Quantification Protocol for Greenhouse Gas Emission Reductions from Pneumatic Devices

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Summary of Revisions

Version	Date	Summary of Revisions
2.1	April 2020	• The end date was removed from Section 1.2 of the protocol. • Updated reference to Standard for Validation, Verification and Audit. • Deleted 'Related Publications' page
2.0	January 2017	• The **Disclaimer** was changed to reflect the credit duration in the event the reduction activity becomes required by law. • Title changed to Quantification Protocol for Greenhouse Gas Emission Reductions from Pneumatic Devices. • The Protocol Scope was expanded to include pneumatic device conversions (high to low conversions), pneumatic device electrification, and vent gas capture. • Protocol applicability conditions and Protocol Flexibility mechanisms were modified to match the expanded scope. For pneumatic device electrification, non-venting applications and vent gas capture, new (greenfield) installations were included in the scope. • The Baseline Condition was updated to include relevant sources and sinks for the expanded scope. • The Project Condition was updated to include relevant sources and sinks for the expanded scope. • The Quantification Methodology was revised to account for the revised scope. • The Documents and Records requirements were clarified. The contingent data collection procedures and quality assurance and quality control were updated.
1.0	October 2009	• Quantification Protocol for Instrument Gas to Instrument Air Conversion in Process Control Systems was published for use in the Alberta offset system.

Table of Contents

Summary of Revisions 3
Related Publications 5
1.0 Offset Project Description 5
1.1 Protocol Scope 6
1.1.1 High to Low or No Bleed Pneumatic Controller Conversions 6
1.1.2 Instrument Gas to Instrument Air System Conversions 6
1.1.3 Pneumatic Device Electrification 7
1.1.4 Pneumatic Vent Gas Capture Projects 7
1.2 Protocol Applicability 8
1.3 Protocol Flexibility 9
1.4 Glossary of Terms 9
2.0 Baseline Condition 11
2.1 Identification of Baseline Sources and Sinks 12
3.0 Project Condition 18
3.1 Identification of Project Sources and Sinks 18
4.0 Quantification of Reduction, Removals, and Reversals of Relevant Sources and Sinks 24
4.1 Quantification Approach 28
5.0 Management of Data Quality 43
5.1 Project Documentation 43
5.2 Record Keeping 44
5.3 Quality Assurance/Quality Control Considerations 44

List of Tables

Table 1: Project Type Applicability 8
Table 2: Description of Baseline Types 11
Table 3: Baseline Sources and Sinks 15
Table 4: Project Sources and Sinks 21
Table 5: Comparison of Sources and Sinks 25
Table 6: Quantification Procedures 29

List of Figures

Figure 1: Process Flow Diagram 13
Figure 2: Baseline Element Life Cycle Chart 13
Figure 3: Process Flow Diagram for Project Condition 19
Figure 4: Project Element Lifecycle Chart 19

List of Appendices

APPENDIX A: Explanation on Gas Equivalency and Leaks 46
APPENDIX B: Device Inventory 54
APPENDIX C: Field Vent Rate Sampling and Emissions Factor Development 55

1.0 Offset Project Description

This quantification protocol is written for the oil and gas industry where natural gas is used to provide pneumatic power for automated process control and operational devices. Some familiarity and understanding of gas and/or oil production operations and pneumatic devices is required.

Oil and gas wells and processing facilities often use pneumatic power for operational devices and process controls. Pneumatic devices may be powered by compressed air, natural gas or propane. Propane is typically delivered to site by truck and compressed air requires the installation of a compressed air system. Readily available pressurized natural gas is always on site and this has made it a very common pneumatic power source in industry. Devices that may be powered by natural gas include pressure controllers, temperature controllers, transducers, liquid level controllers, flow rate regulators and chemical pumps. These devices may have one or two emission rates depending on the design: static vent rate or dynamic vent rate. For the purpose of this protocol, the sum of these two emission rates will be referred to as vent rate, which is the term commonly used in the oil and gas industry. Bleed rate or bleed gas is also used in industry to express the static vent rate and sometimes the sum of these two emission types but will be avoided in this protocol to avoid ambiguity. The vent rate will depend on the type of device, age, gas composition, process conditions and operating condition.

The opportunity for generating emission offsets with this protocol arises from the direct and indirect reduction of greenhouse gas emissions resulting from the conversion of high-venting pneumatic devices to low or non-venting alternatives or the new installation of non-venting alternatives.

Project types included in the protocol that reduce or eliminate methane venting include:

(1) high-to-low vent pneumatic controller conversions;
(2) instrument gas to instrument air pneumatic device system conversions, including air compressors driven by grid supplied electricity, on-site generated electricity including renewables, or direct drive systems powered by fossil fuel combustion, that are used to supply pneumatic air for controllers, pumps, starters and other pneumatic devices;
(3) pneumatic device electrification, including pneumatic controllers and pumps driven directly by grid supplied electricity, on-site generated electricity including renewables; and
(4) pneumatic vent gas capture and destruction projects.

In general, pneumatic devices include pneumatic controllers and chemical injection pumps.

- Pneumatic controllers are a type of pneumatic device that regulate the supply of pneumatic pressure to an actuator which opens, closes or positions a valve to regulate the flow of oil, gas or any other production/process fluid.
- Pneumatic chemical injection pumps inject various chemicals into oil and gas pipelines and vessels as required to prevent corrosion and freezing of entrained fluids. Various chemicals may be used that are required to be injected at a pressure equal to or greater than the operating pressure of the process (the oil and gas production pressure).

Other pneumatic devices that are typical to upstream oil and gas facilities include pneumatic engine starters. This protocol is specific to vent sources that occur as a result of control or pumping equipment design and normal operation. This protocol does not include quantification of vent emissions from reliefs, wellbores, tanks, surface casings and other solution gas sources. This protocol quantifies emission reductions associated with solar electricity generation replacing pneumatic power. Solar generation displacing electricity use is not applicable under this protocol.

This protocol does not stipulate a process change but rather a reduction in venting or change in the power source for pneumatic devices. It is required that a natural gas vent source be reduced or eliminated via a retrofit to an existing device or the addition of a new power source. It should be noted that any volume that would have been vented will now be conserved through reduced fuel gas consumption and will increase the gas production rate slightly. The final fate of the conserved gas is assumed to be combustion by consumer end-users.

1.1 Protocol Scope

The scope of the protocol is to provide a quantification methodology that offset project developers can use to quantify greenhouse gas emission reductions from a methane vent reduction project. A process flow diagram for a typical methane vent reduction project is shown in Figure 1. This protocol includes methane vent reduction opportunities from multiple project types at oil and gas facilities. The various project types included under this protocol are: high to low /no bleed pneumatic controllers, instrument gas to instrument air conversions, pneumatic device electrification, and pneumatic vent gas capture projects.

1.1.1 High to Low or No Bleed Pneumatic Controller Conversions

Pneumatic control devices in the oil and gas industry are commonly used to control pressure flow, levels, and/or temperature. These devices are very robust, require little maintenance and make use of the natural gas pressure, which is readily available on site. Natural gas or fuel gas that is consumed by these devices is vented to the atmosphere. These devices typically outlast the well lifetime and are very seldom replaced or upgraded. The conversion of a high vent controller to a low vent controller reduces the vent rate by use of newer technologies which perform the same control function while reducing natural gas or fuel gas consumption and venting.

Functional equivalence is based on operational hours of a well or site. Process control equipment operates by venting throughout operations so the metric for functional equivalence is hours of operation.

Project types which are included are high to low vent pneumatic controller conversions where both the project and baseline conditions have measurable emissions which contribute to the quantification of emission reductions.

Multiple projects may be aggregated under one project plan as allowed by this protocol, but the data and computational requirements are similar for aggregated and individual projects.

1.1.2 Instrument Gas to Instrument Air System Conversions

It is possible to convert an instrument gas system to a compressed air system while providing the same functionality and achieving a reduction in vented methane to the atmosphere. The scope of this protocol includes conversion of instrument gas to instrument air systems. This project type is considered to be a system conversion throughout this protocol, implying one conversion instance for the purposes of quantification includes the conversion of several gas driven pneumatic devices to air driven devices at a defined location.

Compressed air systems can be installed at locations where fuel gas is used for pneumatic devices and typically requires electricity as a power source. Electricity can be grid supplied or produced via on site generation based on fossil fuel or renewable generation systems.

The volume of air consumed can be measured directly and it is relatively simple to estimate a volume of natural gas that would have been vented based on the volume of air consumed. Some facilities may already have an air compressor system installed in adjacent buildings for other applications. In such cases, expansion of an instrument air system may be quantified under this protocol so long as measured air volumes of the expanded system are available and quantification methods of the expansion align with the methods proposed in this protocol. Emissions in the project condition may or may not be on site and may be quantified using the volume of electricity consumed.

New instrument air systems are eligible at well sites and well pads as the baseline for these locations has been established as a venting pneumatic devices. Instrument air offers a non-venting solution for pneumatic controls systems and pumps at well sites and well pads.

These project types may be conducted as individual instrument gas to instrument air system conversion projects or as part of a broader project though the data and computation requirements are similar. Multiple system conversions/installs or sets of conversions/installs may be aggregated together under one project plan with other project types in this protocol.

1.1.3 Pneumatic Device Electrification

The conversion of pneumatic controllers and/or pneumatically-driven chemical injection pumps to electric controllers and/or electrically-powered chemical injection pumps is included in the scope of this protocol.

It is common for pneumatic chemical injection pumps to be located at well-sites, and at the start of pipeline systems. These devices are very robust, require little maintenance and they make use of the natural gas pressure, which is readily available on site. Natural gas or fuel gas that is consumed by these devices is vented to the atmosphere. These devices typically outlast the well or site lifetime and are very seldom replaced or upgraded. The electrification of a controller or pump replaces the entire actuation device and controller to perform the same function while eliminating natural gas or fuel gas consumption and venting.

Gas-driven chemical injection pumps vent on a per stroke basis and this is the metric for establishing functional equivalence. In the case of electrification of process control equipment, it operates throughout the duration of facility operation and the metric for establishing functional equivalence is the hours of operation.

Pneumatic device electrification includes project types where the baseline condition is measureable. The emissions in the project may include off-site electricity generation (grid) or on-site fossil fuel combustion. Existing device conversions to solar-electric devices or new solar electric device installs are applicable to the scope of this protocol.

These project types may be conducted as individual conversions/installs or as part of a broader electrification conversion/installation program. Measurements or computation may be needed for each device or for the set of conversions/installations. Multiple conversions/installations or sets of conversions/installations may be aggregated together under one project plan with other project types in this protocol.

1.1.4 Pneumatic Vent Gas Capture Projects

It is possible to capture vent gas from some pneumatic vent sources through vent gas capture piping and destroy the vented gas in a flare, incinerator, combustor, solid oxide fuel cell or catalytic combustion device. When not required or prescribed by gas conservation directives, this activity is eligible as an emission reduction for methane vent reduction under this protocol. This project type is considered to be a system conversion throughout this protocol, implying one conversion instance for the purposes of quantification includes the capture of several vent sources at a defined location.

The volume of vented gas is directly measured as it vents from the same devices which remain and represents functional equivalence between the baseline and project since it exists in both conditions. The functional equivalent unit would therefore be the mass of natural gas used for process control and operational functions that is safely disposed of after capture.

Emissions in the baseline are measurable and based on volume of methane destroyed. Project emissions are measurable as well and are based on the volume of methane destroyed. Existing vent gas capture conversions or vent gas capture systems installed as part of a new installation are applicable to the scope of this protocol. Captured vent gas may be destroyed in a catalytic heater, flare, incinerator or other combustion device, with the exception of destruction via internal combustion engines. Destruction via internal combustion engines is contemplated in the Engine Fuel Management and Vent Gas Capture protocol and is not applicable to the scope of this protocol.

These project types may be conducted as individual vent gas capture projects or as part of a broader vent gas capture project though the data and computation requirements are similar. Multiple conversions/installs or sets of conversions/installs may be aggregated together under one project plan with other project types in this protocol.

1.2 Protocol Applicability

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

(1) Pneumatic or electric devices in the project condition perform the same effective process control or operational function as in the baseline condition. This requirement considers changing throughput or production declines. This means the specific frequency of control interventions, volume of methanol injected or other activity may change in time, but safe and reliable operation is maintained. This implies that at a minimum:
   a) low and non-vent devices are effective replacements based on manufacturer specifications,
   b) vent gas capture systems are installed in a manner which allows relief of vent backpressure to maintain functionality of pneumatic devices, and
   c) compressed air systems match or exceed the supply pressure at design volume requirements to meet pneumatic demand.

(2) The protocol is applicable to methane vent reduction projects. Reduction of propane venting and/or conversion from propane to methane is not contemplated in this protocol.

(3) For the purposes of this protocol, "conversions" are considered to occur at brownfield sites with existing equipment being replaced and "installs" are considered to occur at greenfield sites where no equipment existed prior to the implementation of the project. This must be demonstrated by process flow diagrams and/or accounting records, work orders, invoices or other vendor/third party documentation/evidence. Projects applicable to the protocol are shown in Table 1.

Table 1: Project Type Applicability

Project Type	Greenfield / New	Brownfield / Retrofit
High to Low Pneumatic Controller Conversion	**Not applicable**	**Yes, a functioning high vent controller is removed and replaced by a low vent controller.**
Instrument Gas to Instrument Air Conversion	Yes. Only well sites and well pads are eligible for instrument air installations.	Yes, an instrument gas supply system is disconnected from an existing natural gas supply and connected to a compressed air supply system.
Pneumatic Device Electrification	Yes, a new electrified device is applicable when supplied with alternative electricity[1] generation.	Yes, a high vent device is removed and replaced by an electrified device.
Pneumatic Vent Gas Capture	Yes, a vent device is installed with a vent gas capture system.	Yes, an existing high vent device is connected to a vent gas capture system.

(4) The project proponent must inspect and maintain pneumatic devices as part of regular operations for high to low, compressed air and vent gas capture projects. This must be performed annually by performing operator site visits to ensure that pneumatic devices do not excessively vent. Operators must keep records demonstrating the maintenance and inspection activities of facilities. If pneumatic device inspection is not performed according to suggested monitoring frequencies, volumes must be reduced using a Discount Factor. This factor is developed in detail in Appendix A. If pneumatic device inspection becomes required by regulation the offset project must inspect and maintain pneumatic devices as per the requirements of the relevant regulation.

[1] Alternative electricity includes solar, wind, biomass, microturbine, waste pressure, waste heat, solid oxide fuel cell and Stirling engine power sources.

(5) To facilitate verification and allow for changes, the proponent will develop an inventory of devices. Any changes to the inventory (i.e., devices removed) will impact net offsets claimed as illustrated in Appendix B.

Refer to the flexibility mechanism section and Appendix B for more details.

The project must meet the requirements for offset eligibility as specified in the applicable regulation and guidance documents for the Alberta carbon offset system. To provide specific clarity, the emission offset generation opportunity for all projects under this protocol will immediately cease for activities which become required by federal, provincial or municipal law that is applicable to Alberta facilities.

1.3 Protocol Flexibility

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

(1) Project proponents can quantify and aggregate multiple conversions or installs under one project plan. The entire quantification method should apply to each conversion to ensure accuracy. Instrument gas to instrument air and vent gas capture projects may inherently include methane reductions across multiple pneumatic devices under one conversion.
(2) For projects where pneumatic devices are not measured, statistically relevant comparisons or emission factors may be used to quantify emission reductions where provided in this protocol.
(3) Site-specific and make and model-specific emission factors may be substituted for the generic emission factors indicated in this protocol document. The methodology for generation of these emission factors must be sufficiently robust to ensure accuracy. See Appendix C.
(4) Options are presented in Section 2.0 and in Section 4.1 for proponents to determine emissions related to baseline and project activity for certain project types. Preferential order of methods is presented in Section 2.0 for proponents who have the ability to quantify emissions with more accuracy.

1.4 Glossary of Terms

Bleed rate	A common term used in place of vent rate. See Vent Rate.
Brownfield	An existing site that was commissioned prior to the decision to implement the project. Brownfield facilities have operating pneumatic devices prior to the project being implemented.
Confidence interval	Type of interval estimate of a population parameter and is used to indicate the reliability of the estimate.
Dynamic vent rate	Rate at which a device intermittently vents based on field operations and control process. The supply pressure, quality of gas and age of device can all impact the dynamic vent rate.
Fuel gas	Portions of the sales gas used for site operations such as fuel for engines , pressure supply for pneumatic devices, etc.
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. Pneumatic instruments are designed to operate using a pressurized gas (i.e., 20 or 35 psi for commercially available devices), regardless of the gas type.
Greenfield	A newly constructed site that is not commissioned prior to the decision or implementation of low or non-vent pneumatic devices. Greenfield facilities do not have existing pneumatic devices.

High Venting pneumatic device	A device commonly used in oil and gas such as a pneumatic controller or pump that has an alternative lower venting replacement.
Instrument air	Ambient air that is pressurized to supply a pneumatic device with an alternative to natural gas while providing the necessary level of control required for its intended use.
Leak	Unwanted emissions from worm seals, gaskets, and diaphragms, nozzle corrosion or wear from poor quality gas leading to increased flow and loose control tube fitting in a pneumatic device.
Low venting pneumatic device	A device is considered a low venting controller when its manufacturer specified static vent rate is lower than 0.17 sm^3/hr of natural gas.
Mean	A measure of the central tendency, either of a probability distribution or of the random variable characterized by that distribution. It is the sum of values divided by the number of values.
Non-venting device	A control or pumping device that performs its functions with zero emissions. This typically occurs in projects converting pneumatic drives on chemical injection pumps to renewable energy.
Process gas	Raw gas that is moving through a system to be processed and sold.
Pneumatic controllers	A type of device that regulates the supply of pressure to an actuator or control loop, which opens, closes or positions a valve to regulate the flow of oil, gas or any other production/process fluid. An actuator can be coupled with other mechanical devices in a control loop.
Pneumatic chemical injection pumps	A type of device that injects various chemicals into oil and gas pipelines vessels, and wells to prevent corrosion and freezing of entrained fluids. Various chemicals may be used that must be injected at a pressure equal to or greater than the operating pressure of the process (the oil and gas production pressure).
Replacement	The complete swap from one pneumatic device to an alternative.
Retrofit	The addition of new technology or modifications to equipment in existing pneumatic devices that may result in emissions reductions.
Supply gas	Raw gas that is used at a site to power process control devices such as pneumatic controllers and pumps.
Static vent rate	Rate at which a device continuously uses air or natural gas based on manufacturer specification at a steady-state of operation.
Vent rate	Rate at which a device uses air or natural gas intermittently due to design requirements. Rates may vary in the field due to changing conditions. In this protocol, vent rate is used to describe the sum of both static and dynamic rates.

2.0 Baseline Condition

The baseline condition for this protocol is defined as the release of natural gas for process control and operational functions at oil and gas sites through pneumatic device activity. The baseline is site-specific and depends on the site operation. Baseline fuel venting from pneumatic devices depends primarily on the type of pneumatic device and process conditions, although operating condition, age, and other factors can influence venting. Methane is the primary constituent of fuel gas or natural gas that supplies pneumatic power to control operational devices at oil and gas facilities. This is the primary source of greenhouse gas emissions for the baseline. A process flow diagram for a typical baseline using natural gas to provide pressure to pneumatic devices is shown in Figure 1. Vented, flared or combusted gases in the baseline are not typically metered. The different methods to determine the baseline emissions, depending on the type of methane venting reduction project that is implemented are shown in Table 2.

Table 2: Description of Baseline Types

Project Types	Baseline Type	Explanation
Pneumatic controller conversion (applicable to high to low vent conversion baselines and pneumatic controller electrification baselines)	1. Historical Benchmark 2. Comparison Based 3. Performance Standard	1 – If vent measurements are available from devices prior to conversion; a historical benchmark baseline is the most appropriate and preferred option if it is the most accurate representation of emissions that would have occurred in the absence of the project. 2 – If historical benchmark baseline is not possible due to lack of measurements, a comparison based baseline approach is appropriate. A representative, statistically significant set of vent measurements can be used to estimate the baseline. 3 – If a historical benchmark or comparison based baseline approach is not available, a performance standard baseline may be used. Manufacturer vent rates have been demonstrated to underestimate actual emission rates for pneumatic devices[2]and can be used such that the lowest emission rate across the operating envelope is used. Lower emission rates in the baseline are conservative and thus the performance standard baseline approach is appropriate in the absence of other available baseline approaches.
Instrument gas to instrument air system conversion	1. Projection Based	1 – Projection based baselines are the most accurate because they measure actual emission activity and project this to the baseline. Reliable conversions between the volume of air and natural gas that would have been consumed in the absence of the project can be made to estimate the emission rate based on a projection of the volume of air consumed in the project.
Pneumatic pump conversion (applicable to Pneumatic Device Electrification baselines)	1. Projection Based	1 – Projection based baselines for pump electrification are the most accurate because they measure pump activity and project this to the baseline. Reliable

[2] Canadian Environmental Technology Advancement Corporation West. 2008. Efficient Use of Fuel Gas in Pneumatic Instruments. Module 3 of 17. January 2008.

		projections can be made on the volume of natural gas that would have been released in the absence of the project based on the pump stroke count in the project condition.
Pneumatic vent gas capture baselines	1. Projection Based 2. Performance Standard	1 – Projection based baselines for vent gas capture from pumps and controllers at brownfield sites, and pumps and low bleed controllers that are new are the most accurate because they measure actual emission activity and project this to the baseline. Reliable projections can be made on the volume of natural gas that would have been released in the absence of the project based on the volume of gas captured in the project. 2 – In the case of vent gas capture activities implemented on new pneumatic controllers that are not low vent, a performance standard is applicable because crediting of vent gas destruction for this activity is only eligible to the extent that a new low bleed controller would vent, to be consistent with the high to low conversion project type. This does not apply to retrofits.

2.1 Identification of Baseline Sources and Sinks

The identification of sources and sinks in the baseline condition is based on ISO 14064-2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements. Sources and sinks are determined to be either controlled, related or affected by the project and are defined as follows:

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

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

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

All sources and sinks were identified by reviewing the relevant process flow diagrams, consulting with technical experts and reviewing best practice guidance. This iterative process confirmed that sources/sinks in the process flow diagrams covered the full scope of eligible activities under this protocol.

Based on the process flow diagram provided, the baseline sources/sinks were organized into life cycle categories as provided in Figure 1. A description of each source/sink and its classification as controlled, related or affected is provided in Table 3.

Figure 1: Process Flow Diagram

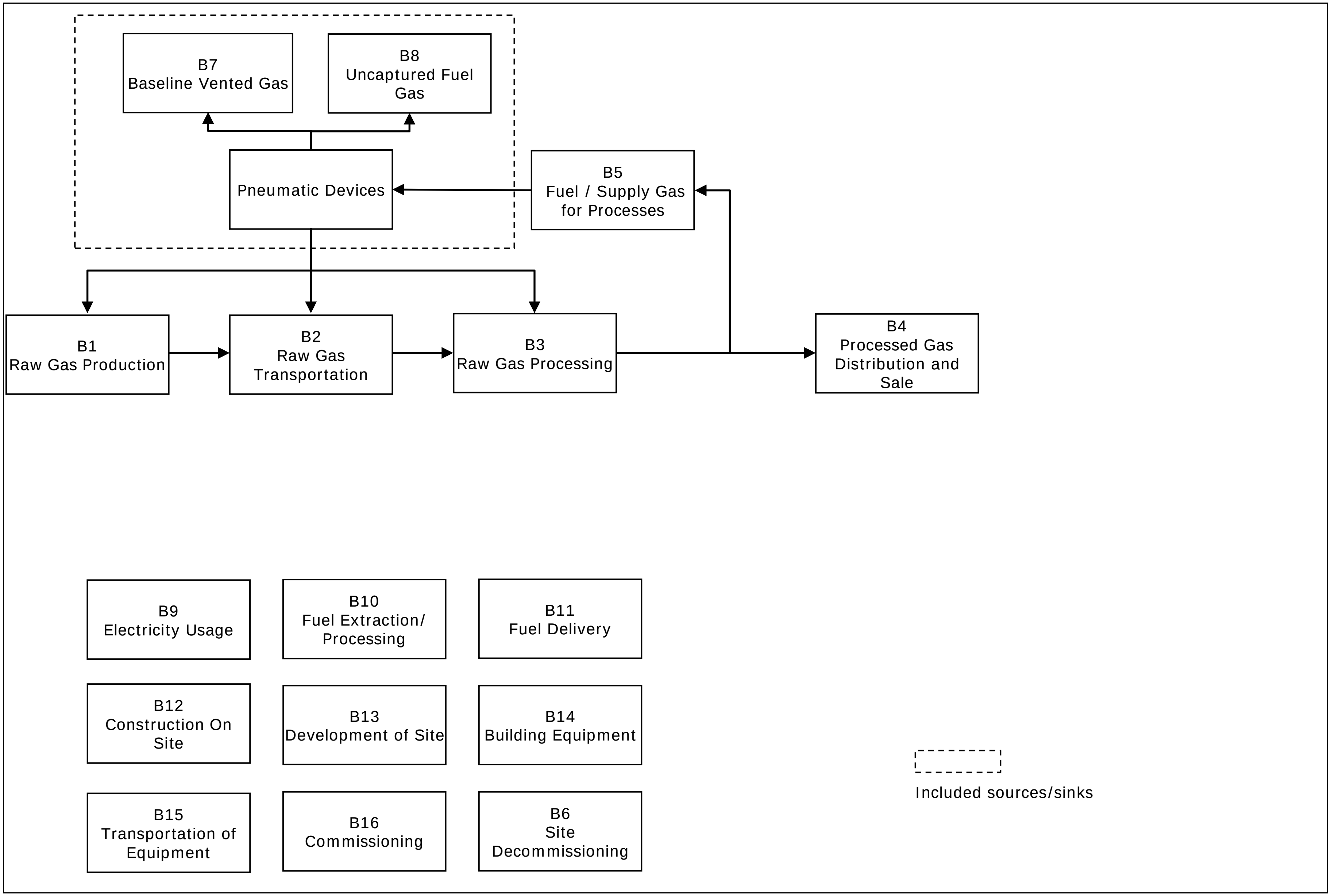
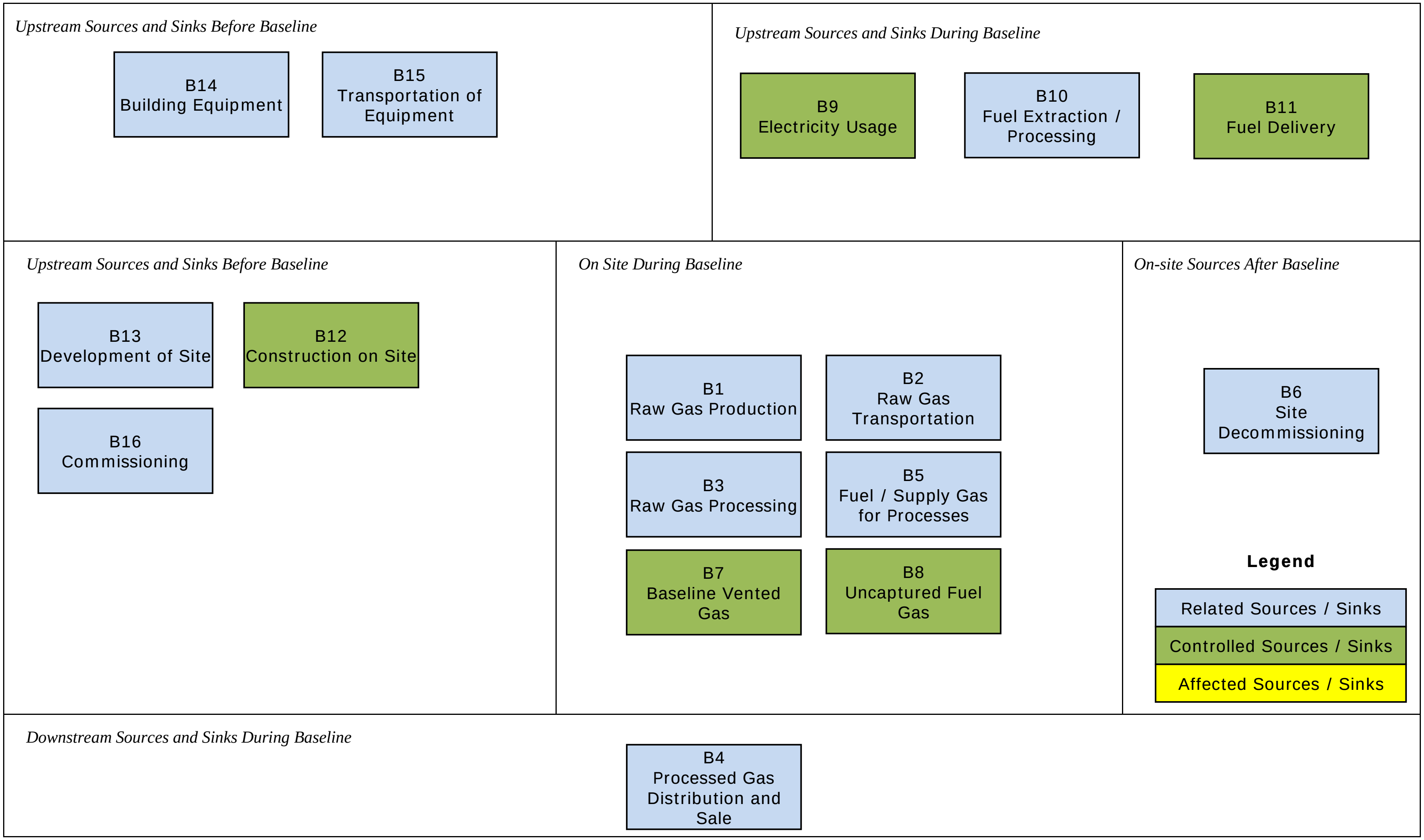


Figure 2: Baseline Element Life Cycle Chart



Upstream Sources and Sinks Before Baseline
B14 Building Equipment
B15 Transportation of Equipment
Upstream Sources and Sinks During Baseline
B9 Electricity Usage
B10 Fuel Extraction / Processing
B11 Fuel Delivery
Upstream Sources and Sinks Before Baseline
B13 Development of Site
B12 Construction on Site
B16 Commissioning
On Site During Baseline
B1 Raw Gas Production
B2 Raw Gas Transportation
B3 Raw Gas Processing
B5 Fuel / Supply Gas for Processes
B7 Baseline Vented Gas
B8 Uncaptured Fuel Gas
On-site Sources After Baseline
B6 Site Decommissioning
Legend
Related Sources / Sinks
Controlled Sources / Sinks
Affected Sources / Sinks
Downstream Sources and Sinks During Baseline
B4 Processed Gas Distribution and Sale

Table 3: Baseline Sources and Sinks

Sources and Sinks	Description	Controlled, Related or Affected
Upstream Sources and Sinks during Baseline Operation		
B9 – Electricity usage	**Electricity may be required for operating the site. 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**
B10 – 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 sources / sinks in this project are considered in this source/sink. Types and quantities of fuels used would need to be tracked.	Related
B11 – Fuel delivery	Some 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 sources / sinks and there is no other delivery.	Related
On-site Sources and Sinks during Baseline Operation		

B1 – Raw gas production	**The raw gas is collected from a group of adjacent wells where moisture content is reduced by removing water and condensate. Condensate is transported to oil refineries for further processing and wastewater is disposed. The quantity of greenhouse gas in the raw gas would need to be tracked. The types and quantities of fuels used in extraction equipment would also need to be tracked. Leaks may also be present in the production process and should be tracked too.**	**Related**
B2 – Raw gas transportation	The raw gas is piped to a natural gas processing plant. The types and quantities of fuels used in transportation would need to be tracked. Leaks may also be present in the pipeline and should be tracked also.	Related
B3 – Raw gas processing	Processing of raw gas is required to remove hydrogen sulphide, carbon dioxide, water vapour and heavier hydrocarbons. Clean gas is ready to be distributed and sold. Heavier hydrocarbons are also removed and transported to oil refineries. The quantity of greenhouse gas in the processed gas would need to be tracked. Leaks may also be present in the production process and should be tracked too. Possibility of venting gas must also be considered and tracked.	Related
B5 – Fuel gas for process	Many processes require clean gas to function. This clean gas, also referred to as fuel gas, is drawn from the processed gas. Equipment in the processes which also use this fuel include compressors, boilers, heaters, engines, glycol dehydrators, refrigerators and chemical injection pumps (CIP). The types and quantities of fuels used in processing would need to be tracked. Leaks may also be present in the production process and should be tracked.	Related
B7 – Baseline vented gas	Pneumatic devices function by venting fuel gas or raw gas. The quantity of gas vented in the baseline condition has a direct impact on the emissions reduction quantification for controller conversions, instrument air to instrument gas conversion projects and solar electrification projects.	Controlled
B8 – Uncaptured fuel gas	Pneumatic devices function by venting fuel gas or raw gas. The quantity of gas vented in the baseline has a direct impact on the emissions reduction quantification for vent gas capture projects.	Controlled
Downstream Sources and Sinks during Baseline Operation		
B4 – Processed gas distribution and sale	**Natural gas and other commercially viable natural gas liquids (NGL) products may be sent to a pipeline system or transported by rail or truck to customers at another point. The mostly likely use would be controlled combustion to produce carbon dioxide.**	**Related**
On-site Sources and Sinks Before the Baseline Operation		

B12 – 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**
B13 – 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 at the site 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
B16 – Commissioning	Equipment may need to be tested or commissioned to ensure that it is operational. This may result in running the equipment using fossil fuels in order to ensure proper operation. These activities will result in greenhouse gas emissions associated with the combustion of fossil fuels and the use of electricity.	Related
Upstream Sources and Sinks Before the Baseline Operation		
B14 – Building of equipment	**Equipment may need to be built either on 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**
B15 – 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
On-site Sources and Sinks After the Baseline Operation		
B6 – Site decommissioning	**Once the site is no longer operational, it 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**

3.0 Project Condition

The project condition is defined as continued oil and gas production with low or no vent control or chemical injection devices providing process control and operational functions. In the project conditions, venting and/or device activity can be directly measured and/or estimated.

This includes off-site electricity emissions due to increased electricity consumption in low or no vent alternative process control or operational devices and fossil fuel combustion emissions in the case of vent gas destruction. Some non-venting projects may have no measurable project emissions because on-site renewable electricity has been installed to power electric drive equipment.

3.1 Identification of Project Sources and Sinks

Sources and/or sinks for the project condition were identified based on a review of existing best practice guidance contained in relevant greenhouse gas quantification protocols and project configurations. This process confirmed that sources and/or sinks in the process flow diagram covered the full scope of eligible project activities under this protocol. Process elements are described in Figure 3.

These sources and/or sinks were further classified as controlled, related or affected as described in Table 4.

Figure 3: Process Flow Diagram for Project Condition

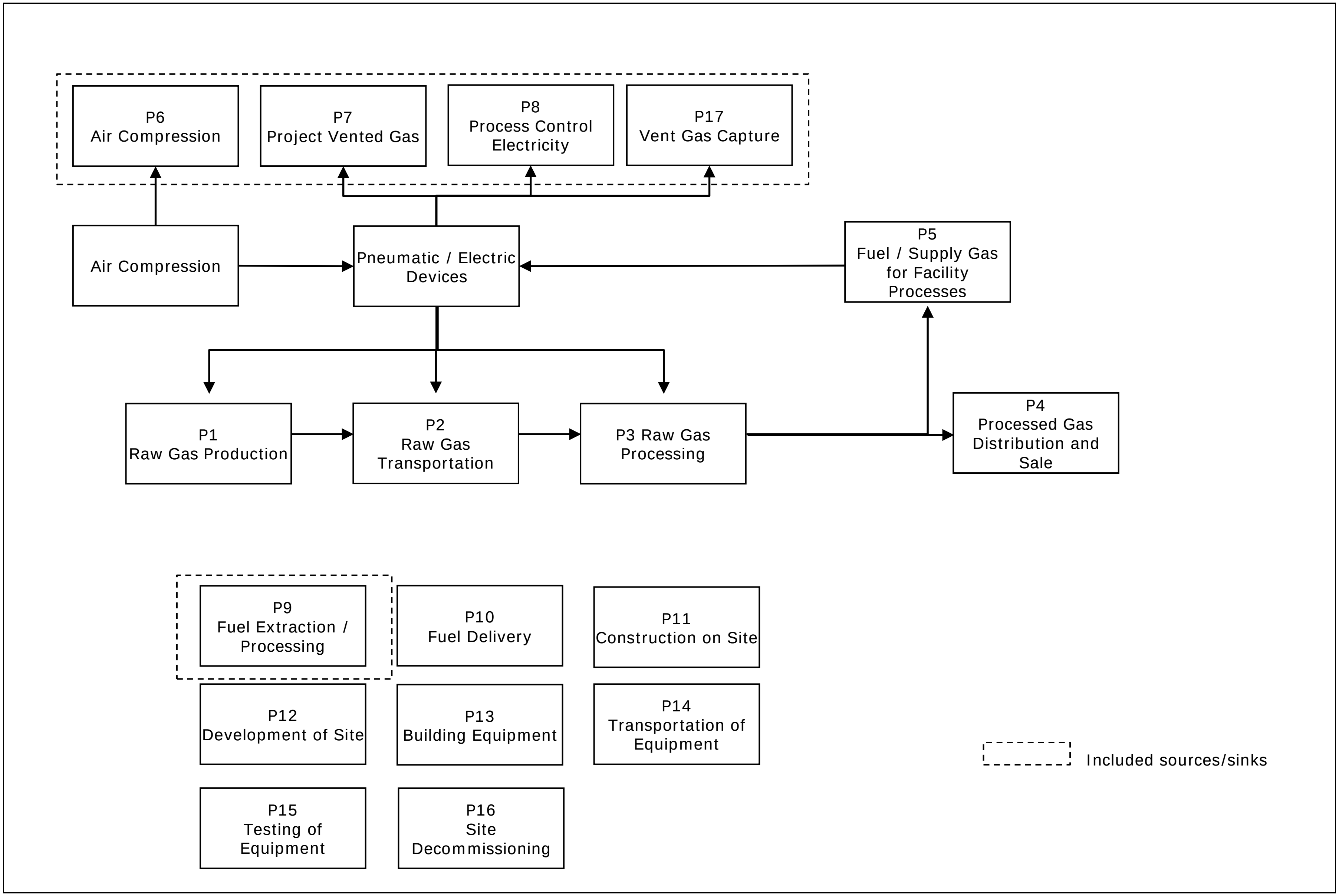


Figure 4: Project Element Lifecycle Chart

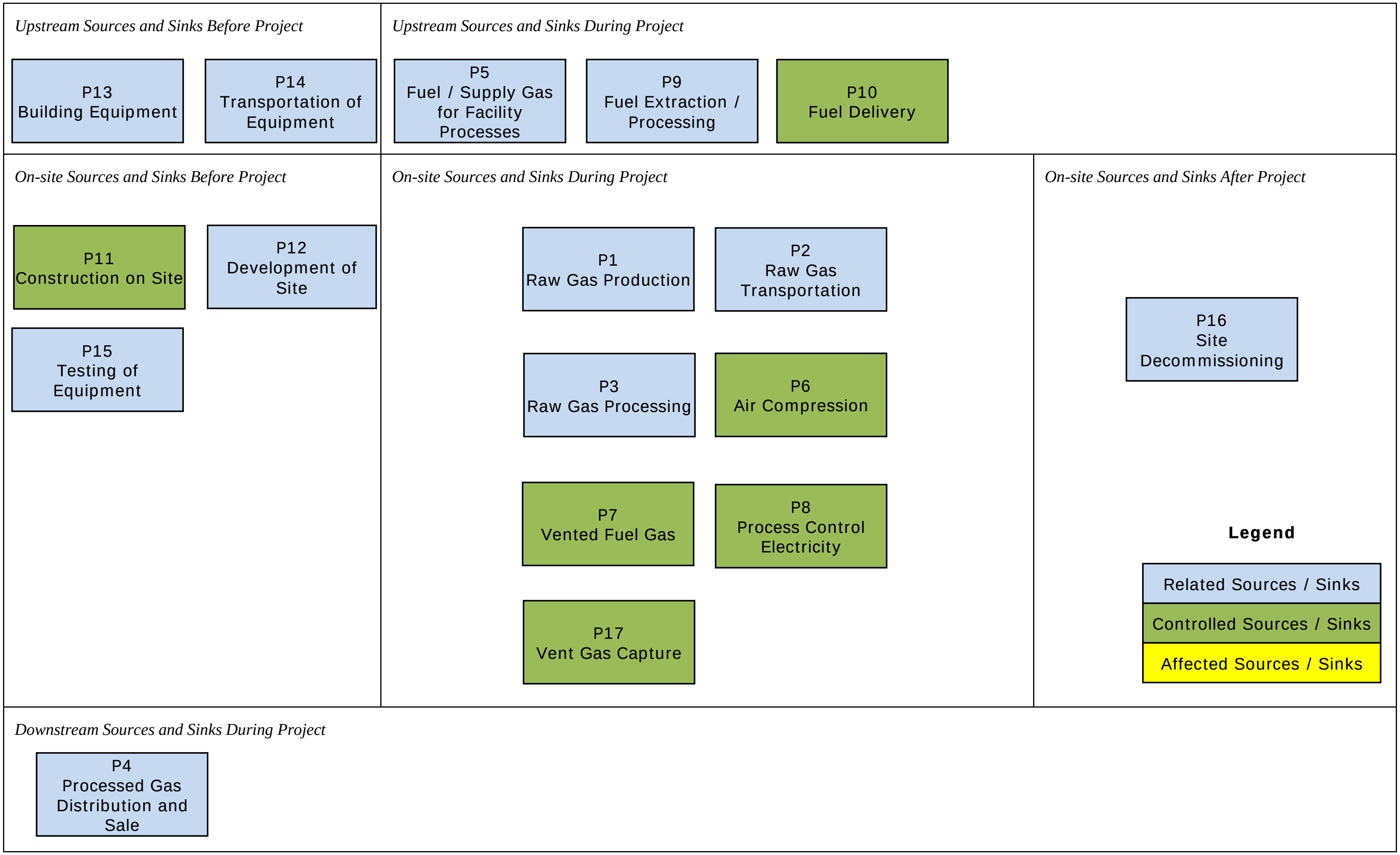

Upstream Sources and Sinks Before Project
P13 Building Equipment
P14 Transportation of Equipment
Upstream Sources and Sinks During Project
P5 Fuel / Supply Gas for Facility Processes
P9 Fuel Extraction / Processing
P10 Fuel Delivery
On-site Sources and Sinks Before Project
P11 Construction on Site
P12 Development of Site
P15 Testing of Equipment
On-site Sources and Sinks During Project
P1 Raw Gas Production
P2 Raw Gas Transportation
P3 Raw Gas Processing
P6 Air Compression
P7 Vented Fuel Gas
P8 Process Control Electricity
P17 Vent Gas Capture
On-site Sources and Sinks After Project
P16 Site Decommissioning
Legend
Related Sources / Sinks
Controlled Sources / Sinks
Affected Sources / Sinks
Downstream Sources and Sinks During Project
P4 Processed Gas Distribution and Sale

Table 4: Project Sources and Sinks

Sources and Sinks	Description	Controlled, Related or Affected
Upstream Sources and Sinks during Project Operation		
P5 – Fuel gas for process	**Many processes at a site require clean gas to function. This clean gas, also referred to as fuel gas, is drawn from the processed gas that will be sold. Equipment in the processes includes compressors, boilers, heaters, engines, glycol dehydrators, refrigerators, and chemical injection pumps (CIP). The types and quantities of fuels used in processing would need to be tracked. Leaks may also be present in the production and should be tracked too.**	**Related**
P8 – Process control electricity	Electric pumps, valves or controllers can use grid electricity as part of regular operations. Electric controls will generate fewer emissions compared to venting pneumatic devices. This source will be zero when projects are converted to air or solar power.	Controlled
P9 – 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 sources / sinks in this project are considered in this source / sink. Types and quantities of fuels used would need to be tracked.	Related
P10 – Fuel delivery	Some 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 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 sources / sinks and there is no other delivery.	Related
On-site Sources and Sinks during Project Operation		

P1 – Raw gas production	**The raw gas is collected from a group of adjacent wells where liquids are removed by separating water and condensate. Condensate is transported to oil refineries for further processing and wastewater is disposed. The quantity of GHGs in the raw gas would need to be tracked. The types and quantities of fuels used in extraction equipment would also need to be tracked. Leaks may also be present in the production and should be tracked too.**	**Related**
P2 – Raw gas transportation	The raw gas is piped to a natural gas processing plant. The types and quantities of fuels used in transportation would need to be tracked. Leaks may also be present in the pipeline and should be tracked also.	Related
P3 – Raw gas processing	Processing of raw gas is required to remove hydrogen sulphide, carbon dioxide, water vapour, heavier hydrocarbons or other impurities. Clean gas is ready to be distributed and sold. The quantity of GHG in the processed gas would need to be tracked. Leaks may also be present in the production and should be tracked too. Possibility of venting must also be considered and tracked.	Related
P6 – Air compression	Air will be used to supply pressure to the pneumatic control instruments. The energy required to run the air compressors could come from grid electricity or on-site combustion of fossil fuels. Quantity and source of the electricity are the important characteristics to be tracked as they directly relate to the quantity of greenhouse gas emissions.	Controlled
P7 – Project vented gas	Pneumatic devices will vent greenhouse gases to the atmosphere as part of regular operations. The low or non-venting pneumatic devices in the project will reduce emissions as part of normal operations compared to high-venting pneumatic devices. This source will be zero when pneumatic devices are converted to instrument air or solar-electric devices. The quantity of gas vented in the project may have an impact on the emissions reduction quantification for controller conversions projects.	Controlled
P17 – Vent gas capture	The quantity of vent gas captured in the project will need to be tracked and has a direct impact on the emissions reduction quantification for vent gas capture projects.	Controlled
Downstream Sources and Sinks during Project Operations		
P4 – Processed gas distribution and sale	**Natural gas and other commercially viable NGL products may be sent to a pipeline system for Distribution and Sale or transported by rail or truck to customers at another point. Avoided greenhouse gas emissions from the fuel gas supply to the control instrumentation should be included here. It is assumed that the mostly likely use of avoided greenhouse gas emissions would be controlled combustion to produce carbon dioxide.**	**Related**
Upstream Sources and Sinks before Project Operations		

P11 – 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**
P12 – Development of the 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 at the site 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 or trenching.	Related
P13 – Building of equipment	Equipment may need to be built either on 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
P14 – 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 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
P15 – 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
On-site Sources and Sinks After the Project Operation		
P16 – Site decommissioning	**Once the site 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**

4.0 Quantification of Reduction, Removals, and Reversals of Relevant Sources and Sinks

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

Emissions that increase or decrease materially as a result of the project must be included and associated greenhouse gas emissions must be quantified as part of the project condition.

All sources and sinks are identified in Table 3 and Table 4. Each source and sink is listed as included or excluded and justification for these choices is provided in Table 5.

Table 5: Comparison of Sources and Sinks

Identified Source and Sinks	Baseline (C, R, A)	Project (C, R, A)	Include or Exclude from Quantification	Justification for Inclusion / Exclusion
Upstream Sources and Sinks				
P1 – Raw Gas Production	N/A	Related	Exclude	Excluded as the production of raw gas is not impacted by the implementation of the project and as such the baseline and the project conditions will be functionally equivalent.
B1 – Raw Gas Production	Related	N/A	Exclude	
P2 – Raw Gas Transportation	N/A	Related	Exclude	Excluded as the transportation of raw gas is not impacted by the implementation of the project and as such the baseline and the project conditions will be functionally equivalent.
B2 – Raw Gas Transportation	Related	N/A	Exclude	
P3 – Raw Gas Processing	N/A	Related	Exclude	Excluded as the processing of raw gas is not impacted by the implementation of the project and as such the baseline and the project conditions will be functionally equivalent.
B3 – Raw Gas Processing	Related	N/A	Exclude	
P5 – Fuel Gas For Processing	N/A	Related	Exclude	Excluded as the fuel gas is not impacted by the implementation of the project and as such the baseline and the project conditions will be functionally equivalent.
B5 – Fuel Gas For Processing	Related	N/A	Exclude	
P6 – Air Compression	N/A	Controlled	Include	Air compression systems may have electricity emissions to account for. The air compressor and air management system will require electricity that is incremental to baseline electricity consumption. Emissions from electric device conversions are included.
P8 – Process Control Electricity	N/A	Related	Include	Included as electrified control devices or electric chemical pumps may have additional electricity emission compared to the baseline condition.
B9 – Electricity Usage	Controlled	N/A	Exclude	Existing air compression systems that are expanded to include pneumatic devices may have electricity emissions to account for in the baseline. The project air compressor and air management system will require electricity that is incremental to baseline electricity consumption but these emissions are conservatively accounted in all project scenarios under this protocol and this source is therefore redundant and excluded.
P9 – Fuel Extraction / Processing	N/A	Related	Include	Include as the extraction and processing of project fuels results in tangible emissions

B10 – Fuel Extraction / Processing	Related	N/A	Exclude	Fuel extraction and processing emissions may vary depending on the stage of processing or transportation of the gas. Emissions from fuel extraction and processing may not be relevant to the baseline condition. It is conservative to exclude baseline emissions
P10 – Fuel Delivery	N/A	Related	Exclude	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 equivalent.
B11 – Fuel Delivery	Related	N/A	Exclude	
On-site Sources and Sinks				
P7 – Project Vented Gas	N/A	Controlled	Include	Included as the venting of gas results in tangible emissions
B7 – Baseline Vented Gas	Controlled	N/A	Include	
B8 – Uncaptured Fuel Gas	Controlled	N/A	Include	Emissions reductions from installing or upgrading a vent gas capture and destruction system. Venting of gas results in tangible emissions in the baseline condition, destruction of vent gas has tangible emissions in the project condition.
P17 – Vent Gas Capture	N/A	Controlled	Include	
Downstream Sources and Sinks				
P4 – Processed Gas Distribution and Sale	N/A	Related	Exclude	Excluded as the emissions from the distribution and sale of avoided vented gas is the sole responsibility of the end user. It is assumed the final use of this gas will be controlled combustion to produce carbon dioxide. Accountability of this gas is in the hands of end users.
B4 – Processed Gas Distribution and Sale	Related	N/A	Exclude	Excluded as the emissions from the distribution and sale of gas is the sole responsibility of the end user and it is assumed the final use of this gas will be controlled combustion to produce carbon dioxide.
Other				
P11 – 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.
B12 – Construction on site	Related	N/A	Exclude	
P12 – Development of Site	N/A	Related	Exclude	Emissions from development of site are not material given the long project life and the minimal development of site typically required.
B13 – Development of Site	Related	N/A	Exclude	

P13 – Building of Equipment	N/A	Related	Exclude	Emissions from building of equipment are not material given the long project life and the minimal building equipment typically required.
B14 – Building of Equipment	Related	N/A	Exclude	
P14 – 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.
P15 – 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.
B15 – Transportation of Equipment	Related	N/A	Exclude	
P16 – Site Decommissioning	N/A	Related	Exclude	Emissions from decommissioning of site are not material given the long project life and the minimal decommissioning typically required.
B6 – Site Decommissioning	Related	N/A	Exclude	

4.1 Quantification Approach

Quantification of the reductions, removals and reversals of relevant sources and sinks for each of the greenhouse gases will be completed using the methodologies outlined in Table 6. These calculation methodologies serve to complete the following equations for calculating the emission reductions from the comparison of the baseline and project conditions.

Project proponents may aggregate multiple project activities at one facility, and projects at multiple facilities, together under one project plan. The quantification approaches presented below are intended to be extensible, meaning individual projects may be quantified together using repeated instances of the appropriate equations. Projects quantified under an aggregated approach are still subject to the requirements of this protocol at an individual level, including being able to satisfy the quantification approaches described below as a stand-alone quantification exercise.

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

For projects including high to low and electrification projects:

$$\text{Emissions}_{\text{Baseline}} = \text{Emissions}_{\text{Baseline Vented Gas}}$$

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

For projects including instrument gas to instrument air projects:

$$\text{Emissions}_{\text{Baseline}} = \text{Emissions}_{\text{Baseline Vented Gas}}$$

$$\text{Emissions}_{\text{Project}} = \text{Emissions}_{\text{Air Compression}} + \text{Emissions}_{\text{Fuel Extraction / Processing}}$$

For projects including vent gas capture projects

$$\text{Emissions}_{\text{Baseline}} = \text{Emissions}_{\text{Uncaptured Fuel Gas}}$$

$$\text{Emissions}_{\text{Project}} = \text{Emissions}_{\text{Vent gas capture}} + \text{Emissions}_{\text{Fuel Extraction / Processing}}$$

Where:

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

$\text{Emissions}_{\text{Baseline Vented Gas}}$ = emissions under B7 Baseline Vented Gas

$\text{Emissions}_{\text{Uncaptured Fuel Gas}}$ = emissions under B8 Uncaptured Fuel Gas

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

$\text{Emissions}_{\text{Project Vented Gas}}$ = emissions under P7 Project Vented Gas

$\text{Emissions}_{\text{Air Compression}}$ = emissions under P6 Air Compression

$\text{Emissions}_{\text{Fuel Extraction / Processing}}$ = emissions under P9 Fuel Extraction and Processing

$\text{Emissions}_{\text{Vent Gas Capture}}$ = emissions under P17 Vent Gas Capture

$\text{Emissions}_{\text{Process Control Electricity}}$ = emissions under P8 Process Control Electricity

Table 6: Quantification Procedures

Sources and Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
Project Sources and Sinks						
P7 – Project Vented Gas	$Emissions_{Project\ Vented\ Gas} = \Sigma_j (Vented\ Gas_{Project,j} * \%CH_4 * \rho CH_4/1000) * GWP_{CH4} + \Sigma_j (Vented\ Gas_{Project,j} * \%CO_2 * \rho CO_2 / 1000)$ *Where:* $Vented\ Gas_{Project} = Op.\ Hrs._j * (Q_{Project,j})$ *(for converting controllers to lower venting controllers)* $Q_{Project,j}$ $= Q_{Direct\ Measurement\ j}$ *(for controllers with direct measurement samples)* $= Q_{Average\ Controller\ Type\ j}$ *(for controllers with average measurement samples)* $= Q_{Manufacturer\ Specification\ j}$ *(for controller with no direct measurement or sample statistics)*					
	$Emissions_{Vent\ Gas\ For\ Control\ Instruments}$	tonnes of, CO_2e	N/A	N/A	N/A	Quantity being calculated.
	Volume of Vented Gas Emitted by Pneumatic Device / $Vented\ Gas_{Project}$	m^3	Calculated	Method provided in equations above	Per report	Intermediary quantity being calculated.
	Methane Composition in Vented Gas / % CH_4	%	Measured	Direct measurement	Annual	Vented gas composition should remain relatively stable during steady-state operation.
	Carbon Dioxide Composition in Vented Gas / % CO_2	%	Measured	Direct measurement	Annual	Vented gas composition should remain relatively stable during steady-state operation.

	Density of Methane / ρ_{CH4}	kg / m^3	Estimated	Reference value corresponding to conditions at which volumes are reported	N/A	If this value is used all values must be adjusted for standard temperature and pressure (STP).
	Density of Carbon Dioxide / ρ_{CH4}	kg / m^3	Estimated	Reference value corresponding to conditions at which volumes are reported	N/A	If this value is used all values must be adjusted for standard temperature and pressure (STP).
	Pneumatic Device Index Value / j	-	-	Index value to identify device	Per report	Assigned value to be identified each reporting period.
	Operating Hours / Op. Hrs.	hrs	Measured	Direct measurement	Annual	Continuous operating time measurement is highest level possible.
	Vent Rate of Low Vent Control Device / $Q_{Project}$	m^3 / hr	Measured or Estimated	Determined based on project type	Per report	Value is an intermediate used for subsequent calculations, based on project type.
	Measured Vent Rate of Control Device / $Q_{Direct\ Measurement}$	m^3 / hr	Measured	Direct Measurement	Once	Direct measurement of vent rate provides high confidence.
	Statistical Vent Rate of Control Device / $Q_{Average\ Controller,\ Type}$	m^3 / hr	Estimated	See Appendix C	Once	Changes to emission rates are likely equivalent between baseline and project condition and statistically relevant emission factors can provide sufficient confidence in emission reduction assertions.
	Manufacturer Specified Vent Rate of Low Vent Controller / $Q_{Manufacturer\ Specification}$	m^3 / hr	Estimated	See Appendix C reference manufacturer documents	Once	Changes to emission rates are likely equivalent between baseline and project condition and manufacturer specifications are conservative estimates.
P9 – Fuel extraction /	$Emissions_{Fuel\ Extraction\ /\ Processing} =$ $\Sigma\ (Vol.\ Fuel_i * EF_{i,CO2}) * EF_{CO2} +$					

processing	$[\Sigma\,(Vol.\ Fuel_i * EF_{i,CH4}) * EF_{CH4}] * GWP_{CH4}$ + $[\Sigma\,(Vol.\ Fuel_i * EF_{i,N2O}) * EF_{N2O}] * GWP_{N2O}$

Emissions $_{Fuel\ Extraction\ /\ Processing}$	tonnes of CO_2e	N/A	N/A	N/A	Quantity being calculated.
Volume of Fossil Fuel i Combusted in the Project / Vol. Fuel	L, m^3, or other	Measured	From P6 – Air Compression and Management / "Vol. Fuel", P8 Process Control Electricity / "Vol. Fuel", P17 Vent gas capture / "Captured Gas" and/or P7 Project Vented Gas / "Vented Gas $_{Project}$"	Per report	Calculated values are determined each reporting period.
$EF_{i,CO2}$ CO_2 Emissions Factor for Extraction and Processing for each fuel	kg CO_2 per L, m^3, or other	Estimated	Provided in Carbon Offset Emission Factors Handbook	Annual	Must use most current factors published in the Carbon Offset Emission Factors Handbook.
$EF_{i,CH4}$ CH_4 Emissions Factor for Extraction and Processing for each fuel	kg CH_4 per L, m^3, or other	Estimated	Provided in Carbon Offset Emission Factors Handbook	Annual	Must use most current factors published in the Carbon Offset Emission Factors Handbook.
$EF_{i,N2O}$) N_2O Emissions Factor Extraction and Processing for each fuel	kg N_2O per L, m^3, or other	Estimated	Provided in Carbon Offset Emission Factors Handbook	Per report	Must use most current factors published in the Carbon Offset Emission Factors Handbook.
Fuel Type Index Value / i	-	-	Index value to identify fuel type	Per report	Assigned value to be identified each reporting period

	$GWP_{CH4, N2O}$ Global Warming Potential	Unitless	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Must use most current factors published in the Carbon Offset Emission Factors Handbook.
P6 – Air compression and management	$$Emissions_{\text{Air Compression and Management}} = Electricity_{\text{Air Compression and Management}} * EF_{\text{Elec Supply}} / 1000$$ *Where:* $$EF_{\text{Elec Supply}}$$ $$= EF_{grid} \text{ (for projects using grid electricity)}$$ $$= 0 \text{ (for projects using on-site renewable electricity)}$$ $$= Vol.\ Fuel_i * \sum_{CO2,\ CH4,\ N2O} (EF\ Fuel_i * GWP_{CO2,\ CH4,\ N2O}) / Net\ Elec \text{ (for projects using on-site fossil fuel electricity)}$$					
	$Emissions_{\text{Air Compression and Management}}$	tonnes of CO_2 e	N/A	N/A	N/A	Quantity being calculated
	Emission Factor for Electricity Supply / $EF_{ElecSupply}$	$kgCO_2e$ / kWh	Calculated	Method provided in equations above	Per report	Intermediary quantity being calculated
	Total Quantity of Electricity Consumed by the Air Compression and Management System / $Electricity_{\text{Air Compression and Management}}$	kWh	Estimated	Estimated based on full duty and load of equipment specifications for entire duration of reporting period or measured.	Per report	Estimated parameter is a conservative overestimation in absence of equipment measurement.
	Emission Intensity Factor for Grid Sourced Electricity Consumption /	tCO_2e / MWh (equiv. to $kgCO_2e$ / kWh)	Estimated	Provided in Carbon Offset Emission Factors Handbook, Electricity Grid Use and Displacement Factors /	Annual	Must use most current factors published by Alberta Climate Change Office.

	EF $_{Grid}$			"Increased on-site grid electricity use"		
	Volume of Fossil Fuel i Combusted / Vol. Fuel $_i$	m^3, L or eq.	Measured	Direct metering	Continuous metering	Frequency of metering is highest level possible.
	Net On-Site Electricity Generation / Net Elec	kWh	Measured	Direct metering	Continuous metering	Frequency of metering is highest level possible.
	CO_2 Emissions Factor Each Type of Fuel i / EF Fuel $_{CO2}$	kg CO_2 per m^3, L or eq.	Estimated	Provided in Carbon Offset Emission Factors Handbook	Per report	Must use most current factors published in the Carbon Offset Emission Factors Handbook.
	CH_4 Emissions Factor for Each Type of Fuel i / EF Fuel $_{CH4}$	kg CH_4 per m^3, L or eq.	Estimated	Provided in Carbon Offset Emission Factors Handbook	Per report	Must use most current factors published in the Carbon Offset Emission Factors Handbook.
	N_2O Emissions Factor for Each Type of Fuel i / EF Fuel $_{N2O}$	kg N_2O per m^3, L or eq.	Estimated	Provided in Carbon Offset Emission Factors Handbook	Per report	Must use most current factors published in the Carbon Offset Emission Factors Handbook.
	Fuel Type Index Value / i	-	-	Index value to identify fuel type	Per report	Assigned value to be identified each reporting period
	$GWP_{CO2, CH4, N2O}$ Global Warming Potential	Unitless	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Must use most current factors published in the Carbon Offset Emission Factors Handbook.
P8 – Process control electricity	$Emissions_{\text{Electric Process Control}} = Electricity_{\text{Process Control}} * EF_{\text{Elec Supply}} / 1000$					
	Emissions $_{\text{Electric Process Control}}$	tonnes of CO_2e	N/A	N/A	N/A	Quantity being calculated.
	Total Quantity of Electricity Consumed for	kWh	Estimated/ Measured	Estimated based on equipment specifications. In the	Per report	Both methods are standard practice. Estimated parameter is standard practice and a conservative

	Control Functions / Electricity $_{Process\ Control}$			case of renewable electricity generation, the quantity of electricity consumed is not necessary since the emission factor, and emissions will be zero		overestimation in absence of equipment measurement. If measurement has no impact on emissions, measurement is not necessary.
	Emission Intensity Factor for Electricity Consumption / EF $_{Elec\ Supply}$	Kg CO_2e / kWh	Estimated	See P6 – Air Compression and Management / "EF $_{Elec\ Supply}$"	Per report	Calculated values are determined each reporting period
P17 – Vent gas capture	$Emissions_{Vent\ Gas\ Capture} =$ $Captured\ Gas * DE * EF\ Fuel_{CO2} / 1000000 +$ $Captured\ Gas * DE * EF\ Fuel_{CH4} * GWP_{CH4} / 1000000 +$ $Captured\ Gas * EF\ Fuel_{N2O} * GWP_{N2O} / 1000000 +$ $Captured\ Gas * (1-DE) * GWP_{CH4} * \%CH_4 * \rho CH_4 / 1000000$ *Where Captured Gas:* *= Direct Metering* *= Σ Vent Gas (from P7)* *= Op. Hours * Load * Fuel Con. Rate*					
	Emissions $_{Vent\ Gas\ Capture}$	tonnes of CO_2e	N/A	N/A	N/A	Quantity being calculated
	Volume of Captured Gas Combusted / Captured Gas	m^3	Calculated	Methods provided in equations above	Per Report	Intermediary quantity being calculated.

	Destruction Efficiency of Combustion Source / DE	%	Estimated	Reference provided in Appendix C or manufacturer specification.	Per report	Must use the value in Appendix C unless proponent can provide project specific destruction efficiency.
	CO_2 Emissions Factor for Vent Gas Capture Combustion / EF Fuel $_{CO2}$	g CO_2 per m^3	Estimated	Provided in Carbon Offset Emission Factors Handbook, Fuel Combustion Related Emissions / "Producer Consumption (non-marketable product)"	Per report	Must use most current factors published in the Carbon Offset Emission Factors Handbook.
	CH_4 Emissions Factor for Vent Gas Capture Combustion / EF Fuel $_{CH4}$	g CH_4 per m^3	Estimated	Provided in Carbon Offset Emission Factors Handbook, Fuel Combustion Related Emissions / "Producer Consumption (non-marketable product)"	Per report	Must use most current factors published in the Carbon Offset Emission Factors Handbook.
	N_2O Emissions Factor for Vent Gas Capture Combustion / EF Fuel $_{N20}$	g N_2O per m^3	Estimated	Provided in Carbon Offset Emission Factors Handbook, Fuel Combustion Related Emissions / "Producer Consumption (non-marketable product)"	Per report	Must use most current factors published in the Carbon Offset Emission Factors Handbook.
	Direct Metering of fuel gas consumed/Direct Metering	m3	Measured	Direct metering	Continuous metering	Frequency of metering is the highest level possible.

	Sum of Vent Volumes from different sources/Σ Vent Gas (from P7)	m3	Calculated	Methods for determining “Vent Gas” volumes provided in P7	Per Report	This is an intermediary quantity.
	Operating Hours / Op. Hrs	hrs	Measured	Direct measurement of combustion device.	Annual	Continuous operating time measurement is highest level possible.
	Fuel Device Load/ Load	%	Measure	Direct measurement of fuel use device.	Once	Reading from fuel use device.
	Fuel Consumption Rate/Fuel Con. Rate	Kg/hr	Estimated	Referenced from manufacturer specifications	Once	Estimated parameter is a conservative overestimation in absence of equipment measurement.
	$GWP_{CO2, CH4, N2O}$ Global Warming Potential	Unitless	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Must use most current factors published in the Carbon Offset Emission Factors Handbook.
	Methane Composition in Vented Gas / % CH_4	%	Measured	Direct measurement	Annual	Vented gas composition should remain relatively stable during steady-state operation.

	Density of Methane / ρ_{CH4}	kg / m^3	Estimated	Reference value corresponding to conditions at which volumes are reported	N/A	If this value is used all values must be adjusted for standard temperature and pressure (STP).
Baseline Sources and Sinks						
B7 – Baseline Vented gas	$$Emissions_{Baseline\ Vented\ Gas} = \Sigma_j (Vented\ Gas_{Baseline,j} * \%CH_4 * \rho CH_4 / 1000) * GWP_{CH4} + \Sigma_j (Vented\ Gas_{Baseline,j} * \%CO_2 * \rho CO_2 / 1000)$$ *Where:* *Vented Gas* $= Q_{Air\ Driven\ Devices} * (1 - DR) * GER$ *(for controllers and pumps converted to instrument air)* $= Op.\ Hrs._j * (Q_{Baseline,j})$ *(for converting controllers to lower or non-venting controllers)* $= Strokes_j * EF_{Pump\ Type\ j}$ *(for converting pumps to non-venting equivalents)* $Q_{Baseline,j}$ $= Q_{Direct\ Measurement\ j}$ *(for controllers with direct measurement samples)* $= Q_{Average\ Controller\ Type\ j}$ *(for controllers with average measurement samples)* $= Q_{Manufacturer\ Specification\ j}$ (for controller with no direct measurement or sample statistics)						
	$Emissions_{Baseline\ Vented\ Gas}$	tonnes of CO_2e	N/A	N/A	N/A	Quantity being calculated
	Volume of Vented Gas Emitted by Pneumatic Device / $Vented\ Gas_{Baseline}$	m^3	Calculated	Method provided in equations above	Per report	Intermediary quantity being calculated.

	Methane Composition in Vent Gas / % CH_4	%	Measured	Direct measurement	Annual	Fuel gas composition should remain relatively stable during steady-state operation.
	Carbon Dioxide Composition in Vent Gas / % CO_2	%	Measured	Direct measurement	Annual	Fuel gas composition should remain relatively stable during steady-state operation.
	Density of Methane / ρ_{CH4}	kg / m^3	Estimated	Reference value corresponding to conditions at which volumes are reported	N/A	If this value is used all values must be adjusted for standard temperature and pressure (STP).
	Density of Carbon Dioxide / ρ_{CH4}	kg / m^3	Estimated	Reference value corresponding to conditions at which volumes are reported	N/A	If this value is used all values must be adjusted for standard temperature and pressure (STP).
	Pneumatic Device Index Value / j	-	-	Index value to identify device.	Per report	Assigned value to be identified each reporting period.
	Compressed Air Used for Pneumatic Device / $Q_{Air\ Driven\ Devices}$	m^3	Measured	Direct measurement of air supply to air driven devices	Continuous metering	Frequency of metering is highest level possible.
	Discount Rate due to Leaks/ DR	%	Estimated	See Appendix A	See Appendix A	See Appendix A.
	GER – gas equivalency ratio	-	Estimated	See Appendix A	See Appendix A	See Appendix A.
	Operating Hours / Op. Hrs. j	hrs	Measured	Direct measurement	Annual	Continuous operating time measurement is highest level possible.

	Vent Rate of High Vent Control Device / $Q_{Baseline}$	m^3 / hr	Measured or Estimated	Determined based on project type	Per report	Value is an intermediate used for subsequent calculations, based on project type.
	Pump Strokes / Strokes	-	Measured	Direct measurement	Continuous	Continuous counting is the highest frequency of monitoring possible.
	Pump Emission Factor / $EF_{Pump\ Type}$		Estimated	See Appendix C	Annual	Annual estimates in consideration of changes to injection pressure provide sufficient confidence in emission rates and manufacturer specifications are conservative estimates.
	Measured Vent Rate of Control Device / $Q_{Direct\ Measurement}$	m^3 / hr	Measured	Direct measurement	Once	Direct measurement of vent rate provides high confidence.
	Statistical Vent Rate of Control Device / $Q_{Average\ Controller,\ Type}$	m^3 / hr	Estimated	See Appendix C	Once	Variation in emission rates are likely equivalent between baseline and project condition and statistically relevant emission factors can provide sufficient confidence in emission reduction assertions.
	Manufacturer Specified Vent Rate of High Vent Controller / $Q_{Manufacturer\ Specification}$	m^3 / hr	Estimated	See Appendix C or reference manufacturer documents	Once	Changes to emission rates are likely equivalent between baseline and project condition and manufacturer specifications are conservative estimates.
	$GWP_{CO2,\ CH4,\ N2O}$ Global Warming Potential	Unitless	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Must use most current factors published in the Carbon Offset Emission Factors Handbook.

B8 – Uncaptured fuel gas	$$Emissions_{Uncaptured\ Fuel\ Gas} =$$ $$Captured\ Gas * (1 – DR) * \%CH4 * \rho CH4 / 1000 * GWP_{CH4} +$$ $$Captured\ Gas * (1 – DR) * \%CO2 * \rho CO2 / 1000$$ $$Where\ Captured\ Gas:$$ $$= Direct\ Metering$$ $$= \Sigma\ Vent\ Gas\ (from\ B7)$$ $$= Op.\ Hours * Load * Fuel\ Con.\ Rate$$					
	Emissions Uncaptured Fuel Gas	tonnes of CO_{2e}e	N/A	N/A	N/A	Quantity being calculated
	Volume of Captured Gas Combusted / Captured Gas	m^3	Measured	For pumps, existing high vent controllers, and low vent controllers: measured from P17 – Vent Gas Capture / “Captured Gas”. For new high vent controllers: estimated from Appendix C, Table C2 based on low venting equivalents	Continuous metering or estimated once	Frequency of metering is highest level possible. Estimation is a conservative low vent equivalent for new high vent pneumatic controllers
	Discount Rate due to Leaks / DR	%	Estimated	See Appendix A	Per report	See Appendix A.
	Methane Composition in Captured Gas / % CH_4	%	Measured	Direct measurement	Annual	Fuel gas composition should remain relatively stable during steady-state operation.

	Carbon Dioxide Composition in Captured Gas / % CO_2	%	Measured	Direct measurement	Annual	Fuel gas composition should remain relatively stable during steady-state operation.
	Density of Methane / ρ_{CH4}	kg / m^3	Estimated	Reference value corresponding to conditions at which volumes are reported	Once	If this value is used all values must be adjusted for standard temperature and pressure (STP).
	Density of Carbon Dioxide/ ρ_{CH4}	kg / m^3	Estimated	Reference value corresponding to conditions at which volumes are reported	Once	If this value is used all values must be adjusted for standard temperature and pressure (STP).
	Direct Metering of fuel gas consumed/Direct Metering	m3	Measured	Direct metering	Continuous metering	Frequency of metering is the highest level possible
	Sum of Vent Volumes from different sources/Σ Vent Gas (from B7)	m3	Calculated	Methods for determining "Vent Gas" volumes provided in B7	Per Report	This is an intermediary quantity
	Operating Hours / Op. Hrs	hr	Measured	Direct measurement of combustion device.	Annual	Continuous operating time measurement is highest level possible.

	Fuel Device Load/ Load	%	Measure	Direct measurement of fuel use device.	Once	Reading from fuel use device.
	Fuel Consumption Rate/Fuel Con. Rate	Kg/hr	Estimated	Referenced from manufacturer specifications	Once	Estimated parameter is a conservative overestimation in absence of equipment measurement.
	$GWP_{CO2, CH4, N2O}$ Global Warming Potential	Unitless	Estimated	Provided in Carbon Offset Emission Factors Handbook	N/A	Must use most current factors published in the Carbon Offset Emission Factors Handbook.

5.0 Management of Data Quality

Projects must be supported with data of sufficient quality to fulfill the quantification requirements and be substantiated by company records for the purpose of verification to a reasonable level of assurance. Reasonable assurance means the verifier must be able to reach a positive finding on the accuracy and correctness of the GHG assertion.

In support of this requirement project data must be managed in a manner that substantiates that:

- emissions and reductions that have been recorded pertain to the offset project;
- all emissions and reductions that should have been recorded were;
- emissions and reductions quantification has been recorded appropriately;
- emissions and reductions have been recorded in the correct reporting period;
- emissions and reductions have been recorded in the appropriate category; and
- must have an auditable data management system.

Based on these requirements, data must be quantifiable and verifiable using replicable means. That is, an independent verifier should be able to reach the same conclusions using evidence-supported data. The Alberta carbon offset system cannot accept data that is based on attestation.

The project developer shall establish and apply quality management procedures to manage data and information. Written procedures must be established for each measurement task outlining responsibility, timing and record location requirements. Requirements can be found in the Standard for Validation, Verification and Audit.

5.1 Project Documentation

Documentation for project eligibility includes:

- the name, contact information, and statement of qualification of the project developer(s);
- evidence of the project start date;
- an inventory of project activities for aggregated projects including multiple methane venting reduction projects;
- evidence and explanation of ownership for each project;
- all applicable permits for project condition;
- evidence that each project results in emission reductions located in Alberta including legal land location or GPS coordinates of the site via the inventory or a spatial locator; and
- project quantification and calculations.

Documentation for the baseline condition includes:

- justification for changes from the included or excluded sources and sinks;
- the total emissions for sources/sinks included in the baseline;
- calculations applied to measured baseline data and justifications for any deviations from those calculations; and
- the measured baseline data as recorded from the measurement device before calculations are applied.

Documentation for the project condition includes:

- justification for changes from the included or excluded project sources/sinks;
- for each project year, the total emissions accounted under each included source/ sink;
- evidence of timing of project implementation;
- for each project year, calculations applied to measured project data and justifications for any deviations from those calculations; and
- for each project year, the measured project data as recorded from the measurement device, before calculations are applied.

5.2 Record Keeping

Alberta Climate Change Office requires that project developers retain records for the longer of eight years after the related tonnes are serialized or seven years after they are retired for compliance. Where the project developer is different from the person implementing the activity, as in the case of an aggregated project, the individual projects and the aggregator, must both maintain sufficient records to support the offset project. The following records must be collected and disclosed to the third party verifier and/or government auditor upon request.

Record keeping requirements:

- raw baseline period data, independent variable data, and static factors within the measurement boundary;
- a record of maintenance and annual inspection of pneumatic devices;
- a record of conversion (in cases of conversion);
- a record of all adjustments made to raw baseline data with justification;
- all analysis of baseline data used to create mathematical model(s);
- all data and analysis used to support estimates and factors used for quantification;
- common practices relating to possible greenhouse gas reduction scenarios discussed in this protocol;
- metering equipment specifications (model number, serial number, manufacturer's calibration procedures);
- a record of changes in static factors along with all calculations for non-routine adjustments including discount rates for projects without leak detection;
- all calculations of greenhouse gas emissions/reductions and emission factors;
- measurement equipment maintenance activity logs;
- measurement equipment calibration records; and
- initial and annual verification records and audit results.

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

- all records must be kept in areas that are easily located;
- all records must be legible, dated and revised as needed;
- all records must be maintained in an orderly manner;
- all documents must be retained in accordance to regulatory requirements;
- electronic and paper documentation are both satisfactory; and
- copies of records should be stored to prevent loss of data.

Attestations are not considered sufficient evidence that an activity took place and do not meet verification requirements.

5.3 Quality Assurance / Quality Control Considerations

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

- protecting monitoring equipment (sealed meters and data loggers);
- protecting records of monitored data (hard copy and electronic storage);
- checking data integrity on a regular and periodic basis (manual assessment, comparing redundant metered data, and detection of outstanding data/records);
- comparing current estimates with previous estimates as a reality check;
- providing sufficient training to operators to perform maintenance and calibration of monitoring devices or contract with qualified third parties;
- establishing minimum experience and requirements for operators in charge of project and monitoring;
- ensuring that the changes to operational procedures continue to function as planned and achieve greenhouse gas reductions;

- ensuring that the measurement and calculation system and greenhouse gas reduction reporting remains in place and accurate;
- checking the validity of all data before it is processed, including emission factors, static factors and acquired data;
- performing recalculations of quantification procedures to reduce the possibility of mathematical errors;
- storing the data in its raw form so it can be retrieved for verification;
- recording and explaining any adjustment made to raw data in the associated report and files; and
- developing a contingency plan for potential data loss.

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

Alberta Environment and Parks
Climate Implementation and Compliance Branch
12th Floor, 10025 – 106 Street
Edmonton, Alberta, T5J 1G4
E-mail: AEP.GHG@gov.ab.ca

APPENDIX A: Explanation on Gas Equivalency and Leaks

Gas Equivalence Ratio (GER)

The capacity of a device to flow air or gas is expressed in terms of C_V, or flow coefficient. The C_V measures the impact on flow from diverse factors to a device such as:

- orifice size (diameter of the piping or opening through the valve);
- length of piping or opening through the valve;
- turbulence caused by bends or turns in the piping;
- restrictions, or anything that reduces the orifice size or the flow path; and
- shape of the orifice.

For this protocol, the formula employed by the Instrument Society of America (ISA) based on L.R. Driskell's work will be used to develop equivalence between air consumption and natural gas that would have been consumed. This formula may be found in ANSI/ISA-75.02-1996 Control Valve Capacity Test Procedures and is an established method used by industry to calculate the C_V for pneumatic devices. The expanded formula can be found in L.R. Driskell's New approach to Control Valve Sizing.

Gas and air are considered compressible fluids. In pneumatic devices, flow can be choked or non-choked. Flow in a duct or passage such that the flow upstream of a certain critical section cannot be increased by a reduction of downstream pressure is defined as choked. For the purpose of this protocol, choked conditions will be used because these conditions represent a conservative approach in estimating air volumes, explained in detail in this section.

For compressible fluid flow in non-choked conditions, the flow rate can be expressed as:

$$Q_{SCFH} = 4.17 * C_V * P_{1psia} * Y \sqrt{\frac{x}{G_g * T_{\circ R}}} \qquad (1)$$

where

$$Y = 1 - \frac{x}{3 * F_k * X_T} \qquad \text{(Limits } 1.0 \geq Y \geq 0.667 \text{ for air)} \qquad (2)$$

Q_{SCMH} = fluid volumetric flow rate (m^3/h);

C_V = flow coefficient;

P_{1kPa} = inlet pressure;

Y = expansion factor;

x = pressure drop ratio to absolute inlet pressure

G_g = gas specific gravity (this is the density of the gas divided by the density of air at the same conditions);

$T_{\circ K}$ = temperature in degrees Kelvin;

F_k = ratio of specific heats (equal to the specific heat ratio of the gas divided by the specific heat ratio of air); and

X_T = maximum pressure ratio before choking.

When choking occurs, (1) and (2) are still valid with the exception that $x=X_T$. Equation (2) becomes

$$Y = 1 - \frac{1}{3 * F_k} \qquad (3)$$

where

$$F_k = \frac{k}{1.4} \tag{4}$$

k is the ratio of specific heats for a given gas (1.4 is the ratio specific heat for air, 1.3 for methane). The heat capacity ratio or adiabatic index or ratio of specific heats, is the ratio of the heat capacity at constant pressure (C_P) to heat capacity at constant volume (C_V). It is the ratio of specific heats between 2 gases; in the case of the protocol, the ratio between air and air (used as reference), and the ratio between methane and air, the gas of interest.

Approach

In order to establish the equivalence of how much natural gas would have been vented if the air system had not been installed, the assumption of equal C_V for both gas and air powered devices must be established. Therefore (1) for CH_4 can be expressed as:

$$Q_{CH4} = 4.17 * C_V * P_{1kPa} * Y_{CH4} * \sqrt{\frac{x}{G_{CH4} * T_{\circ K}}} \tag{5}$$

where:

Q_{CH4} = CH_4 volumetric fluid flow rate

Similarly, (1) for air can be expressed as

$$Q_{AIR} = 4.17 * C_V * P_{1kPa} * Y_{AIR} * \sqrt{\frac{x}{G_{AIR} * T_{\circ K}}} \tag{6}$$

where:

Q_{AIR} = air volumetric flow rate

It should be noted that a specific pneumatic instrument has a unique C_v, regardless of the liquid or gas being consumed by the instrument. By substituting (6) into (5) as a function of C_V and eliminating common terms,

$$Q_{CH4} = Q_{AIR} * \frac{1}{\sqrt{\frac{1}{G_{AIR}}}} * \frac{1}{Y_{AIR}} * Y_{CH4} * \sqrt{\frac{1}{G_{CH4}}} \tag{7}$$

The fuel gas supply and compressed air will travel along the same pipe network. Pressures cancel each other out since they are assumed equal as per the consideration of functional equivalence ($P_{1kPa\ AIR} = P_{1kPa\ CH4}$).

Because the pipeline is thin and not insulated, the temperature of the gas (either fuel supply gas or air) will reach approximate ambient temperature just before being vented by the pneumatic device after having travelled through the pipe network ($T_{AIR}=T_{CH4}$). For this reason, the temperatures of either fuel gas or compressed air were considered comparable and cancel each other out in equation (7).

Finally, x was taken as x_T or the limiting condition when choking occurs. If YC_v is plotted against x, there is a linear relationship with a negative slope as x increase. Choked condition will occur when $Y*C_v=.667*C_v$ for air and $Y*C_v=.644*C_v$ for methane. Note that the corresponding values of $x_{T\ AIR}$ when $Y*C_v=.667*C_v$ is slightly less than the corresponding value of $x_{T\ CH4}$ when $Y*Cv=.644*C_v$ for a given device. When dividing $x_{T\ CH4}$ by $x_{T\ AIR}$ and square-rooting, this value is slightly greater than 1. For simplicity and conservativeness in calculations, the value was equaled to 1 in equations (6).

Rearranging terms and assuming choked conditions in (3)

$$Q_{CH4} = Q_{AIR} * \sqrt{\frac{G_{AIR}}{G_{CH4}}} * \frac{1 - \frac{1}{3 * F_{CH4}}}{1 - \frac{1}{3 * F_{AIR}}} \qquad (8)$$

The following are the assumptions used to state conservativeness in the approach:

Equation (2) is used to show all the possible pressure drops that can be experienced by the device before it reaches the critical pressure and then asymptotes under choked conditions.
Under choked conditions, $x=X_T$. Choked flow is a limiting condition which occurs when the mass flow rate will not increase with a further decrease in the downstream pressure environment while upstream pressure is fixed. Using equation (3), for air Y=0.667 and natural gas Y=0.643, so Y_{CH4}/Y_{AIR} = .965 in equations (7) and consequently (8). Under unchoked conditions and the extreme right-hand side of Figure A1 (for F_k=1.00 and x_{vc}=0.0), F_{CH4}=.935 and F_{AIR}=1, so it follows that Y_{CH4}/Y_{AIR} = 1. Note that Y_{AIR} and Y_{CH4} have been normalized with respect to Y_{AIR}. As can be seen, Y_{CH4}/Y_{AIR} drops from 1 in unchoked conditions to .965 in choked conditions. So by assuming choked conditions, the quantities are discounted at .965 and not 1. The approach "loses" 0.035 (1-.965) of the possible credits claimable, so it underestimates the quantities by 3.5% and provides a conservative approach. Table A2 summarizes the calculations for Y_{CH4}, Y_{AIR} and x/x_T using equations in the ISA standard. The yellow row indicates choked conditions. Note that x_T is the terminal or limiting pressure where choking begins.

Table A1 Evolution of Y $_{CH4}$/Y $_{AIR}$ from Un-choked to Choked Conditions

X / x_T	Y $_{CH4}$ k=1.31	Y $_{AIR}$ k=1.4	Y $_{CH4}$ / Y $_{AIR}$
0	1	1	1
0.1	0.964	0.967	0.998
0.2	0.929	0.933	0.995
0.3	0.893	0.9	0.992
0.4	0.858	0.867	0.989
0.5	0.822	0.833	0.986
0.6	0.786	0.8	0.983
0.7	0.751	0.767	0.980
0.8	0.715	0.733	0.975
0.9	0.679	0.7	0.971
1	0.644	0.667	0.966

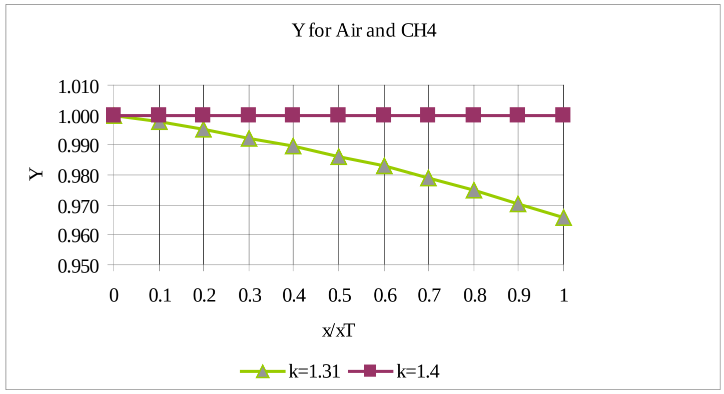


Figure A1 Y for air and CH4 (normalized with respect to air)

From the figure in Table A2, it is clear that by dividing methane as it asymptotes by the reference gas (with a value of Y $_{AIR}$/Y $_{AIR}$ = 1), the minimum value will occur when choked conditions occur, or when FCH4 asymptotes at .965.

Specific gas gravities for greenhouse gases present in fuel supply gas at NTP[3] are summarized in Table A2.

Table A2 Specific Gravity of Gases Present in Fuel Gas

Gas	S.G.
Air	1.000
Carbon dioxide	1.519
Methane	0.5537
Natural Gas	0.60 – 0.70

Using G_{CH4} = .5537, G_{AIR} = 1, and k = 1.31 for pure methane, (7) becomes:

$Q_{CH4} = 1.2977\ Q_{Air}$

GEF = 1.2977

This represents the volumes of pure methane that would have been vented instead of air

Conservativeness of Approach

ISO 14064-2:2006(E) Section 3.7 introduces the principle of conservativeness and guidance is given on its application:

"Use conservative assumptions, values and procedures to ensure that GHG [greenhouse gas] emission reductions or removal enhancements are not over-estimated."

3 Normal Temperature and Pressure is defined as air at 20oC (293.15 K, 68oF) and 1 atm (101.325 kPa)

As stated previously, the parameter that has the most effect on flow in pneumatic devices is Y, the expansion factor. The ISA standard (sections 8.3.4 to 8.3.7) states that for the evaluation of C_v for a pneumatic device, at least two points are needed that comply with the following conditions

(1) $(Y^*C_v)_1 \geq 0.97(YC_v)_0$ where $(Y^*C_v)_0$ corresponds to $x \approx 0$; and
(2) $(Y^*C_v)_n \leq 0.87(Y^*C_v)_0$
(3) The test points are plotted on linear coordinates as (Y^*C_v) vs. x and a linear curve fitted to the data The value of C_v for the specimen (device) shall be taken from the curve at x=0, Y=1. The value of x_T for the specimen shall be taken from the curve at $Y^*C_v=0.667^*C_v$.

$Y^*C_v=0.667^*C_v$ corresponds to the critical ratio of air, which is the medium (type of gas) most commonly used for compressible fluid testing. The equations in the ISA standard are all corrected with respect to air which allows for testing with different types of gases, not just air. The other value of interest with respect to this protocol is $YC_v=0.644^*C_v$, or the corresponding x_T for methane.

Figure A2 (with values in Table A3) is an example of this plotting procedure to evaluate C_v and x_T[4]. C_v was taken as 35.52 as an example. Note that $x_{T\ CH4}$ (blue line) is slightly higher than $x_{T\ AIR}$ (red line) at all times, regardless of the C_v value because the slope (m) of the linear curve (line) is always negative thus guaranteeing that $x_{T\ CH4}$ will always be greater than $x_{T\ AIR}$.

Table A3: Illustrative Example of Y^*C_V versus x

		Y * Cv
x	Y	35.200
0.000	1.000	35.200
0.021	0.970	34.144
0.092	0.870	30.624
0.236	0.667	23.467
0.252	0.644	22.661

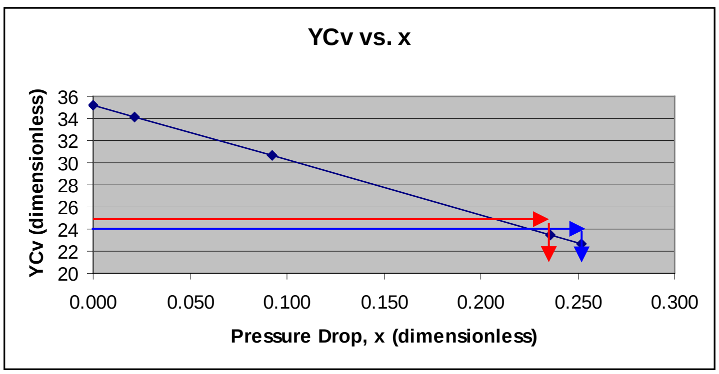


Figure A2 Example of fitted data to linear curve

The value of $x_{T\ CH4}$ (=0.252) is slightly higher than $x_{T\ AIR}$ (=0.225) in this example. It is true that $x_{T\ CH4} \neq x_{T\ AIR}$ at all times because $x_{T\ CH4}$ will always be greater than $x_{T\ AIR}$. If this is assumed, then data can be generated for the expansion factors Y as summarized in TABLE A.4 and shown in Figure A3. $x/x_{T\ CH4}$ and $x/x_{T\ AIR}$ are evaluated individually (i.e. $x_{T\ CH4} \neq x_{T\ AIR}$ is assumed). Note that if the pneumatic device runs on air, the maximum pressure drop it experiences is 0.225, which corresponds to Y_{AIR}= 0.667. The pressure drop if the device runs on CH_4 would be the same, which corresponds to Y_{CH4}= 0.682. Y_{CH4}/Y_{AIR} would be 0.682/ 0.667 or 1.022. It should be noted that air is flowing choked and CH_4 is flowing unchoked if the same pressure drop ratio is assumed. Therefore, air flow will enter choked conditions before CH_4 does at all times because $x_{T\ CH4} > x_{T\ AIR}$, regardless of C_V. If unchoked conditions are assumed also, this approach will increase the value of Y_{CH4}/Y_{AIR} from 1 to an asymptote of roughly 1.022.

1.022 is higher than the one calculated assuming $x_{T\ CH4}= x_{T\ AIR}$, which corresponds to Y_{CH4}/Y_{AIR}= 0.644/ 0.6667 or .966. The value of .966 is conservative because it underestimates the actual value of quantifiable emissions (which would use 1.022 if $x_{T\ CH4} \neq x_{T\ AIR}$). Conclusively, assuming $x_{T\ CH4} = x_{T\ AIR}$ both under choked conditions

[4] Stubbs, W.L. 1998. Establishing a new method for determining valve flow coefficient. Micro Magazine, May, p. 39-51.

simplifies and reduces calculations, and further metering requirements while assuring conservativeness as per ISO guidance.

Note on Pressure Drop, x

Typically, pneumatic devices are designed to operate at 20 PSI (~138 kPa) or 35 PSI (~241 kPa). The pressure drop, x (dimensionless), defined by the ISA standard is the ratio of pressure drop to absolute inlet pressure ($\Delta p/p_1$). Δp is the differential pressure, p_1-p_2. p_1 is the upstream absolute static pressure, measured two nominal pipe diameters upstream of the valve-fitting equipment. p_2 is the downstream absolute static pressure, measured six nominal pipe diameters upstream of the valve-fitting equipment. To approximate x in a field setting, p_1 can be assumed to be the design pressure and p_2 the atmospheric pressure at sufficient distance downstream. Therefore, x can be calculated as

$$x_{138kPa} = \frac{138-101}{138} = .275;$$

$$x_{240kPa} = \frac{241-101}{241} = .581$$

These are typical x values to be found in the field. These can be normalized with respect to $x_{T\ CH4}$ or $x_{T\ AIR}$ if the values are known from the manufacture. However, this may be impractical and tedious to accomplish. The proposed approach simplifies and keeps a conservative approach, in line with the ISO principle.

Table A4: Y with the Conditions $x_{T\ CH4} = x_{T\ AIR}$ and $x_{T\ CH4} \neq x_{T\ AIR}$

x_T	CH4 = 0.252			AIR = 0.225			Y_{CH4} / Y_{AIR}	Y_{AIR} /				Y_{CH4} / Y_{AIR}
x	x	x / x_T	Y_{CH4}	x	x / x_T	Y_{AIR}	($x_{TCH4}=x_{T\ AIR}$)	Y_{AIR}	x	x / x_T	Y_{CH4}	($x_{TCH4} \neq x_{T\ AIR}$)
0.0	0.000	0.0	1.000	0.000	0.0	1.000	1.000	1.000	0.000	0.000	1.000	1.000
0.1	0.025	0.1	0.964	0.023	0.1	0.967	0.998	1.000	0.023	0.089	0.968	1.002
0.2	0.050	0.2	0.929	0.045	0.2	0.933	0.995	1.000	0.045	0.179	0.936	1.003
0.3	0.076	0.3	0.893	0.068	0.3	0.900	0.992	1.000	0.068	0.268	0.905	1.005
0.4	0.101	0.4	0.858	0.090	0.4	0.867	0.989	1.000	0.090	0.357	0.873	1.007
0.5	0.126	0.5	0.822	0.113	0.5	0.833	0.986	1.000	0.113	0.446	0.841	1.009
0.6	0.151	0.6	0.786	0.135	0.6	0.800	0.983	1.000	0.135	0.536	0.809	1.011
0.7	0.176	0.7	0.751	0.158	0.7	0.767	0.979	1.000	0.158	0.625	0.777	1.014
0.8	0.202	0.8	0.715	0.180	0.8	0.733	0.975	1.000	0.180	0.714	0.746	1.017
0.9	0.227	0.9	0.679	0.203	0.9	0.700	0.971	1.000	0.203	0.804	0.714	1.020
1.0	0.252	1.0	0.644	0.225	1.0	0.667	0.966	1.000	0.225	0.893	0.682	1.023

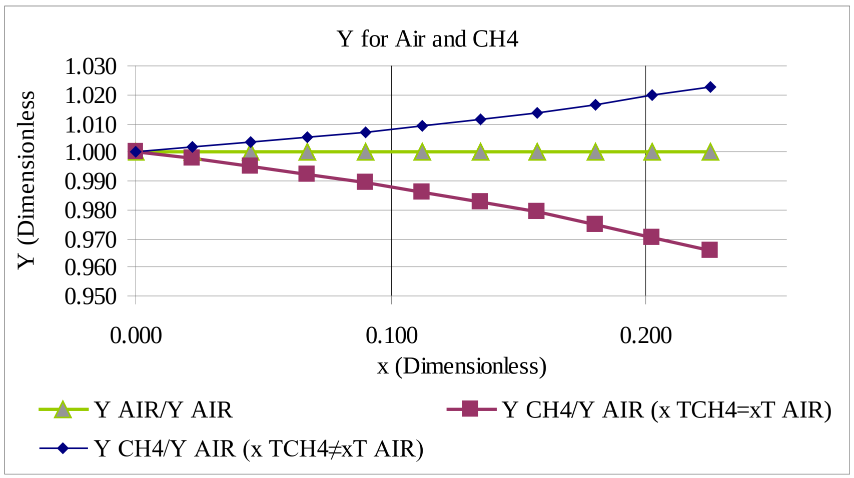


Figure A3 Expansion curves for Y_{CH4}/Y_{AIR} $x_{T\ CH4} = x_{T\ AIR}$ and $x_{T\ CH4} \neq x_{T\ AIR}$

Leaks

Minimizing leaks by making use of a regular inspection and maintenance program ensures that metered air volumes are not overestimated, and hence gas that would have been vented had the instrument air conversion not taken place. At times a regular inspection and maintenance program is not practical or programmed at different time periods that do not coincide with the implementation of the conversion project. Estimates based on best practices and emission factors from credited references are used to discount metered air volumes to safeguard conservativeness in these estimations.

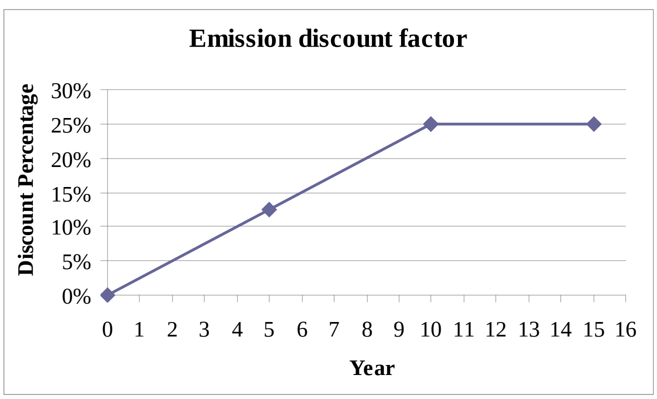
The discount factors presented here are based on rates from the EPA's Natural Gas STAR Program Lessons Learned-Convert Gas Pneumatic Controls to Instrument Air. Instrument control devices in service and that have not been repaired will leak as time passes. A 2.5 per cent yearly linear increase in leaks is assumed. For devices that have been recently inspected and repaired, the discount rate is assumed to be zero. For devices or pipe networks that have not been inspected and repaired in the last 10 years, the discount rate increases linearly until reaching 25%. The maximum discount rate is 25% for devices with more than 10 years without inspection and repairs. The equations used to calculate the discount rate are as follows:

Table A5: Discount Rate Values for Quantification

Years Since Last Inspection	Discount Rate (DR)
0	0
1 to10	0.025 * Years since Last Inspection
>10	0.25

This relationship is assumed linear and is illustrated in Figure A4. As an example, if the last inspection and repair took place 5.5 years ago, then the minimum of that year interval is 5.5 times 2.5 % yearly increase due to leaks yields a 12.5 % leak rate. The discount rate is therefore 12.5%.

Figure A4 Linear relationship between elapsed time and discount factor.



This discount rate is used to adjust the baseline and maintain a conservative approach.

APPENDIX B: Device Inventory

Inventory Minimum Requirements

As part of applicability to this protocol and project installation or conversion, the project proponent must take an inventory of pneumatic devices associated with methane vent reduction projects. The parameters/meta data the project proponent must record include (where applicable):

(1) Pneumatic device serial number or unique identifier – To identify and track pneumatic devices in the inventory, unique identifiers or serial numbers (if available) should be used. All pneumatic devices including those within an instrument gas to air conversion and vent gas capture projects will have unique identifiers. These identifiers are to be used for on-going monitoring and verification that the devices remain in service and remain operational and should have some physical identifier on the device (serial or tag) to facilitate physical confirmation of devices.

(2) Methane Vent Reduction Index – Denoted as 'j' throughout the quantification methods in Section 4.1, a unique identification to each conversion project should be assigned in the inventory to ensure clarity and transparency when conducting quantification. Instrument gas to instrument air projects, vent gas capture and electrification may have a single index value assigned to all pneumatic devices that are affected by the conversion system. In aggregated projects, each instance of this index requires an execution of the complete quantification methodology presented in Section 4.1.

(3) Project Type – Denote the project type for each Methane Vent Reduction Index. Project types are listed in the protocol scope section. Each Methane Vent Reduction Index instance may have one and only one project type.

(4) Location – To help locate devices and facilitate physical monitoring and verification of devices, a location of the installation site must be included and may be a Legal Sub-Division (LSD) description, street address or latitude/longitude coordinates. In larger facilities (gas plants and compressor stations, a description of where the device is located on site (i.e., which building) may be included to facilitate location on site.

(5) Old Device Type – Manufacturer / Model Number / Vintage or Version as appropriate should be recorded for each device that is replaced. If a new install, denote in the inventory as a "new install" or "greenfield".

(6) New Device Type – Manufacturer / Model Number / Vintage or version as appropriate should be recorded for each device that is replaced. If gas to air conversion or vent gas capture where there is no new device, denote "same device with air supply" or "same device with vent gas capture".

(7) Old Device Sample Vent Rate – If applicable, record the old device sample vent rate. Not applicable for instrument gas to air conversion or vent gas capture projects.

(8) New Device Sample Vent Rate – If applicable, record the new device sample vent rate. Not applicable for instrument gas to air conversion projects.

(9) Replacement Date – Record of the date in which the conversion project took place. Not applicable for instrument gas to air conversion or vent gas capture projects.

(10) Decommissioning Date – For devices that were decommissioned during the project crediting period, decommissioning dates should be recorded such that crediting ceases at this date. Decommissioned devices should remain in the inventory for the duration of the project and after as prescribed in the record keeping requirements regardless of whether the device remains on site or is physically removed.

(11) Supply / Signal Pressure – For functional equivalence of instrument gas to air systems, supply or signal pressure should be recorded in the inventory and must match between baseline and project conditions. Not applicable to other project types.

(12) Injection Pressure – For accuracy, the injection pressure of pumps should be similar between the baseline and project condition. Not applicable to other project types.

APPENDIX C: Field Vent Rate Sampling and Emissions Factor Development

This appendix serves as guide to ensure that basic requirements are met when pneumatic device vent rates are sampled in the field for the purposes of quantification of emission reductions associated with methane vent reduction projects. Additionally, if enough measurements are collected, emissions factors for different makes and models of pneumatic devices can be generated.

Field Vent Rate Sampling Procedure, $Q_{\text{Average Controller}}$

Meter Types

When collecting field sample measurements, different measurement instruments can be used to measure the vent rate of a pneumatic device. Depending on what type of measurement instrument is used and what type of pneumatic device is being measured, the project proponent must ensure certain constraints are observed to maximize accuracy. Common measurement devices are:

(1) High Flow Vent Detection Meter –A high flow vent detection meter determines the vent rate of a pneumatic device by actively drawing a large volume of air through a metering device from the approximate location of a vent. The measurement premise assumes that the vent rate is significantly lower than the volume of air drawn through the metering device and as such, all gases that were vented are also drawn through the meter in a mixture with the air. By measuring the flow rate and heating value of the mixture, an accurate representation of the vented gas flow rate can be established and reported. The benefits of this meter type are that it imparts no backpressure on a vent source and maintains stable accuracy at low turn-down. The drawback is that it is has limited total accuracy, requires a very accurate understanding of the composition of vent gas at the moment when measurement was done and this meter type has a prolonged response time, which makes it less accurate for variable flow vent rate measurement.

(2) Positive Displacement Meter – A positive displacement meter is a type of flow meter that requires direct connection to a vent gas source, where vented gas displaces alternating volumetric chambers within the meter to record discrete volume measurements in time. The vent rate of a pneumatic device is determined by accumulating discrete volumetric displacement measurements in time and correcting for temperature and pressure to standardized conditions based on the pressure and temperature sensors in the meter. The benefit of this meter types is that it has a high accuracy on total accumulated flow, very stable accuracy at low turn down for total accumulated flow and a relatively good response for variable flow vent rate measurement. The drawbacks of this meter type is that there may be a back-pressure imposed which alters performance of a venting device, or may encourage a leak elsewhere in the pneumatic system, skewing the results recorded by the meter.

(3) Total Pressure Loss Measurement – A total pressure loss meter is a type of flow determination completed by tying in a known volume of supply gas (typically nitrogen tanks) via a dedicated regulator and recording the pressure changes before and after a given time period of operation. The benefit of this meter is that it allows for very accurate volumetric determinations that are indifferent to variable or low flow conditions. The drawback of this meter type is that it requires the supply source for a pneumatic device to be temporarily changed and may or may not be disruptive to the process it controls.

(4) Thermal Mass Flow – A heated element is directly connected to a flow stream and controlled to a specific temperature and passing gases cool the element at a rate proportional to their mass flow. The benefits of this meter type is that it measures mass flow rather than volume and has a high accuracy. The drawbacks to this meter type is that it has low response time to variable flow rates, requires an accurate representation of the gases heat capacity (and by extension composition) and may have limited turndown.

There are varieties of other meter types that may also be applicable to metering the particular scenarios envisioned by this protocol. In general, vent rate determinations are characterized by low pressure, low and variable flow rates, low tolerance to back-pressure and typically an approximate gas composition at the exact moment of flow rate measurement. There are always benefits and drawbacks to any metering technology, which must be understood and managed in a manner appropriate to each application. This protocol does not prescribe meter types that are applicable; rather it requires proponents to ensure metering is sufficiently accurate and precise to support emission reduction assertions.

Measurement Principles

Methane venting reductions associated with the implemented project can be quantified from pre-project and project vent measurements. The following are requirements for a vent rate measurement sample.

- It is important that the same sampling procedure and type of measurement instrument be used to measure the baseline and project condition. This helps to eliminate biases that may arise if certain measurement techniques were only applied to the baseline or project set of emission rates.
- Measurements must be corrected or normalized as appropriate for each measurement technique to account for variations in local ambient temperatures, gas temperatures and barometric pressures.
- Some devices function in cyclical or intermittent manners such as level controllers and pumps and at least two dynamic cycles or strokes (i.e. two dump intervals for tank level controllers or two strokes for pumps) must be captured from these devices types to capture a data sample that is representative of an annual average. Measurement times will therefore vary for different devices and from device to device depending on duty and load.
- Obvious device case leaks or venting from locations other than the vent port invalidates a measurement and therefore care must be taken by the measurement technician.

The following are recommended but not required for a vent rate measurement sample.

- The field sampling can be done using mass flow meters, hi-flow sampler meters, positive displacement meters or measuring the total pressure loss from a known supply volume.
- In preferential order, whenever possible, measurement should be taken at device supply ports, vent ports, or as close as possible to the vent port.
- Backpressure from the measurement instrument imposed on the device should be minimized through the use of minimal connection tubing as is reasonably necessary, appropriate choice of measurement technology given the nature of the vent source and proper maintenance of measurement systems.

Emission Factors

To generate emission factors the project proponent must use multiple field measurement samples. Field samples can be collected from a single project producer or multiple producers to develop an emission factor. Field samples can be collected from Alberta, British Columbia or Saskatchewan due to the similar operating conditions and geological formations.

Emission factors will be specific to a make and model of pneumatic controller (ie) Fisher 4150, however different companies can make equivalent devices. Controllers are considered equivalent devices if they have interchangeable parts. A list of commonly found equivalent devices was compiled using information from device vendors and subject matter experts.

Table C1 Equivalent Pneumatic Devices

Description	Make	Model	Equivalents	Name

Pressure Controller	**Fisher**	**4150**	**CVS 4150** **Fisher 4150K** **Fisher 4160R** **Fisher 4150K** **Fisher 4160** **DynaFlo 4000**	**Fisher 4150**
Level Controller	Norriseal	1001	Norriseal 1001A	Norriseal 1001
Level Controller	Fisher	2900	Fisher 2901 Fisher 2900A Fisher 2901A	Fisher 2900
Transducer	Fisher	546	Fisher 546S	Fisher 546
Level Controller	Fisher	2680	Fisher 2680A	Fisher 2680
High-Low Pressure Pilot	Fisher	4660	Fisher 4660A	Fisher 4660
Positioner	Fisher	FIELDVUE DVC6000	FisherDVC6030 FisherDVC6020 FisherDVC6010	Fisher FIELDVUE DVC6000
Level Controller	Fisher	2660	Fisher 2660A	Fisher 2660
Controller/Receiver	Fisher	2506	Fisher 2516	Fisher 2506

Proponents may demonstrate further equivalent devices specific to any project by evidencing that repair kits and replacement parts are interchangeable and that the overall design is sufficiently similar.

To ensure accuracy in the emission factors, the same type of measurement device (i.e., hi-flow sampler meter) must be used to capture all the data points that will subsequently generate the emission factor. In both the baseline and project conditions, emission factors can be used if they were generated from the same type of measurement device.

An emission factor can be used in both the baseline and project condition or in only the baseline or only the project condition if a direct measurement of that specific device was taken in either condition.

At least 30 field sample measurements must be taken to generate an emission factor for a controller or pump. If less than 30 field samples have been taken for a pneumatic controller or pump, make and model, the historic benchmark should be used to quantify emissions reductions. If a project proponent has to use the manufacturer specified vent rate because a particular replacement lacks a direct measurement or enough data points to generate an emission factor, the manufacturer specified vent rate should be used in both the baseline and project condition.

For both controllers and pumps that have field vent rate measurements, emissions factors can be generated using the following equation:

$$Q_{\,Average\ Controller} = \sum_{j=1}^{n} \frac{Q_{Direct\ Measurement,j}}{n}$$

where:

$Q_{\text{Direct Measurement}}$ = vent rate of all the data points used to generate the emission factor

n = number of samples used to generate the emission factor

j = index value for pneumatic device

If a project proponent develops an emission factor for a make and model of a pneumatic device, that emission factor is eligible for the lifetime of the project.

Manufacturer Specification, $Q_{\textbf{Manufacturer Specification}}$

In the absence of a direct measurement or an emission factor for a pneumatic device in both the baseline and project condition, manufacturer specified vent rates may be used to quantify the emission reduction. These vent rates can be referenced from Table C2 or they can come directly from manufacturer brochures.

Most manufacturers report the vent rate at two supply pressures. In the absence of a recorded supply pressure, the project proponent should use the lower manufacturer vent rate to ensure conservativeness. If the manufacturer bleed rate is not in Table C2, the project proponent should reference manufacturer documents.

Table C2 Specified Manufacturer Vent Rates for Common Pneumatic Devices[5]

Controller Model	Supply Pressure (psi)	Manufacturer Specified Vent Rate, $Q_{\text{Manufacturer Specification}}$ (scfh)[6]
Pressure Controllers		
Ametek Series 40	20	6
	35	6
Bristol Babcock Series 5453-Model 10F	20	3
	35	3
Bristol Babcock Series 5455-Model 624-III	20	2
	35	3
Bristol Babcock Series 502 A / D (recording controller)	20	<6
	35	<6
Dynaflo 4000LB	20	1.6
	35	2.6
Fisher 4100 Series (Large Orifice)	20	50
	35	50
Fisher 4150 and 4160	20	35
	35	42
Fisher C1	20	3.9
	35	5.8
Fisher 4194 Series (Differential Pressure)	20	3.5
	35	5
Fisher 4195	20	3.5
	35	5
Foxboro 43AP	20	18
	35	18
ITT Barton 338	20	6
	35	6
ITT Barton 335P	20	6
	35	6
Natco CT	20	35

[5] Canadian Environmental Technology Advancement Corporation-West Efficient 2008. Use of Fuel Gas in Pneumatic Instruments Module 3 of 17. May 2008.

[6] Vent rates are specified for volumes of air. For methane vent rates values must be multiplied by 1.29.

Controller Model	Supply Pressure (psi)	Manufacturer Specified Vent Rate, $Q_{\text{Manufacturer Specification}}$ (scfh)[6]
	35	35
Transducers		
Bristol Babcock Series 9110-00A	20	0.42
	35	0.42
Fisher i2P-100LB	20	2.1
	35	3.1
Fisher i2P-100	20	6.3
	35	10.2
Fisher 546	20	21
	35	30
Fisher 646	20	<1
	35	<1
Fisher 846	20	<1
	35	<1
Level Controllers		
Dynaflo 5000	20	0
	35	0
Fisher 2900	20	23
	35	23
Fisher 2500	20	42
	35	42
Fisher 2660 Series	20	1
	35	1
Fisher 2100 Series	20	<1
	35	<1
Fisher 2680	20	<1
	35	<1
Fisher L2 (throttling)	20	1
	35	1.5
Fisher L2 (snap acting)	20	1
	35	1.5
Fisher L2 (on-off)	20	1
	35	1.5
Fisher L2sj	20	0.3
	35	0.45
Invalco CT Series	20	1.5
	35	40
Norriseal 1001	20	N/A
	35	N/A
Norriseal 1001(A)	20	0.007

Controller Model	Supply Pressure (psi)	Manufacturer Specified Vent Rate, $Q_{\text{Manufacturer Specification}}$ (scfh)[6]
	20	0.2
	35	0.007
	35	0.2
Wellmark 2001	20	0.007
	20	0.2
	35	0.007
	35	0.2
Positioners		
Fisher 3582	20	14
	35	18
Fisher 3661	20	8.8
	35	12.1
Fisher 3590 (Electro-pneumatic)	20	24
	35	36
Fisher 3582i (Electro-pneumatic)	20	17.2
	35	24
Fisher 3620J (Electro-pneumatic)	20	18.2
	35	35
Fisher 3660	20	6
	35	8
Fisher FIELDVUE DVC5000	20	10
	35	15
Fisher FIELDVUE DVC6000 (standard)	20	14
	80	49
Fisher FIELDVUE DVC6000 (low bleed)	20	2.1
	80	6.9
Fisher FIELDVUE DVC6200 (standard)	20	14
	80	49
Fisher FIELDVUE DVC6200 (low bleed)	20	2.1
	80	6.9
Masoneilan SVI Digital	20	<1
	35	<1
Moore Products – Model 750P	20	
	35	42
Moore Products – 73 – B PtoP	20	36
	35	
PMV D5 Digital	20	<1
	35	<1
Sampson 3780 Digital	20	<1
	35	<1
Siemens PS2	20	1.2

Controller Model	Supply Pressure (psi)	Manufacturer Specified Vent Rate, $Q_{Manufacturer\ Specification}$ (scfh)[6]
VRC Model VP7000 PtoP	35	1.2
	20	<1
	35	<1

Pump Emissions, $EF_{Pump\ Type}$

The pump emission factor is referenced from manufacturer specifications. At a given supply pressure and injection pressure, a pump will consume and vent a known volume of gas for each stroke or volume of chemical injected. In the absence of a known stroke count, project proponents can use the volume of chemical injected to determine the volume of gas vented in the baseline, as per Flexibility Mechanism 4.

Project proponents should reference manufacturer specifications to determine the vent rate per stroke and should account for the injection pressure and supply pressure where available. In the absence of available supply pressure or injection pressure, proponents should use and justify the most conservative, and therefore lowest emission rate for baseline emission estimations.

Destruction Efficiency, DE

For different vent gas capture projects, different destruction devices can be used. A common vent gas capture project would use a catadyne heater to destroy previously vented gas from pneumatic devices. If a project uses a catadyne heater the destruction efficiency is assumed to be 60% unless a project proponent provides different justification[7].

Guidance for Selection of Baseline Emission Factors for Greenfield Installations of Electric Pumps or Electric Controllers.

For new build or greenfield sites where no prior pneumatic equipment existed at the site, the project proponent must establish the baseline scenario by collecting an inventory of pneumatic equipment specifications from a statistically representative sample of similar facilities constructed within the past 5 years (constructed after Jan 1, 2012) by the same operator. If that operator cannot provide a representative sample of facilities in that region, then supplemental data may be used from other operators with facilities in the same region.

To develop the baseline, the following factors should be taken into account at a minimum:

For pneumatic pumps:

1. Equipment make and model (e.g. Williams pump model "WRB 1 - 11 104M NN SE BB" or "CR P1000V800 A PE")
2. Pump type (e.g. piston or diaphragm)
3. Pump plunger size (e.g. 1/4", 3/8", 1/2", 3/4" or 1" etc.)
4. Pump injection pressure or discharge pressure (psig)
5. Pneumatic supply pressure (e.g. 100 psig)
6. Chemical type (methanol, corrosion inhibitor, soap, de-waxing agent, etc.)
7. Chemical injection rate (Litres/day) or strokes per minute

[7] Hayes et al. 2009. Catalytic combustion of VOC in a counter diffusive reactor Catalysis Today 155 (2010) 147–153 suggests destruction efficiency of approximately 60%

8. Sweet or sour gas service and availability of a source of sweet gas to run pneumatics. The use of sour gas to drive pneumatic equipment is not an eligible baseline.

For pneumatic controllers:

1. Pneumatic equipment make and model (e.g. Fisher I2P-100)
    a. The pneumatic relay type must be included where applicable such as for pneumatic device types that come with either a high bleed or a low bleed relay such as the DVC Fieldvue Positioner.
    b. Only pneumatic makes/models that are commercially available on the market should be considered in the baseline.
2. Pneumatic supply pressure (e.g. 20psig or 35psig)
3. Device output pressure range (e.g. 6 to 30 psig)
4. Sweet or sour gas service and availability of a source of sweet gas to run pneumatics. The use of sour gas to drive pneumatic equipment is not an eligible baseline.