing of equipment typically required.
B 13 Testing of Equipment	Related	N/A	Excluded	Emissions from testing of equipment are not material for the baseline given the minimal testing of equipment typically required.
P 14 Site Decommissioning	N/A	Related	Excluded	Emissions from decommissioning of site are not material given the long project life and the minimal decommissioning typically required.
B 14 Site Decommissioning	Related	N/A	Excluded	Emissions from decommissioning of site are not material for the baseline given the minimal decommissioning typically required.

2.5. Quantification of Reduction, Removals, and Reversals of Relevant SS's

2.5.1. Quantification Approach

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 1.5**, below. These calculation methodologies serve to complete the following three equations for calculating the emission reductions from the comparison of the baseline and project conditions.

The general approach is to calculate the offsets as follows:

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

$$\text{Emissions}_{\text{Baseline}} = \text{Emissions}_{\text{Fuel Extraction / Processing}} + \text{Emissions}_{\text{Electricity Consumption}} + \text{Emissions}_{\text{Vented Emissions}}$$

$$\text{Emissions}_{\text{Project}} = \text{Emissions}_{\text{Fuel Extraction / Processing}} + \text{Emissions}_{\text{Electricity Consumption}} + \text{Emissions}_{\text{Vented Emissions}}$$

where

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

$\text{Emissions}_{\text{Fuel Extraction/Processing}}$ = emissions under SS B 6 from fuel extraction and processing of fuels used in the baseline

$\text{Emissions}_{\text{Electricity Consumption}}$ = emissions under SS B 3 from electricity used to operate pumping system

$\text{Emissions}_{\text{Vented Emissions}}$ = emissions under SS B 4 from vented gas to operate pumping systems

$\text{Emissions}_{\text{Project}}$ = sum of the emissions under the project condition.

$\text{Emissions}_{\text{Fuel Extraction/Processing}}$ = emissions under SS P 6 emissions from fuel extraction and processing used in the project

$\text{Emissions}_{\text{Electricity Consumption}}$ = emissions under SS P 3 from electricity used to operate pumping system

$\text{Emissions}_{\text{Vented Emissions}}$ = emissions under SS P 4 from capture of vented gas to operate pumping systems

1 **TABLE 1.5: Quantification Procedures**

1. 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						
P 6 Fuel Extraction/ Processing	$\text{Emissions}_{\text{Fuel Extraction / Processing}} = \sum (\text{Vol. Fuel}_i * \text{EF}_{\text{Fuel}_i \text{CO}_2}); \sum (\text{Vol. Fuel}_i * \text{EF}_{\text{Fuel}_i \text{CH}_4}); \sum (\text{Vol. Fuel}_i * \text{EF}_{\text{Fuel}_i \text{N}_2\text{O}})$					
	Emissions _{Fuel Extraction / Processing}	kg of CO ₂ e	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel and electricity use on site is likely aggregate for each of these SS's.
	Volume of Each Type of Fuel/ Vol. Fuel _i	m ³	Measured	Direct metering or reconciliation of volumes based on P3 and P4	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 Fuel Including Production and Processing / EF _{Fuel_{CO2}}	kg CO ₂ per m ³	Estimated	From Environment Canada reference documents	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH ₄ Emissions Factor for Fuel Including Production and Processing / EF _{Fuel_{CH4}}	kg CH ₄ per m ³	Estimated	From Environment Canada reference documents	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N ₂ O Emissions Factor for Fuel	kg N ₂ O per m ³	Estimated	From Environment Canada reference	Annual	Reference values adjusted annually as part

	Including Production and Processing / EF Fuel _{N20}			documents		of Environment Canada reporting on Canada's emissions inventory.
P 3 Electricity Consumption	<p><i>The following equation (1) should be used to calculate emissions from Electricity Consumption for projects that use electricity from the grid. Note that this emission factor can be based on electricity displacement factor for Alberta. Equation (2) is used if the metered quantity is the volume of fluid displaced.</i></p> <p>1. Emissions_{Electricity Consumption} = $\Sigma (EF_{Electricity} * Electricity Use_i)$</p> <p>2. Emissions_{Electricity Consumption} = $\Sigma ((EF_{Electricity} / PDF_{New Pump_i}) * Vol. Fluid_i)$</p> <p><i>The following equation (3) should be used to calculate emissions from Electricity Consumption for projects that use on-site electricity generated from fossil fuels.</i></p> <p>3. Emissions_{Electricity Consumption} = $\Sigma (Vol. Fuel_i * EF_{Fuel_i CO_2});$ $\Sigma (Vol. Fuel_i * EF_{Fuel_i CH_4});$ $\Sigma (Vol. Fuel_i * EF_{Fuel_i N_2O}).$</p> <p><i>Note that pumps running on renewable energy sources such as solar or power have a default EF of 0 kg of CO₂e /kWh.</i></p>					
	Emissions _{Electricity Consumption}	kg of CO ₂ e	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel and electricity use on site is likely aggregate for each of these SS's.
	Emission Factor for Grid-Generated Electricity / EF _{Electricity}	kg of CO ₂ e/kWh	Estimated	From Environment Canada reference documents	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	Electricity Used by Pump i /Electricity Use _i	kWh	Measured	Direct metering or reconciliation of volumes	Continuous metering or monthly	Both methods are standard practice. Frequency of metering is

					reconciliation	highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Pump Displacement Factor for Low/No GHG Intensive Pump/ PDF _{New} Pump _i	m ³ /kWh	Estimated	Estimated based on manufactures' technical specifications for project pump	N/A	Available from the manufacturer and should be an average under steady state operations.
	Volume of Fluid Displaced _i / Vol. Fluid _i	m ³	Measured	Direct metering or reconciliation of volumes	Continuous metering or monthly reconciliation	Both methods are standard practice. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Volume of Fossil Fuel _i / Vol. Fuel _i	m ³	Measured	Direct metering or reconciliation of volumes	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 Each Type of Fuel _i / EF _{CO2} Fuel _{CO2}	kg CO ₂ per m ³	Estimated	From Environment Canada reference documents	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 _i / EF _{Fuel_{CH4}}	kg CH ₄ per m ³	Estimated	From Environment Canada reference documents	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's

	N ₂ O Emissions Factor for Each Type of Fuel i / EF Fuel _{N2O}	kg N ₂ O per m ³	Estimated	From Environment Canada reference documents	Annual	emissions inventory. Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
P 4 Vented Emissions	Captured under B4					
Baseline SS's						
	Emissions _{Fuel Extraction / Processing} = $\sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\text{CO}_2})$; $\sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\text{CH}_4})$; $\sum (\text{Vol. Fuel}_i * \text{EF Fuel}_{i\text{N}_2\text{O}})$					
	Emissions _{Fuel Extraction / Processing}	kg of CO ₂ e	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel and electricity use on site is likely aggregate for each of these SS's.
	Volume of Fossil Fuel i / Emissions _{Fuel Gas}	m ³	Estimated	Estimated based on volumes of fuel type for B3 and B4	-	Estimated using technical specifications for equipment used in baseline condition
B 10 Fuel Extraction/ Processing	CO ₂ Emissions Factor for Fuel Including Production and Processing / EF Fuel _{CO2}	kg CO ₂ per m ³	Estimated	From Environment Canada reference documents	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH ₄ Emissions Factor for Fuel Including Production and Processing / EF Fuel _{CH4}	kg CH ₄ per m ³	Estimated	From Environment Canada reference documents	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.

	N ₂ O Emissions Factor for Fuel Including Production and Processing / EF Fuel _{N2O}	kg N ₂ O per m ³	Estimated	From Environment Canada reference documents	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
B 3 Electricity Consumption	<p><i>The following equation (1) should be used to calculate emissions from Electricity Consumption for projects that used electricity from the grid. Note that this emission factor can be based on electricity displacement factor for Alberta. Equation (2) is used if the metered quantity is the volume of fluid displaced.</i></p> <p>1. Emissions_{Electricity Consumption} = $\Sigma (\text{Electricity Use}_i * (\text{PDF}_{\text{New Pump } i} / \text{PDF}_{\text{Old Pump } i}) * \text{EF}_{\text{Electricity}})$</p> <p>2. Emissions_{Electricity Consumption} = $\Sigma ((\text{EF}_{\text{Electricity}} / \text{PDF}_{\text{Old Pump } i}) * \text{Vol.}_{\text{Fluid } i})$</p> <p><i>The following equation (3) should be used to calculate emissions from Electricity Consumption for projects that used on-site electricity generated from fossil fuels.</i></p> <p>3. Emissions_{Electricity Consumption} = $\Sigma (\text{Vol.}_{\text{Fuel } i} * \text{EF}_{\text{Fuel } i \text{ CO}_2} * (\text{PDF}_{\text{New Pump } i} / \text{PDF}_{\text{Old Pump } i});$ $\Sigma (\text{Vol.}_{\text{Fuel } i} * \text{EF}_{\text{Fuel } i \text{ CH}_4} * (\text{PDF}_{\text{New Pump } i} / \text{PDF}_{\text{Old Pump } i});$ $\Sigma (\text{Vol.}_{\text{Fuel } i} * \text{EF}_{\text{Fuel } i \text{ N}_2\text{O}} * (\text{PDF}_{\text{New Pump } i} / \text{PDF}_{\text{Old Pump } i}).$</p>					
	Emissions _{Electricity Consumption}	kg of CO ₂ e	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel and electricity use on site is likely aggregate for each of these SS's.
	Electricity Used by Pump i / Electricity Use _i	kWh	Measured	Direct metering or reconciliation of volumes from P3	Continuous metering or monthly reconciliation	Both methods are standard practice. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.

	Pump Displacement Factor for Low/No GHG Intensive Pump/ PDF _{New Pump i}	m ³ /kWh	Estimated	Estimated based on manufactures' technical specifications for project pump	N/A	Available from the manufacturer and should be an average under steady state operations.
	Pump Displacement Factor for High GHG Intensive Pump/ PDF _{Old Pump i}	m ³ /kWh	Estimated	Estimated based on manufactures' technical specifications for project pump	N/A	Available from the manufacturer and should be an average under steady state operations.
	Emission Factor for Grid-Generated Electricity / EF _{Electricity}	kg of CO ₂ e/kWh	Estimated	From Environment Canada reference documents	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	Volume of Fluid Displaced i / Vol. Fluid i	m ³	Measured	Direct metering or reconciliation of volumes	Continuous metering or monthly reconciliation	Both methods are standard practice. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Volume of Fossil Fuel i / Vol. Fuel i	m ³	Measured	Direct metering or reconciliation of electricity consumption from P3	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 Each Type	kg CO ₂ per m ³	Estimated	From Environment Canada reference	Annual	Reference values adjusted annually as part

	of Fuel i / EF Fuel CO2			documents		of Environment Canada reporting on Canada's emissions inventory.
	CH ₄ Emissions Factor for Each Type of Fuel i / EF Fuel _{CH4}	kg CH ₄ per m ³	Estimated	From Environment Canada reference documents	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N ₂ O Emissions Factor for Each Type of Fuel i / EF Fuel _{N2O}	kg N ₂ O per m ³	Estimated	From Environment Canada reference documents	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
B 4 Vented Emissions	<p><i>The fuel gas supply is methane-rich gas used at the facility. As such, the calculation of emission from the baseline will only use the methane component; the carbon dioxide component is not included as emissions are negligible.</i></p> <p><i>Equation (1) is used to calculate emissions from pump systems that operate on natural gas supplied from the facility's fuel gas supply during the baseline condition using metered quantities of electricity.</i></p> <p>1. Emissions_{Vented Emissions} = $\Sigma (\text{Electricity Use}_i * \text{PDF}_{\text{New Pump } i} * \text{PDF}_{\text{Gas Pump } i} * \rho_{\text{CH}_4} * \%_{\text{CH}_4 \text{ Fuel}} / \%_{\text{CH}_4 \text{ Reference}} * \text{GWP}_{\text{CH}_4})$</p> <p><i>Equation (2) is used to calculate emissions from pump systems that operate on natural gas supplied from the facility's fuel gas supply during the baseline condition using metered quantities of fluid displaced.</i></p> <p>2. Emissions_{Vented Emissions} = $\Sigma (\text{Vol. Fluid } i * \text{PDF}_{\text{Gas Pump } i} * \rho_{\text{CH}_4} * \%_{\text{CH}_4 \text{ Fuel}} / \%_{\text{CH}_4 \text{ Reference}} * \text{GWP}_{\text{CH}_4})$</p>					
	Emissions _{Vented Emissions}	kg of CO ₂ e	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel and electricity use on site is likely aggregate for each of these SS's.
	Electricity Used by Pump i / Electricity Use _i	kWh	Measured	Direct metering or reconciliation of electricity consumption	Continuous metering or monthly	Both methods are standard practice. Frequency of metering is

				from P3	reconciliation	highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Pump Displacement Factor for Low/No GHG Intensive Pump/ PDF _{New Pump i}	m ³ /kWh	Estimated	Estimated based on manufactures' technical specifications for project pump	N/A	Available from the manufacturer and should be an average under steady state operations.
	Pump Displacement Factor for Gas-Powered Pump/PDF _{Gas Pump}	m ³ gas per m ³ fluid	Estimated	Estimated based on manufactures' technical specifications for baseline pumps. Refer to APPENDIX A for details	N/A	Volumes of gas used to power gas-powered pumps can be estimated using information from facility operations.
	Density of Methane / ρ _{CH4}	Kg / m ³	Estimated	0.717kg/m ³ at STP	N/A	If this value is used all values must be adjusted for standard temperature and pressure.
	Reference Percent Methane in Fuel Gas /% _{CH4 Reference}	%	Estimated	From manufactures' assumptions in determining technical specifications for given pump ¹	N/A	Reference values from manufactures' assumptions when calculating vented rates provides for reasonable diligence and accuracy.
	Percent Methane in Fuel Gas /% _{CH4 Fuel}	%	Measured	Direct Measurement	Annual	Fuel gas volumes should remain relatively stable during steady-state operation.
	Global Warming	Kg CO ₂ e/Kg	Estimated	From Environment	Annual	The applicable global

¹ 100% reference can be used for conservativeness.

	Potential of Methane/ GWP_{CH_4}	CH_4		Canada; IPCC		warming potential of CH_4 is 21 as per the IPCC, ISO, Environment Canada and other internationally accepted best practice guidance.
	Volume of Fluid Displaced i / $Vol._{Fluid\ i}$	m^3	Measured	Direct metering or reconciliation of volumes	Continuous metering or monthly reconciliation	Both methods are standard practice. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.

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1 **2.5.2.Contingent Data Approach**

2 Contingent means for calculating or estimating the required data for the equations
3 outlined in section 2.5.1 are summarized in **TABLE 1.6**, below.

4 **2.6. Management of Data Quality**

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

10 The project proponent shall establish and apply quality management procedures to
11 manage data and information. Written procedures should be established for each
12 measurement task outlining responsibility, timing and record location requirements. The
13 greater the rigor of the management system data, the more easily an audit will be to
14 conduct for the project.

15 **2.6.1.Record Keeping**

16 Record keeping practices should include:

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

24 **2.6.2.Quality Assurance/Quality control (QA/QC)**

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

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

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1 **TABLE 1.6: Contingent Data Collection Procedures**

1. 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						
P 6 Fuel Extraction/Processing	Volume of Each Type of Fuel/ Vol. Fuel _i	L/m ³ /other	Estimated	Reconciliation of volume of fuel used within given time period	Monthly	Provides reasonable estimate of the parameter when the more accurate and precise method cannot be used.
P3 Electricity Consumption	Electricity Used by Pump _i /Electricity Use _i	kWh	Estimated	Reconciliation of electricity used within given time period	Monthly	Provides reasonable estimate of the parameter when the more accurate and precise method cannot be used.
	Pump Displacement Factor for Low/No GHG Intensive Pump/ PDF _{New Pump_i}	m ³ /kWh	Estimated	Estimated based on technical specifications for project pump of similar type	N/A	Available from any manufacturer when the more accurate and precise method cannot be used.
	Volume of Fluid Displaced _i / Vol. Fluid _i	m ³	Estimated	Reconciliation of volume of fluid displaced within given time period	Monthly	Provides reasonable estimate of the parameter when the more accurate and precise method cannot be used.
	Volume of Fossil Fuel _i / Vol. Fuel _i	m ³	Estimated	Reconciliation of volume of fuel used within given time period	Monthly	Provides reasonable estimate of the parameter when the more accurate and precise method cannot be used.

Baseline SS's						
B 6 Fuel Extraction/Processing	Volume of Each Type of Fuel/ Vol. Fuel _i	L/m ³ /other	Estimated	Reconciliation of volume of fuel used within given time period	Monthly	Provides reasonable estimate of the parameter when the more accurate and precise method cannot be used.
B 3 Electricity Consumption	Electricity Used by Pump _i /Electricity Use _i	kWh	Estimated	Reconciliation of electricity used within given time period	Monthly	Provides reasonable estimate of the parameter when the more accurate and precise method cannot be used.
	Pump Displacement Factor for Low/No GHG Intensive Pump _i /PDF _{New Pump i}	m ³ fluid per kWh	Estimated	Estimated based on technical specifications for project pump of similar type	N/A	Available from any manufacturer when the more accurate and precise method cannot be used.
	Pump Displacement Factor for High GHG Intensive Pump _i /PDF _{New Pump i}	m ³ fluid per kWh	Estimated	Estimated based on technical specifications for project pump of similar type	N/A	Available from any manufacturer when the more accurate and precise method cannot be used.
	Volume of Fluid Displaced _i / Vol. Fluid _i	m ³	Estimated	Estimated based on technical specifications for liquid injection rate ²	Monthly	Provides reasonable estimate of the parameter when the more accurate and precise method cannot be used.

² For verification, the project proponent must show that the pump was operating by identifying the run time of principal operating equipment or other practical indicators within the facility.

	Volume of Fossil Fuel i / Vol. Fuel i	m^3	Estimated	Reconciliation of volume of fuel used within given time period	Monthly	Provides reasonable estimate of the parameter when the more accurate and precise method cannot be used.
B 4 Vented Emissions Fuel Gas	Electricity Used by Pump i /Electricity Use i	kWh	Estimated	Reconciliation of volume of fuel used within given time period from P3	Continuous metering or monthly reconciliation	Provides reasonable estimate of the parameter when the more accurate and precise method cannot be used.
	Pump Displacement Factor for Low/No GHG Intensive Pump i /PDF $_{New Pump i}$	m^3 fluid per kWh	Estimated	Estimated based on technical specifications for project pump of similar type	N/A	Available from any manufacturer when the more accurate and precise method cannot be used.
	Pump Displacement Factor for Gas-Powered Pump/PDF $_{Gas Pump}$	m^3 gas per m^3 fluid	Estimated	Estimated based on manufactures' technical specifications for baseline pumps of similar make	N/A	Provides reasonable estimate of the parameter when the more accurate and precise method cannot be used.
	Percent Methane in Fuel Gas Used by Manufacturer/ $\%_{CH4}$ $_{Reference}$	%	Estimated	From accredited sources or industry standards for similar types of equipment	-	Provides reasonable and conservative estimate of the parameter when the more accurate and precise method cannot be used.
	Percent Methane in Fuel Gas/ $\%_{CH4}$ $_{Fuel}$	%	Estimated	From accredited sources or industry standards	-	Provides reasonable estimate of the parameter when the more accurate and precise method cannot be used.
	Volume of Fluid	m^3	Estimated	Estimated based on	Monthly	Provides reasonable

	Displaced i / Vol. Fluid i			technical specifications for liquid injection rate ³		estimate of the parameter when the more accurate and precise method cannot be used.
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³For verification, the project proponent must show that the pump was operating by identifying the run time of principal operating equipment or other practical indicators within the facility.

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APPENDIX A - Examples of How to Determine PDF

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1 This section serves as a guide to establish Emissions Factors (EF) for gas-powered pumps
 2 which can include chemical pumps, glycol dehydrators among others. The project
 3 proponent should justify the selection of the EF based on sound engineering principles,
 4 knowledge of the pump operating characteristics, and reasonable assumptions. Two
 5 examples are provided in the following pages. These are used for illustrative purposes.
 6 The assumptions made here are general. If the project proponent has access to more
 7 detailed assumptions or characteristics of the pumps, these should take precedence over
 8 the general approach presented here.

9 The final section of this appendix details the steps necessary to determine the EF in terms
 10 of units of metered fluids.

11 **PDF for Gas Powered Chemical Injection Pumps**

12 This section serves as a guide to establish PDF for gas-powered pumps which can include
 13 chemical pumps, glycol dehydrators among others. Two examples are provided in the
 14 following pages. These are used for illustrative purposes. The assumptions made here are
 15 general. The final section details the steps necessary to determine the PDF in terms of
 16 units of metered fluids.

17 Determining the PDF for a gas powered pump is performed using the manufactures’
 18 technical specifications for a given pump. The determination is also based on the facility
 19 operator’s working knowledge of the pumps. As an example, a gas powered chemical
 20 injection pump is used to pump methanol into a pipeline. The manufactures’ technical
 21 specifications for gas consumption are given in **FIGURE 1** Error! Reference source not
 22 found..
 23

GAS CONSUMPTION CHART

Standard Cubic Feet of Gas Required to Pump One Gallon

Piston Size		1/2"		3/8"		1/4"		3/16"	
Injection Pressure In PSI	Stroke	Full	1/3	Full	1/3	Full	1/3	Full	1/3
	6000			374	1122	497	1491	589	1776
	5000			355	1065	405	1215	575	1725
	4000			314	942	369	1107	560	1680
	3500	95	285	278	834	355	1065	555	1665
	3000	84	252	243	729	340	1020	545	1635
	2000	76	228	185	555	308	924	530	1590
	1500	71	213	177	531	288	864	476	1428
	1000	62	186	164	492	270	810	469	1407
	500	57	171	148	444	248	744	462	1386
	200	54	162	126	378	245	735	458	1374
100	53	159	120	360	244	732	457	1371	

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 25 Source: http://www.arrowengine.com/media/chempump_overview.pdf, p.9

26 **FIGURE 1 Gas consumption for a given gas powered pump**

1 The facility operator assumes that the pump operated with the following characteristics:

- 2 ▪ Pistons Size-3/8”;
- 3 ▪ Injection Pressure- 3000 PSI; and
- 4 ▪ Stroke- Full

5 Based on these characteristics, the PDF is **243** ft³ of gas/ gallon of chemical. In SI units
6 the PDF is 1834.66 m³ gas/ m³ chemical. The mass PDF is **1315.45** kg of gas / m³
7 chemical assuming a density of .717 kg/m³ for methane and 100% methane composition
8 in fuel gas.

9 **PDF for Gas Powered Glycol Dehydrators**

10 The determination of the PDF for glycol dehydrators follows the EPA’s methodology
11 presented in *Lessons Learned-Replacing Gas-Assisted Glycol Pumps with Electric*
12 *Pumps*. The EF is defined as

$$13 \qquad \qquad \qquad EF= PGU*G*WR*OC$$

14 where

15 EF = Emissions Factor (scf natural gas /MMcf gas processed);

16 PGU = Pump Gas Usage (scf natural gas emitted/gallon TEG);

17 G = Glycol-to-Water Ratio (gallons of TEG/lb water removed);

18 WR = Water Removed Rate (lb water removed/MMcf gas processed); and

19 OC = Over circulation ratio.

20 The following industry accepted Rules-of-Thumb apply:

- 21 ▪ PGU → 3 cubic-ft/gal for gas-assisted pumps, 1cubic-ft/gal for electric pump; the
22 difference being 2 cubic-ft/gal. The electric pump uses electricity only, but the
23 vented portion of the vapours will contain fuel gas even if electric or gas-assisted
24 pumps are used.
- 25 ▪ G = 3 gal TEG/ lb water.

26 Numerical Example:

27 Given

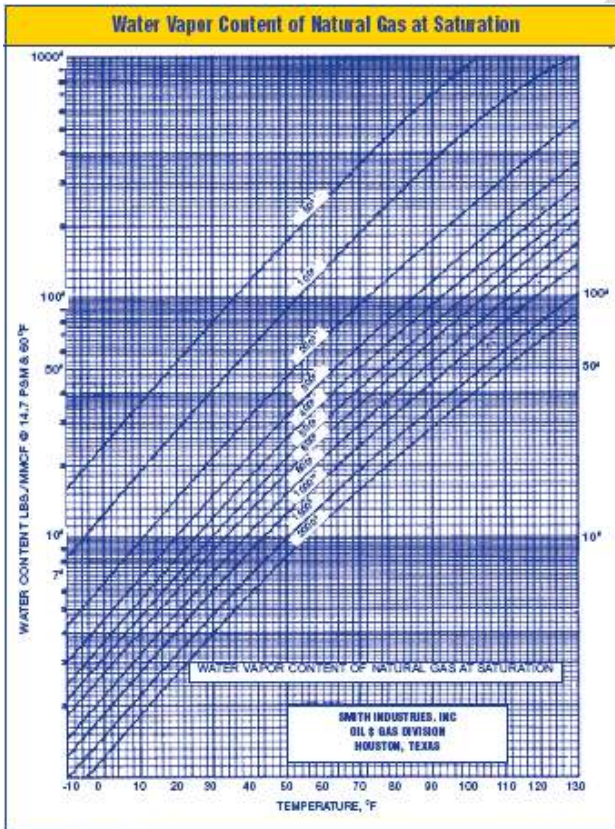
- 28 ▪ PGU = 2 scf natural gas emitted/gallon TEG;
- 29 ▪ G = 3 gallons of TEG/lb water removed;
- 30 ▪ OC = 1:1 to 2.1:1;
- 31 ▪ Inlet pressure 800 psig; and
- 32 ▪ Inlet temperature 94°F.

- 1 ▪ WR = 53 lb water removed/MMcf gas processed:

2 Using the table provided in **FIGURE 2** Error! Reference source not found., the point of
 3 intersection of the x axis (temperature) with the 800 psig curve is read with the
 4 corresponding value on the y axis. A value of 60 lb water removed/MMcf gas processed
 5 is used as a base for WR. 7 lb water removed/MMcf gas processed is the standard water
 6 content for pipeline gas and is subtracted from 60 lb water removed/MMcf gas processed.
 7 The amount of water that must be removed is therefore 53 lb water removed/MMcf gas
 8 processed.

9 $PDF^4 = PGU * G * WR * OC = 2 * 3 * 53 * (\text{Range } 1.1 \text{ to } 2.1)$

10 Based on these characteristics, the PDF will range from **318** to **668** scf of natural gas
 11 emitted/MMcf gas processed. In SI units the PDF is **318** to **668** m³ gas/ MMm³ gas
 12 processed. The mass PDF is **228** to **478.95** kg of gas / MMm³ gas processed assuming a
 13 density of .717 kg/m³ for methane and 100% methane composition in fuel gas.



14 Source: http://www.epa.gov/gasstar/documents/ll_glycol_pumps3.pdf, p16
 15 **FIGURE 2 Water vapor content of natural gas at saturation**

17 **PDF for electrical pumps using field data**

⁴ The EF has been renamed PDF to keep consistency with other types of pumps and the approach being taken in the protocol. The examples still follows the steps from the original EPA document, with the exception of the change in parameter name.

1 PDF is a data parameter that is usually available from the manufacturer’s technical
 2 specifications for electric pumps. This protocol uses that information, or information
 3 from similar pump types. In cases where this parameter cannot be established from either
 4 the manufacturer’s technical specifications or pumps of similar characteristics, the
 5 parameter is estimate using field data. Essentially, the estimation of this parameter
 6 requires two data sources collected from field measurements:

- 7 ▪ Metering of volume of fluid displaced by type i pump; and
- 8 ▪ Metering of electricity consumption by type i pump.

9 Data streams for the two metered quantities are synchronous. A deviation from this is
 10 permissible as on as the data quantities are taken over the same period and reflect a
 11 steady state. Dividing the metered volume of fluid by the metered electricity consumption
 12 will establish the pump capacity. Units should be express as:

$$\text{m}^3 \text{ fluid per kWh}$$

14 **PDF from published data**

15 Emissions are also published in accredited sources and are used for reporting emissions to
 16 pertinent authorities. Typically, the oil and gas industry uses CAPP EFs. Of particular
 17 importance is the use of EFs to estimate emissions from chemical injection pumps and
 18 glycol dehydrators. These EFs are presented in **TABLE B.1** and it is strong
 19 recommended that they be used in the extreme case where no EFs from the manufacturer
 20 are found.

21 **TABLE B.1 EFs from CAPP**

Pump Type	Emissions ^{5,6}
Gas Operated Chemical Injection Pump	0.3945 m ³ /hour/pump
Chemical Injection Pump (diaphragm)	0.4 m ³ /hr @ 140 kpag 0.6 m ³ /hr @ 240 kpag
Chemical Injection Pump (piston)	0.04 m ³ /hr @ 140 kpag 0.06 m ³ /hr @ 140 kpag
Glycol Dehydration Gas pump w/o a flash separator	0.2264 t CH ₄ /10 ⁶ m ³ processed gas
Glycol Dehydration Gas pump w/ a flash separator	0.0054 t CH ₄ /10 ⁶ m ³ processed gas
Glycol Dehydration Electric pump w/o a flash separator	0.0588 t CH ₄ /10 ⁶ m ³ processed gas
Glycol Dehydration Electric pump w/ a flash separator	0.0045 t CH ₄ /10 ⁶ m ³ processed gas

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⁵ CAPP (May, 2002). Guide- Estimation of Flaring and Venting Volumes from Upstream Oil and Gas Facilities.

⁶ CAPP (June, 2003). Guide- Calculating Greenhouse Gas Emissions.

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APPENDIX B – Explanation on Adjustment of Baseline Using Historical Records

DRAFT

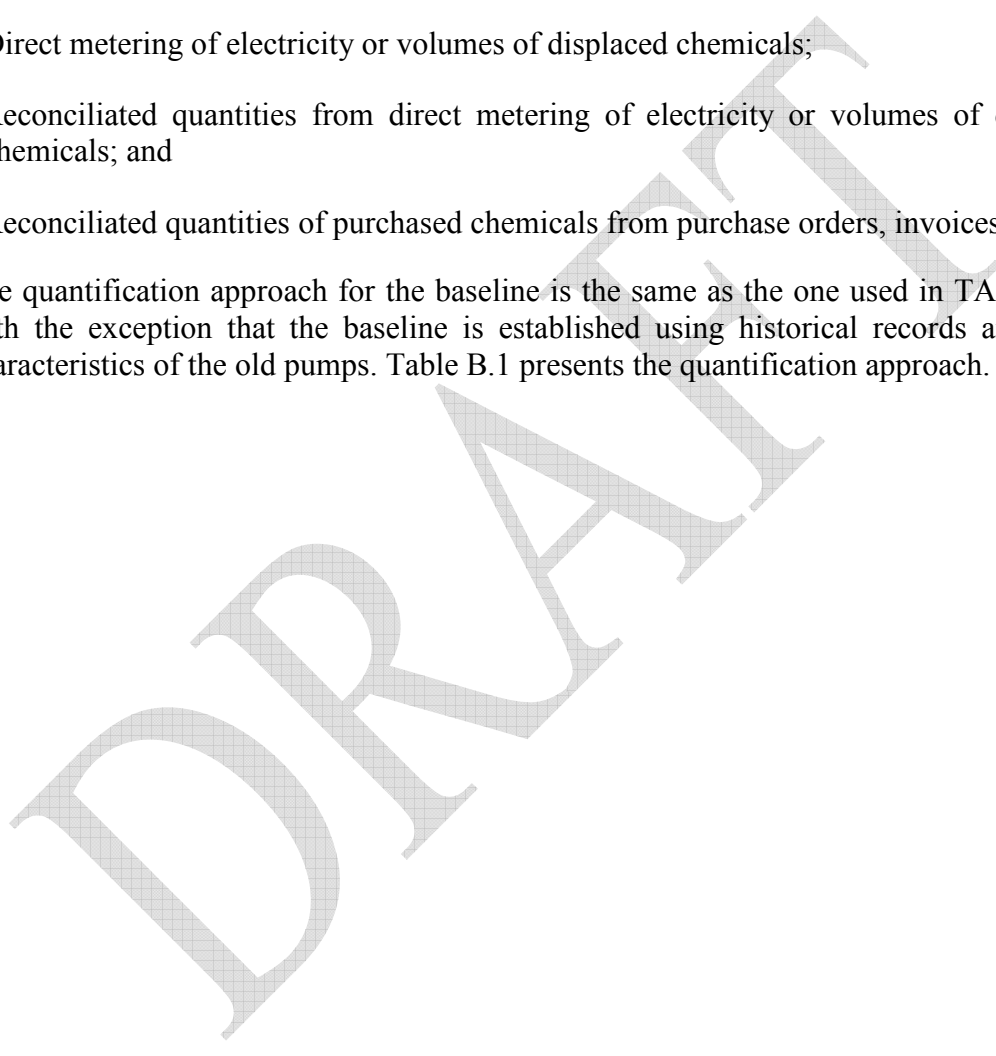
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This Flexibility Mechanism allows project developers to establish a baseline when historical records are available. This Flexibility Mechanism can be used for special cases such as establishing the baseline when an optimization program has been implemented along with a pump conversion program.

The baseline is established using historical records. As such, the historical record may include the following types of data:

- Direct metering of electricity or volumes of displaced chemicals;
- Reconciliated quantities from direct metering of electricity or volumes of displaced chemicals; and
- Reconciliated quantities of purchased chemicals from purchase orders, invoices etc.

The quantification approach for the baseline is the same as the one used in TABLE 1.5, with the exception that the baseline is established using historical records and pump characteristics of the old pumps. Table B.1 presents the quantification approach.



1 **TABLE B.1 Quantification of Baseline Emissions Using Historical Data**

1. Project/ Baseline SS	2. Parameter/ Variable	3. Unit	4. Measured/ Estimated	5. Method	6. Frequency	Justify measurement or estimation and frequency
Baseline SS's						
B 10 Fuel Extraction/ Processing	Emissions _{Fuel Extraction / Processing} = $\Sigma (\text{Vol. Fuel}_i * \text{EF}_{\text{Fuel}_i \text{CO}_2})$; $\Sigma (\text{Vol. Fuel}_i * \text{EF}_{\text{Fuel}_i \text{CH}_4})$; $\Sigma (\text{Vol. Fuel}_i * \text{EF}_{\text{Fuel}_i \text{N}_2\text{O}})$					
	Emissions _{Fuel Extraction / Processing}	kg of CO ₂ e	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel and electricity use on site is likely aggregate for each of these SS's.
	Volume of Fossil Fuel _i / Emissions _{Fuel Gas}	m ³	Estimated	Estimated based on historical volumes	-	Estimated based on historical volumes of fuel type for B3 and B4
	CO ₂ Emissions Factor for Fuel Including Production and Processing / EF Fuel _{CO2}	kg CO ₂ per m ³	Estimated	From Environment Canada reference documents	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH ₄ Emissions Factor for Fuel Including Production and Processing / EF Fuel _{CH4}	kg CH ₄ per m ³	Estimated	From Environment Canada reference documents	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N ₂ O Emissions Factor for Fuel Including Production and Processing / EF	kg N ₂ O per m ³	Estimated	From Environment Canada reference documents	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions

	Fuel _{N2O}					inventory.
B 3 Electricity Consumption	<p>The following equation (1) should be used to calculate emissions from Electricity Consumption for projects that used electricity from the grid. Note that this emission factor can be based on electricity displacement factor for Alberta. Equation (2) is used if the metered quantity is the volume of fluid displaced.</p> <p>1. Emissions_{Electricity Consumption} = Σ (Electricity Use_i * EF_{Electricity})</p> <p>2. Emissions_{Electricity Consumption} = Σ ((EF_{Electricity} / PDF_{Old Pump i}) * Vol. Fluid_i)</p> <p>The following equation (3) should be used to calculate emissions from Electricity Consumption for projects that used on-site electricity generated from fossil fuels.</p> <p>3. Emissions_{Electricity Consumption} = Σ (Vol. Fuel_i * EF_{Fuel i CO2}); Σ (Vol. Fuel_i * EF_{Fuel i CH4}); Σ (Vol. Fuel_i * EF_{Fuel i N2O}).</p>					
	Emissions _{Electricity Consumption}	kg of CO ₂ e	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel and electricity use on site is likely aggregate for each of these SS's.
	Electricity Used by Pump i / Electricity Use _i	kWh	Measured	Historical direct metering or reconciliation of volumes	Continuous metering or monthly reconciliation	Both methods are standard practice. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Emission Factor for Grid-Generated Electricity / EF _{Electricity}	kg of CO ₂ e/kWh	Estimated	From Environment Canada reference documents	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions

						inventory.
	Pump Displacement Factor for High GHG Intensive Pump/ PDF _{Old} Pump i	m ³ /kWh	Estimated	Estimated based on manufactures' technical specifications for project pump	N/A	Available from the manufacturer and should be an average under steady state operations.
	Volume of Fluid Displaced i / Vol. Fluid i	m ³	Measured	Historical direct metering or reconciliation of volumes	Continuous metering or monthly reconciliation	Both methods are standard practice. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Volume of Fossil Fuel i / Vol. Fuel i	m ³	Measured	Historical direct metering or reconciliation volumes	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 Each Type of Fuel i / EF Fuel CO ₂	kg CO ₂ per m ³	Estimated	From Environment Canada reference documents	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 i /	kg CH ₄ per m ³	Estimated	From Environment Canada reference documents	Annual	Reference values adjusted annually as part of Environment

	EF Fuel _{CH4}					Canada reporting on Canada's emissions inventory.
	N ₂ O Emissions Factor for Each Type of Fuel i / EF Fuel _{N2O}	kg N ₂ O per m ³	Estimated	From Environment Canada reference documents	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
B 4 Vented Emissions	<p><i>The fuel gas supply is methane-rich gas used at the facility. As such, the calculation of emission from the baseline will only use the methane component; the carbon dioxide component is not included as emissions are negligible. Equation (1) is used to calculate emissions from pump systems that operate on natural gas supplied from the facility's fuel gas supply during the baseline condition using metered quantities of fluid displaced.</i></p> <p>1. Emissions_{Vented Emissions} = $\sum (\text{Vol. Fluid}_i * \text{PDF}_{\text{Gas Pump } i} * \rho_{\text{CH}_4} * \%_{\text{CH}_4 \text{ Fuel}} / \%_{\text{CH}_4 \text{ Reference}} * \text{GWP}_{\text{CH}_4})$</p>					
	Emissions _{Vented Emissions}	kg of CO ₂ e	N/A	N/A	N/A	Quantity being calculated in aggregate form as fuel and electricity use on site is likely aggregate for each of these SS's.
	Volume of Fluid Displaced i / Vol. Fluid _i	m ³	Measured	Historical direct metering or reconciliation of volumes	Continuous metering or monthly reconciliation	Both methods are standard practice. Frequency of metering is highest level possible. Frequency of reconciliation provides for reasonable diligence.
	Pump Displacement Factor for Gas-Powered	m ³ gas per m ³ fluid	Estimated	Estimated based on manufactures' technical specifications for baseline pumps. Refer	N/A	Volumes of gas used to power gas-powered pumps can be estimated using

	Pump/PDF _{Gas} Pump			to APPENDIX A for details.		information from facility operations.
	Density of Methane / ρ_{CH_4}	Kg / m ³	Estimated	0.717kg/m ³ at STP	N/A	If this value is used all values must be adjusted for standard temperature and pressure.
	Reference Percent Methane in Fuel Gas / % _{CH4 Reference}	%	Estimated	From manufactures' assumptions in determining technical specifications for given pump	N/A	Reference values from manufactures' assumptions when calculating vented rates provides for reasonable diligence and accuracy.
	Percent Methane in Fuel Gas / % _{CH4 Fuel}	%	Measured	Historical Direct Measurement	Annual	Fuel gas volumes should remain relatively stable during steady-state operation.
	Global Warming Potential of Methane/ GWP _{CH4}	Kg CO ₂ e/Kg CH ₄	Estimated	From Environment Canada; IPCC	Annual	The applicable global warming potential of CH ₄ is 21 as per the IPCC, ISO, Environment Canada and other internationally accepted best practice guidance.

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APPENDIX C - Emissions Factor for Selected Fuels⁷

⁷ Source: Environment Canada (2006). NATIONAL INVENTORY REPORT, 1990-2005: GREENHOUSE GAS SOURCES AND SINKS IN CANADA. (Subject to Updates-Project developers should contact Environment Canada for the latest factors).

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Relevant Emission Factors

TABLE C.1: 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 ₂ O)	0.000004	kg N ₂ O 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 ₂ O)	0.000004	kg N ₂ O 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 ₂ O)	0.000003	kg N ₂ O 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 ₂ O)	0.000004	kg N ₂ O per Litre

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TABLE C.2: Emissions Factors for Natural Gas and NGL's

Source	Emissions Factor		
	CO ₂ g/m ³	CH ₄ g/m ³	N ₂ O 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, Agricultural	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

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1 **TABLE C.3: Emissions Factors for Refined Petroleum Products**

Source	Emissions Factor (g/L)		
	CO ₂	CH ₄	N ₂ O
Light Fuel			
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	3080	0.057	0.064
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	0.006	0.031
Forestry, Construction, Public Administration, and Commercial/Institutional	2550	0.006	0.031
Diesel	2730	0.133	0.4

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