TECHNICAL PROTOCOL PLAN FOR ENGINE FUEL MANAGEMENT AND VENT GAS CAPTURE

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Version 1

Table of Contents

List of Tables

List of Figures

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Part A Identification of the Protocol Developer
Part B Technical Protocol Plan

B.1 Description of the Project Type and How Real Reductions Will be Achieved

Introduction

This Technical Protocol Plan (TPP) is targeted at projects that involve the implementation of new engine control systems to establish a lean burn combustion condition within an Original Equipment Manufacturer (OEM) engine design and / or the implementation of a vent gas capture system to capture and combust vented gases.

As such, the GHG emission reduction activities discussed in this TPP relate to improvements in the fuel efficiency of natural gas combustion engines and the opportunity to capture and combust methane emissions that would normally have been vented to the atmosphere. The TPP will accompany the Draft Quantification Protocol for Engine Fuel Management and Vent Gas Capture to provide the necessary background on science and policy issues related to the emission reduction activity.

The Environment Canada (EC) National GHG Inventory reports stationary combustion emissions from fossil fuel production in Section 3.2.1 under Energy Industries. The EC National Inventory also reports fugitive emissions, venting and flaring emissions from the oil and gas industry in Section 3.3.2 under Oil and Natural Gas. In 2005, stationary combustion emissions from petroleum refining and manufacture of solid fuels and other energy industries in Canada totalled 73 Mt CO2e (an increase of 40% since 1990), while fugitive emissions were 65 Mt CO2e (an increase of 60% since 1990)[1]. The implementation of engine fuel management and / or vent gas capture systems may serve as two methods to significantly reduce GHG emissions from these sectors.

The proposed protocol quantifies GHG emission reductions from two related activities: the improvement in the fuel efficiency of natural gas combustion engines and the capture of gases (primarily methane) normally vented to the atmosphere. In particular, the direct and indirect reductions of greenhouse gas (GHG) emissions from this project activity result from the implementation of engine management systems that control the air-fuel ratio to improve fuel use efficiency and from the implementation of vent gas capture systems that prevent the venting of greenhouse gases to the atmosphere. These process changes may be designed for retrofits or for new installations and may impact engine fuel consumption and the vented gas emissions associated with the operation of the engine and other nearby facility equipment.

In most project configurations, vent gases will consist primarily of methane emitted from equipment used in natural gas transmission systems. Under the scope of the proposed

[1] National Inventory Report, 1990-2005: Greenhouse Gas Sources and Sinks in Canada (Environment Canada 2005)

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protocol vent gases would primarily include compressor rod-packing gas or instrument gases that are designed to be vented to allow for safe operation of equipment, gases vented from flash tanks and glycol dehydrator re-boilers and other sources.

The quantification approaches for both components are based on measurement and monitoring and thus provide a high level of accuracy. It is recognized that this approach for the fuel efficiency component in this protocol creates significant data collection / data management burdens on the part of the project developer. However, the approaches outlined in this protocol are intended to allow for the measurement of fuel efficiency gains from any natural gas combustion engine to account for site specific air-fuel ratio set points, loads, engine speeds and variable operating and maintenance practices. Further, consultation with industry experts during the development of this protocol identified that at the time of protocol writing, a technically sufficient data set reflecting the fuel consumption of the current fleet of natural gas combustion engines in Alberta was not available. The data availability has been historically limited due to the fact that manufacturer's fuel consumption data generally does not match actual field operational data and many operating engines do not have their own distinct fuel meters. Therefore, the approach outlined in the proposed protocol was developed to allow for the quantification of fuel savings from the implementation of an engine fuel management system on any type of natural gas combustion engine in a technically robust way to allow for the collection of representative field data that can be used for more accurate generalizations of fuel savings among different classes of engines at a later time using the flexibility mechanism outlined in the proposed protocol.

It is anticipated that once a significant amount of data has been collected on the fuel consumption of the various makes and models of natural gas combustion engines in the Alberta fleet operating under normal Alberta conditions, it will then be possible to utilize a less burdensome and more generalized approach to GHG quantification for the fuel efficiency component of the proposed protocol that is sufficiently conservative, as outlined in the Flexibility Mechanisms described in the TPP (See Section B.14). At that time it will be possible for existing projects installed during 2002-2008 to quantify offsets from the fuel efficiency component of the proposed protocol.

In order to ensure that the implementation of engine fuel management systems has resulted in real GHG reductions the project proponent must demonstrate that project activities (e.g. the installation of vent gas capture and engine control systems) have resulted in more efficient combustion / reduced fuel usage and increased vent gas capture / reduced venting then would normally have occurred.

<u>Overview of GHG Reduction Activity</u>

The GHG reduction activity discussed in this Technical Protocol Plan is the improvement in the fuel efficiency of natural gas combustion engines and the capture of gases (primarily methane) normally vented to the atmosphere. The implementation of engine fuel management and / or vent gas capture systems can reduce GHG emissions through increased energy efficiency, the avoidance of process emissions associated with the

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production of fossil fuels, and the avoided venting and combustion of gases typically released during natural gas extraction, processing and transmission activities. For every unit of fuel saved and for every unit of vent gas captured and combusted, a corresponding greenhouse gas emission reduction can be achieved. The quantity of GHG emissions reduced through the use of engine fuel management systems depends primarily on the quantity and composition of vent gases captured and combusted and the quantity of fuel saved.

Alberta Offset System Eligibility Criteria

In order for a GHG emission reduction activity to create eligible offsets in the Alberta Offset System, a number of eligibility criteria must be met under the Specified Gas Emitters Regulation (SGER), as specified in the February 2008 Offset Credit Project Guidance Document. A summary of how the proposed protocol will address each of the relevant eligibility criteria is given in the following table.

TABLE B.1 Alberta Offset System Eligibility Criteria

Principle	Analysis
Start Date	The proposed protocol is applicable to projects that implement engine management systems and vent gas capture systems after January 1, 2002. The project activities could be implemented as retrofits or new installations.
Crediting Period	Projects applying this protocol will have a credit duration period of 8 years, consistent with Alberta Offset system guidelines.
Real	The implementation of engine management / vent gas capture systems decreases the overall requirements for fossil fuels in the upstream oil and gas sector by improving fuel use efficiency and reducing natural gas venting losses to atmosphere. Therefore, these project activities result in real GHG emission reductions as a result of a net decrease in fossil fuel consumption and a net decrease in vented methane that would have normally occurred during the extraction, processing and transmission of fossil fuels such as natural gas. The proposed protocol requires the project proponent to establish baseline fuel consumption under the unit's original configuration prior to the installation of the engine control system and where applicable the venting of process emissions to the atmosphere, to ensure that only the incremental benefits of the project activity are credited. This baseline fuel consumption would be established relative to a specific engine make, model, air/fuel ratio and configuration prior to any modifications and would be presented as a brake specific fuel consumption (BSFC) curve. For projects that install vent gas capture systems either independently or in conjunction with engine fuel management systems, baseline emissions are determined from the metered quantity of vent gases captured and combusted in the project condition based on their composition (% methane and carbon content). Therefore, baseline emissions are estimated considering the configuration of the unit prior to implementation of the project. Further, activities occurring prior to 2002 or that do not result in an incremental GHG benefit are not credited under the proposed quantification approach to ensure that only real and incremental GHG reductions are credited.
Demonstrable,	GHG reductions from the implementation of engine fuel management and / or vent

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Quantifiable	gas capture systems can be quantified following scientifically acceptable methods based on actual measurement and monitoring. The quantification approaches discussed in this document and the proposed protocol are derived from good practice guidance and the best available science (refer to section B.2) that give a high degree of certainty with regard to the sources and sinks of GHG emissions associated with the project activity. The quantification methodologies outlined in the proposed protocol provide a high level of accuracy and reliability. Baseline fuel consumption would be established relative to the specific engine make, model, air/fuel ratio setting and load demands of the project site. To ensure that quantification is consistent across different projects, an appendix is included with the proposed protocol to guide project developers through the data collection and calculations required to determine the baseline fuel consumption for an engine. Following this guidance ensures that the same assumptions are applied and the same approach is followed by different project developers. For projects that implement vent gas capture systems and use the vent gases as supplemental fuel for operating the unit, baseline emissions are determined from the measured quantity and heat value of vent gases captured and combusted in the project condition. The quantification approach is transparent and consistent with the best practices of the industry. Further the data management requirements discussed in the proposed protocol are rigorous with regard to measurement of the volumes of fuel combusted and the volume / composition of vent gases captured to ensure that real GHG reductions are occurring. Collectively, these steps ensure that the GHG reductions are demonstrable and quantifiable.
Not Required by Law	The proposed protocol covers two different activities and regulations may apply to some upstream oil and gas facilities and not to others, therefore it was necessary to specify in the proposed protocol that only those projects that can demonstrate that no regulations apply to their facility are eligible for offsets. In Alberta, Energy Resources Conservation Board (ERCB) Directive 60 outlines requirements for upstream oil and gas operators related to venting and flaring of certain gas streams and requirements for gas conservation (e.g. solution gas). Any gas streams that are required to be collected and conserved or flared as specified under Directive 060 or other applicable regulations are not eligible to generate offsets using the proposed protocol. Additionally, those sites that are regulated under the Alberta Specified Gas Emitters Regulation (SGER) and required to reduce GHG emissions as of July 1, 2007 would not be eligible to apply the proposed quantification protocol either. There do not appear to be any regulations requiring a certain level of engine fuel use efficiency. Project sites may be required to maintain NO_x emissions and benzene emissions within provincial regulations, but there are no requirements regulating the energy efficiency or fuel consumption of natural gas combustion engines in Alberta. Therefore project activities to improve engine fuel use efficiency would be surplus to regulation if they do not occur within the boundaries of Large Final Emitter sites as defined by the SGER.
Ownership	For consistency with other Alberta Offset System protocols the proposed protocol does not explicitly assign ownership, but instead states the minimum data collection requirements in order to adequately quantify the net GHG benefit of the project activity. It is therefore up to each project proponent to provide proof of ownership of all offsets claimed at the time of third party verification or upon request by Alberta

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	Environment.
Counted Once	In Alberta, engine fuel management and / or vent gas capture systems may be implemented at LFE sites. Given that these facilities are already regulated to reduce GHG emissions (and to avoid the potential of double counting), the proposed protocol is NOT applicable to project sites subject to the SGER (or other applicable provincial or federal climate change regulations).
Verifiable	In general, data quality management must include sufficient data capture such that the mass and energy balances may be easily performed with the need for minimal assumptions and use of contingency procedures. The data should be of sufficient quality to fulfill quantification requirements and be substantiated by company records for the purpose of verification. The primary data would be the quantity and composition of vent gas captured, the metered fuel consumption of the engine in the project condition and the estimated fractional change in fuel consumption due to the installation of the engine management system (i.e. as determined from measurements of the original un-modified engine and the modified engine with the new engine management system operating). Verification against the guidance provided in appendices to the proposed protocol will provide the verifier with a reasonable level of certainty that the proper measurements were made and that modifications to the given quantification approach are limited such that they are acceptable under the protocol's flexibility mechanisms.
Occurred in Alberta	Only projects in Alberta are eligible for offsets. The proposed protocol applies to projects located in Alberta that implement engine fuel management and / or vent gas capture systems.

B.2 Description of Background Information / Best Practice Guidance Used

During the development of the proposed protocol a significant amount of background information was collected from Canadian and international sources on the operation of natural gas combustion engines, engine fuel consumption, sources of vent gases in the upstream oil and gas industry, the impacts of installing engine fuel management and vent gas capture systems and related GHG emissions. This information provided the foundation to identify relevant sources and sinks of GHG emissions, to identify potential project and baseline scenarios, to develop the GHG quantification approaches for relevant sources and sinks and to account for relevant policies. A list of the guidance documents used is provided in Table B.2.

Information sources utilized for the development of GHG Quantification approaches for this project included good practice guidance from the International Standards Organization (ISO), Environment Canada, Alberta Environment and the Canadian Association of Petroleum Producers (CAPP). In addition, project specific information was obtained from the United States Environmental Protection Agency's (EPA) Natural Gas Star and Environmental Technology Verification (ETV) programs, the US EPA Greenhouse Gas (GHG) Verification Series, and various other publications. Regulatory information was obtained from the Alberta Energy and Resources Conservation Board (ERCB), the Canadian Association of Petroleum Producers (CAPP) and other sources, including the REMVue® technology verification assessed by the Petroleum Technology Alliance of Canada (PTAC).

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TABLE B.2 Good Practice Guidance

1. Document Title	2. Publishing Body / Date	3. Description
General Protocol Guidance		
ISO 14064-2: 2006: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements	International Standards Organization, 2006	ISO 14064-2:2006 specifies principles and requirements and provides guidance at the project level for quantification, monitoring and reporting of activities intended to cause greenhouse gas (GHG) emission reductions or removal enhancements. It includes requirements for planning a GHG project, identifying and selecting GHG sources, sinks and reservoirs relevant to the project and baseline scenario, monitoring, quantifying, documenting and reporting GHG project performance and managing data quality.
National Inventory Report, 1990-2005: Greenhouse Gas Sources and Sinks in Canada	Environment Canada, April 2007	On behalf of the Government of Canada, Environment Canada develops and publishes annually Canada's GHG inventory. The inventory reporting format is based on international reporting methods agreed to by the Parties to the UNFCCC, using the procedures of the Intergovernmental Panel on Climate Change (IPCC).
Alberta Offset System Offset Credit Project Guidance Document	Alberta Environment, February 2008	This Offset Credit Project Guidance Document is one of a series of guidance documents prepared for the Specified Gas Emitters Regulatory Framework. The purpose of this Guide is to outline the process and requirements for undertaking offset projects in Alberta.
A National Inventory of Greenhouse Gas (GHG), Criteria Air Contaminant (CAC) and Hydrogen Sulphide (H2S) Emissions by the Upstream Oil and Gas Industry	Clearstone Engineering Ltd. on behalf of the Canadian Association of Petroleum Producers (CAPP), September 2004	This document was used for emission factors to calculate GHG emissions from fuel combustion as well as the upstream emissions from extraction and production of those fuels.
Technical Resources		
Emissions and Efficiency Enhancement with REMVue® Air Fuel Ratio Systems	Petroleum Technology Alliance Canada (PTAC), 2005	Third party verification of the REMVue® Engine Management system conducted through PTAC to verify performance and qualify claims of lower fuel usage, emission savings and engine reliability. Includes field tests on 12 engines equipped with REMVue® systems.
Directive 060, Upstream Petroleum Industry Flaring, Incineration and Venting Guidelines	Energy and Resources Conservation Board (ERCB), 2005	ERCB directive providing regulatory requirements and guidelines for flaring, incineration and venting in Alberta from upstream petroleum industry operations and procedural information on permitting, modeling and measuring requirements.

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1. Document Title	2. Publishing Body / Date	3. Description
Fuel Gas Best Management Practices Module 7- Efficient Use of Fuel Gas in Engines	Canadian Association of Petroleum Producers (CAPP) and CETAC-West, May 2008.	Outlines best management practices related to reducing engine fuel consumption, proper measurement and monitoring practices, maintenance and other background on the types of engines used in Alberta. This document outlines the use of Brake Specific Fuel Consumption as a metric to determine an efficiency improvement in engine fuel use, which was used in the proposed protocol.
University of Alberta Flare Research Project. Final Report.	Kostiuk, Larry. Johnson, Matthew, and Thomas, Glen. University of Alberta. September 2004.	This document summarizes 8 years of research and field testing done in Alberta to assess the efficiency of various types of flares. This information was used in the development of a flexibility mechanism to quantify GHG emissions from flaring.
US EPA New Source Performance Standards CFR 40 Part 60.18.	US EPA, July 2006.	Guidance on flare destruction efficiency and relevant operating parameters that impact flare performance.
Combustion Efficiency of Flares.	Pohl, J. et al. Energy and Environmental Research Corp. Combustion Science and Technology. Volume 50, No 4-6. 1986.	Guidance on flare destruction efficiency and relevant operating parameters that impact flare performance.
US EPA Natural Gas Star Program Reports	US Environmental Protection Agency (EPA), 2005	Outlines methane emission reduction opportunities and lessons learned for small and mid sized natural gas producers including available and commonly implemented technologies and practices, steps to follow and example of projects. This includes reducing emissions from compressor rod packing, glycol dehydrators, etc.
Environmental Technology Verification (ETV) Program Data	US Environmental Protection Agency (EPA), 1999	This program provides high quality peer-reviewed data on technology performance, design, financing, etc. as a means to facilitate the development and acceptance of innovative / improved technologies through performance verification and dissemination of information. The data used in this document relates to verification of a rod packing static sealing device.
Methane to Markets	US Environmental Protection Agency (EPA), 2006	Details losses from different instrument types (i.e. rod packing, compressors, seals) including the economics, methane savings and carbon market value of methane emission reduction opportunities.

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1. Document Title	2. Publishing Body / Date	3. Description
Methods for Reducing Methane Emissions from Natural Gas Systems	US Environmental Protection Agency (EPA), 2005	Details the main sources of gas loss, and the technologies and practices available and commonly implemented to effectively reduce methane emissions.
Greenhouse Gas (GHG) Verification Guideline Series for Natural Gas Compressor Leak Mitigation Technologies	US Environmental Protection Agency (EPA), 1999	Guidelines for verifying GHG reductions from decreasing leaks from natural gas compressor rod packing and reducing leaks when compressors are in stanby mode.
Automated Air Fuel Ratio (AFR) Control Profact Sheet	US Environmental Protection Agency (EPA), Pollution Prevention, 2004	Outline of the technology and practice, operating requirements, potential for emissions reductions and economic analysis of AFR controls.
Upstream Oil and Gas Fact Finding Sheet on Fugitives	PTAC, 2006	Provides definitions for various vent and fugitive gas streams including industry terminology as defined for GHG monitoring and potential mitigation options.

B.3 Regulatory, Legal Requirements and/or Government Incentive/Grant Programs

Relevant Climate Change Regulations

In Alberta, the Specified Gas Emitters Regulation applies to facilities with GHG emissions of greater than 100,000 tonnes CO_2e per year, which are referred to as Large Final Emitters (LFEs). All facilities exceeding this threshold are required to reduce GHG emissions by 12% on an intensity basis beginning July 1, 2007. Because of these requirements, any facilities classified as LFEs are not eligible for offset generation as any emission reduction activity that occurs within the boundary of an LFE site will be subject to the SGER.

In April 2007, the Federal Government released the Regulatory Framework for Air Emissions, which outlined the broad design for regulations of industrial emissions of air pollutants and greenhouse gases. In March 2008, the Federal Government then provided further details on the proposed regulation of GHGs through the “Turning the Corner” document titled “Regulatory Framework for Industrial Greenhouse Gas Emissions.” This framework provided more detailed sector specific regulations for large emitting facilities and included mention of the planned use of a sector-wide approach that would require an 18% reduction threshold from the given facility’s 2006 intensity level for facilities in the oil and gas industry producing more than 10,000 barrels of oil per year or emitting more than 3000 tCO2e/year, starting in 2010. Any emission reductions achieved within the boundary of a regulated site/entity would not be expected to be eligible for offsets under the federal offset system for the same reasons as under the Alberta SGER. It is expected

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that some level of harmonization will be needed in 2010 between the federal and provincial regulations.

Other potentially relevant regulations / requirements

Upstream oil and gas facilities must comply with the requirements of Alberta's ERCB Directive 060 for Upstream Petroleum Industry Flaring, Incineration and Venting. This directive provides regulatory requirements for and procedural information for measuring and reporting flared, incinerated and vented gas.

Effective January 31, 2007 this Directive (previously Guide 60) was amended to require producers to conduct an economic evaluation and potentially implement solution gas conservation. Under this directive facility operators are required to reduce flaring of solution gas and implement conservation activities if vented / flared volumes exceed 900 m^3 per day. Flaring is limited to 640,000 e^3m^3 per year. Facility operators must also ensure that vent gases meet certain benzene and H_2S emissions requirements. A program to detect / repair leaks that meets CAPP Best Practice Guidance on Fugitive Emissions Management is also required.

ERCB Directive 060 also states that the facility operator must recover any fugitive or vent gases (that are not designed in) for which it is economic to do so. As such, all volumes must be combusted if volumes and flow rates are high enough to enable stable combustion. As part of this directive large producers are required to help smaller producers for which the financial burden of recovery is greater.

Vent gases from sources with no facilities or mechanisms installed to recover gases economically must report volumes vented to the ERCB. Vent gases that are not reported include those that are designed in, meaning those used to power pneumatic instruments or pumps which are then vented. Generally, unreported vent gases occur at independent oil and gas well sites or small facilities, and are emitted from chemical injection pumps, instruments and controls at volumes of less than 1-20 m^3 per day.

As indicated above, the ERCB does not specify any specific GHG related regulatory requirements for venting of gases designed into equipment apart from those for benzene and H_2S. As such, the equipment vent gases considered in this protocol are not regulated or required for compliance to GHG related regulations. However, other vent gas streams may be regulated under Directive 060. These streams would not be eligible for offset generation under this protocol.

To ensure that GHG emission reductions are surplus to regulatory requirements, the protocol specifies that the project developer must ensure that there are no regulations requiring the capture and destruction of vent gas emissions from the processes and/or units impacted by the project activity that have been quantified in the baseline as vented GHG emissions.

Current provincial NO_x regulations have led to the industry practice of operating engines at certain excess air to fuel ratios as a means to ensure NO_x emissions meet regulations. At Alberta's current level of regulations, this means operation at almost optimal fuel efficiency, however if regulations were more stringent (i.e. in BC), engines may be required to operate at lower efficiencies to meet NO_x emissions standards, resulting in an increase in CO_2 emissions. As such, as long as the engine management system implemented at a given project site is operating under lean burn conditions (as the system is designed to do) it should meet NO_x standards. Note that best fuel efficiency is achieved at a lambda (see figure below[2]) of 1.26 to 1.4, so there would be no reason to operate the engine at a higher air to fuel ratio unless NO_x standards become more stringent.

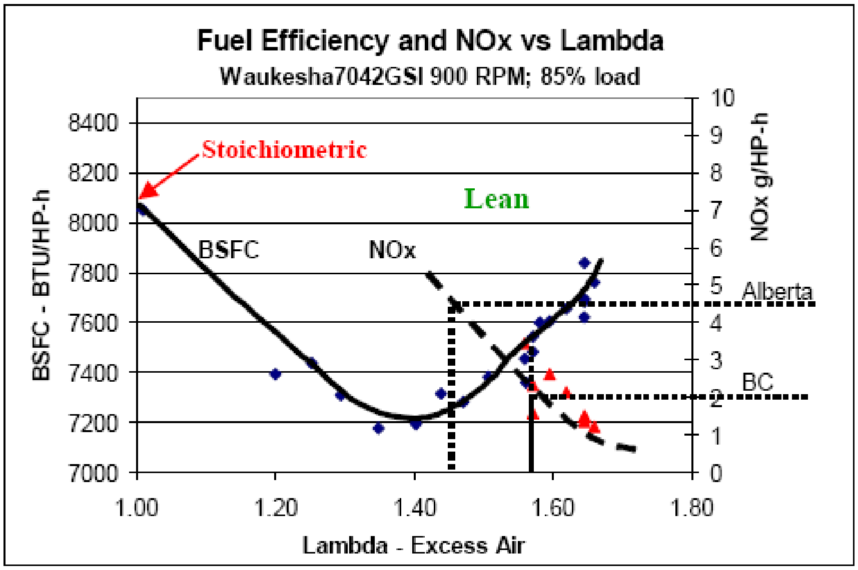

Figure obtained from REM Technology Inc. (2007). *REMVue® Energy Optimization and Slipstream™*.

No applicable provincial or federal regulations require the implementation of energy efficiency measures to reduce engine fuel consumption from natural gas combustion engines. No foreseen future GHG related regulations that would affect the eligibility of offset credits from the project activity are anticipated.

Based on these requirements, the only regulations that may impact some projects are the SGER, which would only impact large emitters, and ERCB Directive 060, which requires that certain vent gas streams be conserved or captured and combusted. It is the responsibility of the project developer to ensure that vent gas streams are surplus to regulatory requirements. Provided that the project proponent has assessed these regulations, there do not appear to be any other regulations that would require the capture of vent gases or specify a required level of engine fuel efficiency. Therefore it is expected that these project activities would be being surplus to legal requirements provided that due diligence has been done to ensure that SGER and Directive 60 requirements are not applicable.

[2] REM Technology Inc. (2007). *REMVue Energy Optimization and Slipstream*. Retrieved June 19 , 2008 from http://www.methanetomarkets.org/events/2006/oil-gas/docs/15jan07 remvue_energy_optimization_and_slipstream.pdf

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Potentially relevant climate change incentives

At the time of writing, there were no known climate change incentives for the implementation of engine fuel management systems on natural gas combustion engines or vent gas capture systems at natural gas extraction, processing and transmission facilities.

B.4 Barriers to Implementation

There are a variety of barriers that may impact the implementation of engine fuel management and / or the implementation of vent gas capture systems. These may include economic barriers, infrastructure barriers, supply and demand constraints, institutional barriers and technological barriers.

In terms of economic barriers affecting the implementation of this type of GHG emission reduction project, it may be argued that the oil and gas industry has the tendency to favour short term economic performance and growth over long term gains and sustainability[3]. As such, the capital and time required for investment in energy efficiency projects may be easily diverted to meet increased demands for production and growth. The personnel required for implementation of energy efficiency projects may also be diverted to meet these demands. This is especially true for smaller companies, which may have less access to the capital and time required to invest in energy efficiency projects and who are highly dependent on share prices and oil/gas prices.

Another barrier to investment may be a lack of understanding of the potential benefits of implementing engine fuel management / vent gas capture systems given that accurate and reliable measurement of engine fuel consumption is not common industry practice and improved monitoring may not be economically feasible. Given that vent gas streams are not accurately measured and sites often do not pay for on-site fuel usage, it may be difficult for potential project developers to quantity the losses being realized from equipment venting. Further, potential project developers may not recognize the potential for the use of intermittent vent gas emission sources as fuel that can be achieved using a technology such as the REM Slipstream™ system.

Since the energy lost in vent gas streams may not be assigned an economic value in company accounting, its significance and magnitude may not be recognized. In order to decrease market barriers, potential project proponents should realize the potential to reduce fuel usage and the emissions associated with vent gas streams and target appropriate solutions.

Generally, the economic burdens associated with performing the necessary measurements to quantify a change in engine fuel consumption from the baseline to the project condition (discussed in Section 7 and Appendices A and B) and going through the

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[3] PTAC. (2005). *Emissions and Efficiency Enhancements with REMVue® AFR Systems*. Prepared by Accurata Inc.

verification process are not anticipated to be an issue given the potential GHG benefits associated with the activity. The more challenging barrier to overcome would be the current industry operating practices, which do not normally rely on direct measurement of fuel consumption and tracking of engine operating parameters (engine loads and speeds).

B.5 Review of Technology / Scientific Knowledge

As discussed, this technical protocol plan is applicable to the implementation of engine fuel management and vent gas capture systems. Current scientific knowledge and technologies relating to these systems were reviewed and summarized below.

Description/Definition of GHG Emission Reductions

Two GHG emission reduction activities are discussed in this TPP, namely the direct emission reductions from reduced fossil fuel consumption due to the installation of engine management systems on natural gas combustion engines and the avoidance of vent gas emissions to the atmosphere through the installation of a vent gas capture system.

The applicable practices producing GHG emission reductions are the implementation of engine management systems that control the air-fuel ratio to improve fuel use efficiency and from the implementation of vent gas capture systems that prevent the venting of greenhouse gases to the atmosphere. The installation of an air-fuel ratio controller could occur independently of the installation of a vent gas capture system, but the installation of a vent gas capture system would likely occur in tandem with the installation of an engine management system due to the high level of control required to utilize the variable flows and compositions of vent gas streams. Typically the vent gas capture system would be designed to collect vent gases from multiple point sources and route the combined stream to a single engine for use as fuel. These process changes may be designed as retrofits to existing equipment or directly installed on new equipment and may impact engine fuel consumption and the vented gas emissions associated with the operation of the engine and other nearby facility equipment.

The most likely configuration to improve engine fuel efficiency would involve the implementation of a new engine control system to establish a lean burn combustion condition within an Original Equipment Manufacturer (OEM) rich burn design as discussed in the following section. It would be possible to install a new air-fuel ratio controller on a lean-burn or stoichiometric engine, but the fuel savings might not be as significant. However, it should be noted that a vent gas capture system could be installed on any engine to decrease GHG emissions provided that the engine is equipped with a suitable engine control system to handle the potentially variable flow rate and energy content of the 'waste' fuel.

GHG Reductions from Engine Fuel Efficiency Improvement

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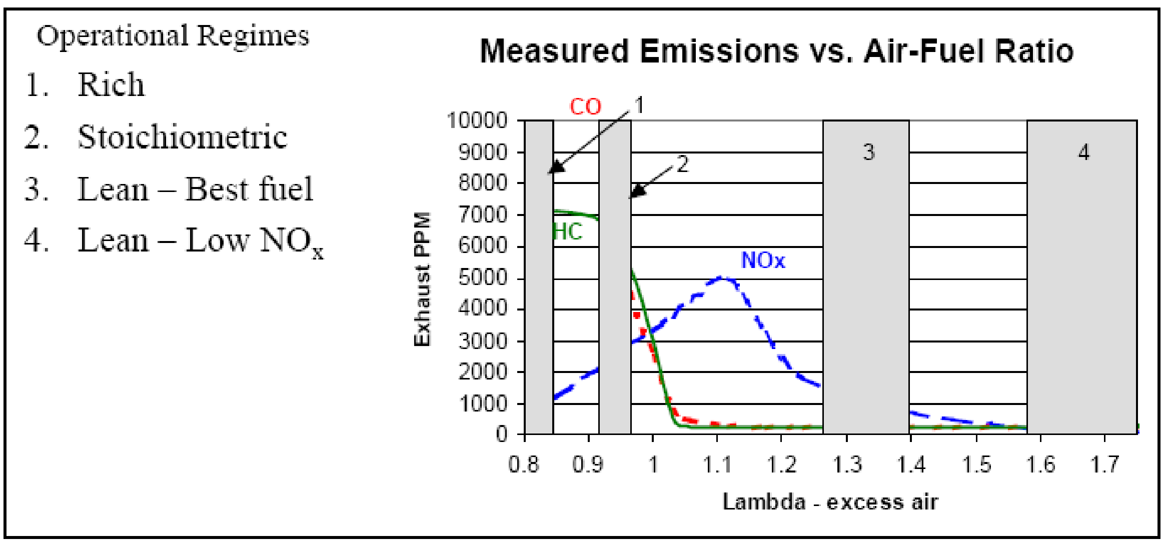
Air Fuel Ratio

The air-fuel ratio for an internal combustion engine refers to the ratio of air to fuel that is fed into the combustion chamber. When the air to fuel ratio is exactly in line with the combustion reaction chemistry (the stoichiometry of the reaction), the air-fuel ratio is called "Stoichiometric." This means that the chemically correct number of moles of oxygen (in air) are fed into the combustion chamber to ensure complete combustion of the fuel.

In cases where excess air is fed to a combustion chamber, the ratio is termed "lean" and when excess fuel is added the ratio is termed "rich." Typically engines operating under lean-burn conditions have better fuel economy, while engines operating under rich-burn conditions have more power and are easier to operate, but conversely have lower fuel efficiency. The choice of operating at rich, lean or stoichiometric air-fuel ratios depends on the relative importance of operational reliability, air pollutant emission limits (eg NO_x and CO) and fuel efficiency. At many sites the operational reliability aspect has favoured rich burn engines. The figure below provides a graphical representation of carbon monoxide, hydrocarbon and nitrogen oxide emissions as a function of the air fuel ratio under the range of operational regimes[4].



The above figure was obtained from: REM Technology Inc. (2007). *REMVue Energy Optimization and Slipstream.*

Lean Burn Characteristics

Lean burn engines use an air to fuel ratio of approximately 30:1, which results in a large excess of oxygen to ensure complete combustion of the fuel. Under lean burn conditions, the best fuel economy is achieved due to more complete combustion, emissions of NO_x are moderate to low, and emissions of CO_2 and CO are low. However, a very lean air-fuel ratio makes lean burn engines more difficult to start and more expensive to maintain.

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[4] REM Technology Inc. (2007). *REMVue® Energy Optimization and Slipstream*. Retrieved June 19 , 2008 from http://www.methanetomarkets.org/events/2006/oil-gas/docs/15jan07-remvue_energy_optimization_and_slipstream.pdf

Rich Burn Characteristics

Under rich burn combustion, fuel is wasted due to inefficient combustion, emissions of NO_x are low and emissions of CO_2 and CO are high compared with emissions under lean burn conditions. A commonly practiced alternative to lean burn engines is to equip a rich burn engine with a catalytic converter[5]. A catalytic converter is often installed on rich burn or stoichiometric engines to meet regulatory air emission requirements. The catalytic converter will reduce exhaust emissions but will not result in any fuel gas savings. The addition of a catalytic converter also reduces fuel efficiency and results in increased operation and maintenance burdens. "Maintenance of the catalyst elements include burn-in or service life milestone replacement, disposal of the heavy metal accumulations on the catalyst as a result of cleaning the medium, exhaust stream sensor replacements, regular monitoring, working at heights to man-handle catalyst elements, and other tasks to calibrate or maintain the engine management systems[6]."

Engine Management Systems

An engine management system is a broad term used to describe a process control system used to control the air flow and fuel flow into an engine to better manage the power demands placed on the engine and improve operation. An engine management system will benefit any engine by enabling the engine operator to change the engine's setting from best power to best fuel while still maintaining stable operation[7]. This adaptive control and stability results in typical fuel savings of approximately 3 to 5%. "Engine management systems are usually associated with air-fuel ratio controllers for rich burn applications using catalytic converters or those supplied by the engine manufacturer for (large) engines with sophisticated engine control requirements"[8].

One type of engine management system that would qualify under this project type is the REMVue® engine management system, of which there are currently over 150 units successfully operating in North America[9]. Other similar engine management systems may also be appropriate provided that the measurement and monitoring approaches used are consistent with those outlined in Section 13.

REMVue® Engine Management System[10]

The REMVue® engine management system provides an alternative to using either a catalytic converter with a rich burn engine or purchasing a lean burn engine, while achieving the fuel economy and emissions of a lean burn engine. It is designed to provide engine stability at lean burn settings. In contrast, according to the Petroleum Technology Alliance Canada (PTAC) study many other engine management systems control the engine at rich settings but these may not provide adequate control at lean settings.

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[5] PTAC. (2005). *Emissions and Efficiency Enhancements with REM AFR Systems*. Prepared by Accurata
[6] ibid
[7] ibid
[8] ibid
[9] PTAC. (2005). *Emissions and Efficiency Enhancements with REM AFR Systems*. Prepared by Accurata
[10] PTAC. (2005). *Emissions and Efficiency Enhancements with REM AFR Systems*. Prepared by Accurata

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The REMVue® system is designed to replace the original equipment manufacturer's (OEM) mechanical air - fuel ratio control system. Essentially it controls engine emissions by establishing a lean burn combustion condition within a rich burn OEM engine design. This is accomplished by optimizing air flow and the fuel gas mass flow fuel meter to control the air-fuel ratio. The system automatically controls the air pressure and fuel gas flow and adjusts the engine's operating characteristics to account for changes in load conditions.

The engines expected to benefit the most from a fuel efficiency and emissions standpoint are the Waukasha rich burn VHP and VGF series, while White Superior engines show improved starting and reliability. The PTAC study found that the REMVue® system should benefit any engine without a suitable engine management system under rich burn, learn burn or stoichiometric combustion conditions. The degree of fuel savings will depend on the engine model and initial air fuel ratio set point as well as site specific conditions.

Components of the engine management system may include the following:

- An automated computing storage system and the mechanical equipment required to link the computer's software package for system operation. This system monitors inputs using a real-time operating system which provides control, monitoring, communications, and calculation functions. There is also a diagnostic option that allows the calculated power, flow, rod load and abnormal cylinder impacts to be displayed and compared with expected values.
- A mass flow fuel gas meter, which replaces the OEM air fuel ratio controller. This meter adjusts the air fuel ratio for changes in fuel gas heating values, engine speeds, loads and temperatures.

According to the PTAC study the REMVue® system will not affect engine power. Changes to engine operation associated with installation of the REMVue® system may include[11]:

- A 10 to 15% increase in peak firing pressure, which may reduce the spark plug life by approximately 10 to 15%;
- Increased cooling required due to increased air volumes, which may require upgrading of the engine's inter-cooler system. Cooling is important as it reduces engine combustion temperatures which means reduced NOx emissions;
- Reduction or no change in servicing frequency; and
- Removal of the catalytic converter (if applicable).

Other conditions affecting the performance of the REMVue® system include the age or hours of operation of the engine at the time of installation, the type of ignition system (i.e. first generation or modern), the composition and quality of fuel gas into the engine, the type of air and oil bath air filtration systems, the exhaust system back pressure and the moisture content and pressure of air input into the engine. Each of these components will

[11] PTAC. (2005). *Emissions and Efficiency Enhancements with REM AFR Systems*. Prepared by Accurata Inc

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influence the fuel consumption and savings achieved and the engine's stability / reliability. The large number of factors that affect engine fuel consumption necessitate the development of quantification procedures based on measurement rather than default factors until such a time as a large data pool exists and from which conservative fuel savings results can be estimated.

Third Party Validation of REMVue Engine Management System

A third party study was conducted by Accurata on behalf of PTAC to qualify claims that "the REMVue® Engine Management system will lower fuel consumption, reduce emission levels and improve engine reliability through reduced exhaust temperatures. BP Canada Energy Company provided the test sites consisting of Waukesha and White Superior engines of various sizes and PetroCanada Oil and Gas provided one site with three similar Waukesha engines. Testing commenced at the BP facilities in October, 2004 and the PetroCanada facility in December, 2004"[12]. Results are presented in Section 5.

GHG Reductions from Vent Gas Capture

Vent Gases

Vent Gases are those gases that are designed to be released to the atmosphere (vented) to allow for safe operation of equipment. The term fugitive emissions is often used interchangeably with vent gases, however for the purpose of this report and the accompanying protocol the term vent gas is used to better reflect the intent of a vent design to emit gases. Fugitive emissions on the other hand include unintentional emissions that may be more difficult to capture and quantify. Many vent gas streams are small and intermittent emission sources and individually have limited value to warrant capture. Collectively, vent gases and fugitive emissions make up a large source of GHG emissions in Alberta at 37.1 Mt CO_{2E} in 2005.

The primary vent gases considered in this project activity consist of compressor rod-packing gas and instrument gas, that are similar in composition to natural gas. Additional sources of vent gases may include gases vented from flash tanks and glycol dehydrator re-boilers, which may have somewhat different compositions from natural gas. All of these gases are vented to the atmosphere, typically during natural gas extraction, processing and transmission activities.

Vent Gas Capture

The scope of this report is limited to the installation of vent gas capture systems to capture vent gases whose collection is not regulated under ERCB directive 060, except in project configurations discussed in Section 14 under Flexibility Mechanisms.

In a vent gas capture system low pressure vent gases that would have otherwise been released to the atmosphere are captured and combusted. While there may be a variety of methods of capturing and destructing vent gases this report focuses on the REM Slipstream™ system. With the Slipstream™ system there is no need for recompression of vent gases or the use of a vapour recovery unit.

[12] ibid

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The Slipstream™ system may be integrated into either existing or new equipment. Once installed it monitors and controls the addition of vent gases to the engine to supplement the normal fuel supply. In this way, the system decreases GHG emissions by destructing the methane contained in the vent gas stream and thereby preventing the release of a greenhouse gas 21 times as potent as CO_2. Additionally the displacement of the conventional fuel supply with a waste gas stream also further reduces GHG emissions. The system also displays and records the mass flow rate and energy content of gas captured and combusted in real time, which allows for calculation of the associated reduction in GHG emissions from the avoided venting of methane emissions and from reduced fossil fuel usage.

Third Party Validation of REM Slipstream™ System

An industry study of the REM Slipstream™ technology was conducted by Accurata and Clearstone Engineering on behalf of PTAC. This study conducted a review of the technology and its implementation, reviewed a pilot project that was conducted, and carried out field tests over a range of operational characteristics and variable vent flow rates.

Results from the validation indicated that the Slipstream™ system adjusted smoothly to variations in vent flow rates, and engine loads and speeds. The GHG reduction potential of the unit was found to be 34% at high engine speeds and 55% at low speeds. To further support this claim, samples were collected and GHG emission reduction claims were verified by the Alberta Research Council (ARC). The PTAC study also confirmed that the system's safety and control functions performed as expected.

For part of the third-party study, Petro-Canada provided an LDAR infrared camera to detect the instrument gas that was being vented to atmosphere. This technology was intended to qualify whether the SlipStream™ system was effectively capturing all of the vented emissions for fuel or if some was allowed to escape from the vent. "Both two-inch vent lines on the units were verified with the LDAR camera as well as an LEL monitor. The LDAR unit showed that all vented instrument gas was being captured by the SlipStream™ system at the booster station.

Scope of activity

The validation of the REMVue® engine management system technology completed by Accurata on behalf of PTAC, focused on the fuel savings from the retrofit of rich-burn natural gas combustion engines, specifically Waukesha and White Superior engines, but the quantification approach was generic to allow for the measurement of the change in fuel consumption for any type of natural gas combustion engine across a range of operating conditions. Therefore the scope does not exclude engines with lean burn or stoichiometric configurations and is not specific to a particular make or model of engine provided that the measurement and monitoring approach outlined in this document and the accompanying protocol is followed. It is recognized that each individual engine will vary in terms of fuel consumption and therefore the most accurate approach is to provide

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a generic method for GHG quantification based on direct measurement for any project installation to follow.

At a later time, when sufficient data has been collected from several project sites, it is expected that a more generalized GHG quantification approach can be used with sufficient accuracy and conservativeness based on the average fraction of fuel saved from the installation of an air-fuel ratio controller on a specific make and model of engine. This approach is discussed under Section B.13 Flexibility Mechanisms.

The scope of the vent gas capture component is intended to be sufficiently broad to cover vent gases that are similar in composition to natural gas as well as other vent gases or process emissions with variable compositions. In many cases the vent gases will be captured from natural gas processing and transmission systems and the composition will be similar to the natural gas normally used as fuel for the engine. For these installations that capture instrument gas or compressor rod packing gas, the default Environment Canada emission factors for combustion of natural gas (or producer consumption) would be applicable.

The opportunity to capture a variety of vent gases exists when utilizing a control system, such as REM Technology Inc.'s Slipstream™, that can adjust the fuel flows as necessary to ensure a consistent fuel energy content entering the engine. The quantification approach is generic to account for the variable composition of other vent gases such as emissions from flash tanks and dehydrator re-boilers. The REM Slipstream™ technology measures the mass flow rate of all captured gases and when combined with routine gas analysis to determine composition and density, the flow rate can be converted into an equivalent quantity of displaced fuel gas. The avoided methane emissions would be determined through the mass flow measurements continuously taken at the input of the captured gas stream into the engine and composition measurements taken on a regular basis to determine the average percentage of methane in the vent gas stream. The quantification approach is flexible to allow for the capture of any vent gas stream provided that the quantity and composition measurements are made. Additionally, a flexibility condition is described in Section B.13 to allow project developers to reduce the flaring of waste gas streams through the installation of an engine management system and a capture system to re-direct the waste gases to the engine.

B.6 Review of Existing Projects

As mentioned, there are over 150 REMVue® engine management systems operating in North America. The operating characteristics and emissions from projects operating under similar social, technological, economic and environmental conditions as discussed in the PTAC report provide a good example of the type and characteristics of potential projects in Alberta. This report examined sites operated by both BP and Petro Canada.

For BP, ten engines at six sites were retrofitted with REMVue® AFR systems. These included three White Superior and seven Waukesha engines. The White Superior engines were all operating with lean burn configurations prior to installation of the REMVue®

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system, but were not operating reliably. The REMVue® system was found to improve the engine's stability, but resulted in no change in emissions or fuel consumption. This was expected as the engine was already operating under lean combustion conditions. For the Waukesha engines, emissions and fuel usage data was not consistent or comparable because engine set points pre and post audit couldn't be matched.

At the Petro Canada site, located in Southern Alberta, three identical Waukesha engines were used for testing. Two of the engines were equipped with REMVue® engine management systems, and the other engine was tested as a control operating at the OEM rich burn configuration. Testing was conducted to develop a load map for the given engine type with the engine being fully loaded to test fuel consumption over the full range of speeds and loads. On average, air emissions were found to be reduced as follows: 87% reduction in CO emissions, a 26% reduction in CO_2 emissions attributed to the leaner air fuel ratio, and a 24% reduction in NO_x due to cooler combustion temperatures and the leaner air fuel ratio. Fuel consumption was decreased by an average of 20 kg per hour when using the REMVue system versus the control rich burn OEM engine. These values are based on engine operation under different air fuel ratios, speeds and loads, and represent actual field operating conditions and average emission reduction potentials for the REMVue engine management system.

A pilot project for field testing of the Slipstream™ vent gas capture system was conducted in the fall of 2007 as a joint initiative between RTI, Power Ignition Controls (PIC), CETAC-West and Alberta innovation and Science. A site operated by Petro Canada located northeast of Medicine Hat was selected as the test site. The slipstream unit was found to reduce GHG emissions to less than 60% of previous levels. There were no operational, safety or other issues associated with the unit[13].

B.7 Summary of Quantification Approaches

Research into various GHG offset systems did not turn up any existing GHG quantification protocols that covered the relevant project activities of engine fuel management and vent gas capture in any detail. However, the proposed protocol could draw on elements from the Alberta Offset System Quantification Protocol for Energy Efficiency Projects to determine emission reductions associated with reduced fossil fuel usage for a given level of production. While the AB Energy Efficiency protocol is directed mainly towards energy efficiency projects in the agriculture sector, some of its components may still be applied to the project activity in question.

In the Energy Efficiency protocol the opportunity for generating carbon offsets arises from the direct and indirect reductions of greenhouse gas (GHG) emissions resulting from the implementation of industrial, commercial and agricultural process changes and facility retrofits that result in overall efficiencies in energy use per unit of productivity.

[13] REM Technology Inc. (2007). *REMVue Energy Optimization and Slipstream*. Retrieved June 19 , 2008 from http://www.methanetomarkets.org/events/2006/oil-gas/docs/15jan07remvue_energy_optimization_and_slipstream.pdf

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Process changes may include the mechanical, biological and/or chemical components of the operation and may impact upon on-site heat, electrical and power requirements.

The baseline condition for the Energy Efficiency protocol is defined as the process configuration prior to the changes or facility retrofits. The baseline is projection based with energy and the associated direct and indirect emissions footprint, per unit of production, being established as part of an energy project assessment or similar method. The project condition is therefore defined as the process configuration following changes or facility retrofits.

The Engine Fuel Management and Vent Gas Capture Protocol follows the same general quantification approach for the engine fuel management and reduced fuel consumption component of the project activity. In this case the assessment of the project configuration prior to the modification is conducted by the project proponent through establishment of the brake specific fuel consumption curve of the unit. The BSFC curve is obtained from a set of measurements of engine fuel consumption at different engine speeds and loads, before and after the installation of the engine management system in order to determine the fractional change in fuel consumption between the project and baseline activity. Once the fractional change in fuel consumption has been established for at least three set points it is then possible to relate the actual monitored engine parameters (RPMs and loads) in the project condition to the fractional change in fuel consumption at the original set points using linear interpolation (for changes in RPM only) or a load normalization method discussed in Appendix C of the proposed protocol (for significant changes in laod). The monthly change in emission reductions from baseline to project are then calculated by multiplying the metered fuel consumption in the project condition times the fractional change in fuel consumption.

For projects that implement vent gas capture systems and combust the vent gases as supplemental fuel for operating the unit, emissions are determined from the measured quantity and heat value of vent gases captured and combusted in the project condition.

Identification of Sources and Sinks of GHG Emissions

In order to develop quantification approaches for the implementation of engine fuel management / vent gas capture systems, it was necessary to examine the different lifecycle emissions from natural gas combustion engines and surrounding upstream oil and gas facilities to identify all potential sources of GHG emissions from fossil fuel production through to combustion and facility operation. The identification of sources and sinks was completed using the best practice guidance documents listed in Table B.2 and by examining typical project configurations. This life cycle analysis was done following the ISO-14064-2 standard where the different sources and sinks (SS's) of GHG emissions were classified as upstream, on-site, downstream, controlled, related and affected. A brief summary of this analysis is presented in this section for context along with a typical process flow diagram incorporating the identified sources and sinks of emissions.

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For engine fuel management and vent gas capture these lifecycle SS's included upstream elements related to; fuel extraction, processing and transportation and electricity usage. No downstream operations were identified. On-site elements included those related to; facility operation, unit operation (engine operation), flaring of process emissions and venting of (methane) emissions captured in the project / capture of vent gases. Facility and unit operation and implementation of engine fuel management and / or vent gas capture systems would also require a variety of infrastructure at different stages of each component's respective lifecycles and the development (and later decommissioning) of this infrastructure would have some associated GHG emissions that are not directly tied to the upstream, downstream or on-site elements.

A process flow diagram was developed for the proposed protocol based on the life cycle analysis of the project activities and the review of the various best practice guidance documents and quantification approaches referenced in section B.2. Figure 1, below, summarizes the different SS's identified. The most material SS's recommended for quantification, as discussed in the following section are shaded in grey in Figure 1. The two dashed lines in Figure 1 represent the boundaries of the facility's operations.

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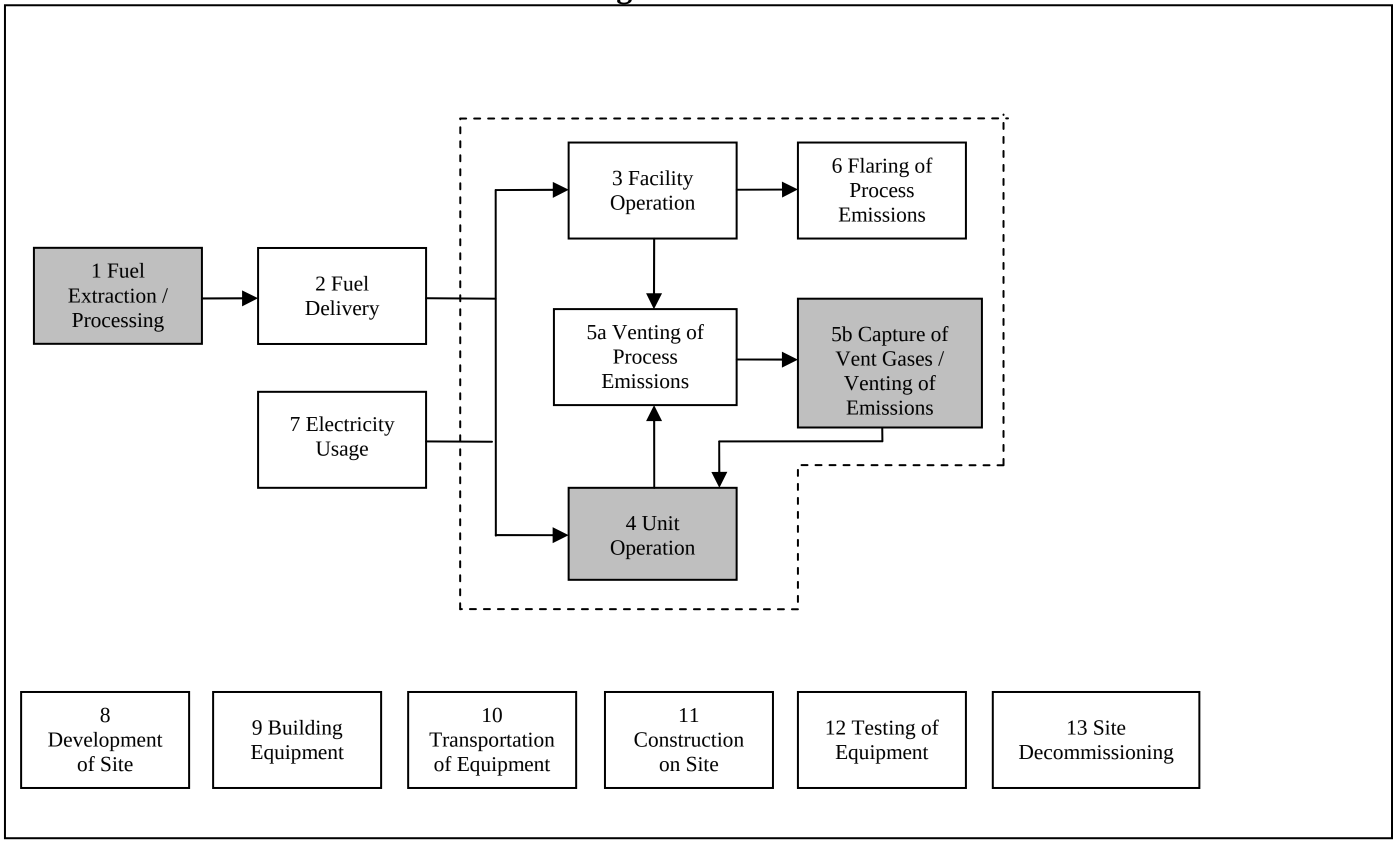
FIGURE 2: Recommended Process Flow Diagram



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Determination of Material Sources and Sinks of GHG Emissions

Following the lifecycle analysis that facilitated the identification of relevant sources and sinks of GHG emissions, a preliminary analysis of these SSs was performed to identify the most material sources of GHG emissions in the project and baseline conditions. These 'material' SSs were then the focal point for the development of quantification approaches. The evaluation of these SS's was completed based on a review of the best practice guidance documents discussed in Section B.2. These Technical Seed Documents (TSDs) formed the basis of the scientific consensus behind the quantification of GHG emissions from engine fuel management and vent gas capture.

Table B.3 summarizes the relevant TSDs that were used in the development of GHG quantification approaches:

TABLE B.3: Quantification Approaches

Technical Seed Document	**Scope of Methodology**	**Emission Sources Identified and Quantified**
Emissions and Efficiency Enhancement with REMVue® Air Fuel Ratio Systems	Third party verification of the REMVue® Engine Management system conducted through PTAC to verify performance and qualify claims of lower fuel usage, emission savings and engine reliability. Includes field tests on 12 engines equipped with REMVue® systems.	• Unit Operation (stationary combustion)
CETAC-WEST Fuel Gas Best Management Practices (2008)	Outlines practical guidance for facility operators to achieve efficient use of fuel gas in engine operation.	• Unit Operation (Stationary Combustion): Fuel consumption in Baseline versus Project due to Implementation of an Air-Fuel Ratio Controller
Canadian Association of Petroleum Producers (CAPP) Guide to Calculating GHG Emissions (2003)	Provides a standardized approach to estimating and benchmarking GHG emissions from a variety of oil and gas operations.	• Unit Operation (Stationary Combustion) • Venting Emissions
Canadian Association of Petroleum Producers (CAPP) Best Management Practice: Management of Fugitive Emissions at Upstream Oil and Gas Facilities (2005)	Provides guidance on the management of fugitive emissions at oil and gas facilities from leaks, including measurement and monitoring.	• Venting Emissions

Based on the above TSDs and technical guidance listed in Table B.2, it was determined that the primary sources of GHG emissions were related to process emissions from venting and unit operation at the facility (i.e. the engine), which included emissions from fossil fuel combustion. Other less material sources of GHG emissions included the upstream extraction and production of fossil fuels required for unit operation.

Development of a Quantification Approach

Based on the review of the above best practice guidance documents, it was deemed necessary to develop the quantification approach in the proposed protocol around two main parameters: the GHG emissions from operation of the engine and the emissions associated with the capture and combustion of vent gases that would have been released in the baseline condition.

The quantification of the first parameter requires the calculation of the fractional change in fuel consumption of the engine at a set of reference conditions using direct measurements of the un-modified engine and the modified engine. The fractional change in fuel consumption at those reference conditions are then corrected for the actual site operating conditions to determine the estimated change in fuel consumption at the new conditions based on RPM and load. This approach builds upon the Fuel Gas Best Management Practice guidance published by CETAC-WEST, which recommends the use of BSFC as a metric to determine fuel efficiency improvements in engines.

The data for this factor will be determined by developing a BSFC curve pre and post implementation of the engine fuel management system to determine the fractional change in fuel consumption at different engine speeds and loads. This data will then be used to derive a value for the incremental fuel consumption between the project and baseline. Metered fuel consumption for the project condition, the mass, density and heating value of fuel gas and supplemental fuel supplied by the vent gas capture system and the monthly average engine RPM and load will be required to calculate emissions. This data has to be audited by a third party each year and then later submitted to Alberta Environment for review, which ensures its accuracy and completeness.

The second parameter requires the determination of the mass of vent gas consumed in the engine as supplemental fuel, and various characteristics of the vent gas captured including density, heating value and the percentage of methane and other hydrocarbons. Measurement and monitoring requirements for this parameter were developed following Best Management Practice guidance on the Management of Fugitive Emissions at Upstream Oil and Gas Facilities published by Canadian Association of Petroleum Producers (CAPP).

Further quantification methods that enable project flexibility are discussed in section B.13.

B.8 Other Impacts (optional)

No other air emissions, odors, risks or environmental impacts are anticipated with the installation of an engine management system used to reduce the air fuel ratio and potentially to capture vent gases for use as an engine fuel.

In fact, as discussed in Section B.6 at the Petro Canada site three Waukesha engines were tested and on average air emissions were found to be reduced as follows: 87% reduction in CO emissions, a 26% reduction in CO_2 emissions attributed to the leaner air fuel ratio,

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and a 24% reduction in NO_x due to cooler combustion temperatures and the leaner air fuel ratio.

The project activity would contribute towards Alberta ERCB's resource conservation goals by productively using sources of vent gas. In addition, project developers may observe enhanced unit reliability, increased production, reduced fuel costs and longer operation and maintenance intervals[14]. Any units equipped with a catalytic converter prior to the project (or whose installation is avoided by the project activity) will likely benefit from reduced operation and maintenance issues and avoid the required disposal of the heavy metals that accumulate on the catalyst during catalyst cleaning processes, as a catalytic converter would no longer be required.

Further an engine management system would occupy very limited space and would not noticeably change the footprint of the facility housing the engine. There are no incremental impacts to the air, water or land anticipated due to the installation of an engine management system on a combustion engine. The vent gas capture system would occupy a very small footprint and be unnoticeable amongst other facility infrastructure.

As discussed, the REMVue® technology validation demonstrated significant reductions in carbon monoxide, total unburned hydrocarbons and nitrogen oxides, all air pollutants with associated health impacts. Further, fuel consumption would be reduced by the implementation of engine fuel management and could be even further reduced through the use of captured vent gases as supplemental fuel. The capture of vent gases would also decrease the quantity of hydrocarbons emitted to the air and represent a positive impact with respect to air pollution.

B.9 Assessment of Baseline Scenarios

An assessment of potential baseline scenarios was conducted based on the recommended methodology from best practice guidance in the Alberta Offset Credit Project Guidance Document. Potential baseline options were assessed based on their capacity to incorporate two aspects of the baseline: the GHG emissions from engine fuel consumption and the GHG emissions from venting GHG emissions at the site. Each baseline scenario also contemplated the selection of a static or dynamic approach. Table B.4 provides a summary of the baselines considered.

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[14] PTAC. (2005). *Emissions and Efficiency Enhancements with REM AFR Systems*. Prepared by Accurata Inc.

TABLE B.4 Assessment of Possible Baseline Scenarios

1. Baseline Options	2. Description	3. Static/ Dynamic	4. Accept or Reject and Justify
1.Historic Benchmark	A) Assessment of the baseline scenario based on site specific fossil fuel consumption data from the operation of the site for one or more years prior to installation of engine fuel management.	Static.	Reject. The use of site specific historic data would not provide a high level of accuracy given that engine fuel consumption will vary depending on operating conditions including hours of operation, RPM's and loads. Further, it is not common practice for project proponents to directly meter fuel consumption for each unit / engine and data may not be available.
	B) Assessment of baseline scenario based on site specific venting emissions, determined from historic data from the site for one or more years prior to installation of vent gas capture systems.	Static.	Reject. Venting emissions are difficult to meter and metering is not common industry practice. Further many vent gas streams are small and intermittent emission sources and individually have limited value to warrant metering in the baseline.
2.Performance Standard	A) Assessment of the typical GHG emissions from the fuel consumption of 'typical' engine of a given make and model.	Dynamic or Static	Reject. The operational characteristics of the engine will vary depending on make / model, air fuel ratio setting, load demands, age and other characteristics at the site thereby rendering extrapolation over a range of operating conditions potentially imprecise. Consultation with industry experts confirmed that no comprehensive data set exists in Alberta to properly characterize fuel consumption for given types of engines as the manufacturer's data represents ideal conditions in the laboratory and can differ by 30% from field conditions.
	B) Assessment of the baseline scenario based on the typical composition and quantity of gases vented from compressor rod-packing gas, instrument gas, etc. during natural gas extraction, processing and transmission activities.	Dynamic or Static.	Reject. Detailed data on the venting of gases from each source would need to be obtained. This data may not accurately represent site venting emissions. Further, depending on the site this approach may lead to a significant over or under estimation of venting emissions.
3.Comparison-based	A) Assessment of baseline GHG emissions from the unit / engine based on the performance and fuel consumption from a control group.	Dynamic	Reject. This method is analytically and data intensive, and there is significant variation in fuel consumption between individual engines and at different sites depending on a number of operating characteristics.

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1. Baseline Options	2. Description	3. Static/ Dynamic	4. Accept or Reject and Justify
	B) Assessment of baseline GHG emissions from venting based on the quantity and composition of gases vented from a control group representative of typical industry practice.	Dynamic.	Reject. This approach is not practical as it would be necessary to characterize average industry emissions from a wide variety of vent gas sources to represent the 'control' group. Generalizing venting emissions by defining control groups would be challenging given that venting can vary significantly between sites and depending on the equipment and operations at each site.
4. Projection-Based	A) Assessment of the baseline GHG emissions from engine operation using several set point measurements of the fuel consumption of both the pre-existing engine and the modified engine to estimate GHG emissions from fuel consumption in the baseline. The change in fuel consumption would be assessed for a set of specific (reference) operating conditions and then the compared to the actual monitored engine operating conditions (in the project condition) to determine the estimated baseline emissions at the new set of conditions.	Dynamic	Accept. This approach is applicable for determining GHG emissions from fuel consumption given that metered data is utilized from both the original un-modified engine and the modified engine. The change in fuel consumption due to the modification is then calculated at that set of reference conditions using the metered data. By tracking the actual operating conditions after the engine modification it is possible to correct the baseline fuel consumption at the reference points (load and RPM) to the new operating conditions (e.g. through load normalization methods, or linear interpolation between two RPMs). Further, unlike the other baseline options this approach uses site-specific data of unit fuel consumption at different RPM's and loads obtained from direct measurement.
	B) Assessment of baseline GHG emissions from venting using the metered quantity and composition of vent gas captured in the project condition to assess the quantity and composition of gases that would have been released in the baseline scenario.	Dynamic.	Accept. This approach is applicable for quantifying the GHG emissions from vent gas capture given that the quantity and composition of gases captured and combusted in the project condition can be used to estimate emissions in the baseline. Further, unlike the other baseline options this approach is based on direct measurement of the characteristics of vent gases that would have been emitted in the absence of the project.
5.Other	A) Other quantification that may be applicable to the site-specific circumstances that can be justified with reasonable assurance.	Static or Dynamic.	Reject. Not Applicable. Project Specific.

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B.10 Selection of Baseline Scenario

The development of quantification approaches for the implementation of engine fuel management and / or vent gas capture systems required the examination of a variety of baseline scenarios as described in Section B.9. The main criteria used to evaluate each scenario included data availability, environmental integrity, accuracy, consistency with Alberta project configurations and ease of application (e.g. through monitoring requirements).

The business as usual case (i.e. the baseline condition) for this protocol is defined as the fuel consumption of the unit under its original configuration prior to the installation of the new engine management system and/or the venting of process emissions to the atmosphere. The recommended baseline option for the proposed protocol is the projection based approach for both the baseline avoided emissions from reduced engine fuel consumption and reduced venting.

Under this scenario the baseline is site specific and depends on the operating characteristics and performance of the particular unit(s) and the type of engine management system being installed. The baseline fuel consumption would be established relative to a specific engine make, model, air/fuel ratio setting and the load demands of the project site. The industry standard is to present this information as a ratio of the fuel energy flow rate into the engine to the brake power output of the engine, called the Brake Specific Fuel Consumption (BSFC). The BSFC is obtained through measurement of the unit before and after the installation of an engine management system in order to provide a snapshot of the change in fuel consumption from the baseline to the project condition.

In order to quantify the baseline GHG emissions, the project proponent will be responsible for measuring the brake specific fuel consumption of the unit operating at the original baseline air-fuel ratio at three different set points (RPM and loads) before the engine fuel management system is installed in the project activity. The BSFC is then measured at the same three set points after the installation of the engine management system to determine the fractional change in fuel consumption between the baseline and project activity. The fractional change in fuel consumption represents the BSFC of the unit at its original configuration minus the BSFC of the modified unit all divided by the BSFC of the modified unit, with all BSFC values measured at the same RPM.

Once the fractional change in fuel consumption has been established for three set points it is then possible to estimate the baseline fuel consumption at a new set of operating conditions (i.e. the actual monitored engine RPMs and loads in the project condition). The fractional change in fuel consumption at the new set points can be estimated using linear interpolation for changes in RPM (if load does not change more than 5%) or using a load normalization method described in Appendix C of the proposed protocol.

This approach utilizes metered fuel consumption data per unit of brake power output (BSFC) to establish the fractional improvement in fuel consumption based on different

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engine operating parameters (e.g. load and RPMs) and allows the project proponent to track what the baseline fuel consumption would have been had the new engine control system not been implemented. This will ensure that the impacts of variable loads, engine speeds, maintenance practices and other engine or site specific conditions are captured to provide an accurate representation of the baseline fuel consumption for each installation.

For projects that implement vent gas capture systems and combust the vent gases as supplemental fuel for operating the unit, the baseline emissions are determined from the measured quantity, composition and heating value of vent gases captured and combusted in the project condition.

The recommended baseline scenario for the proposed protocol is dynamic as the emissions profile for the baseline activities would be expected to change materially relative to the defined unit and may fluctuate due to supply and demand dynamics, as well as other market conditions.

B.11 Definition of the Project Condition

The proposed protocol is applicable to projects that involve the implementation of engine fuel management and / or vent gas capture systems to decrease the quantity of fuel required to operate a natural gas combustion engine and reduce vent gas emissions. The project activity thereby reduces GHG emissions associated with operation of the engine and venting at the project site.

To demonstrate that a project is covered by the scope of the proposed protocol, the project proponent must show that certain activities (e.g. the implementation of engine fuel management / vent gas capture) have resulted in reduced fuel consumption and venting emissions as compared to the baseline condition. This evidence will provide the project proponent with the mechanisms to demonstrate the incremental GHG benefit of implementing engine fuel management and / or vent gas capture systems at the site. In particular the project developer must meet the following requirements:

Brake Specific Fuel Consumption: The determination of brake specific fuel consumption and fractional change in fuel consumption for the quantification of the baseline engine fuel consumption should be completed according to the guidelines discussed in Appendix C of the proposed protocol.

Unit Functionality: The engine modification must not impair the functionality of the unit, process or overall facility such that additional energy inputs are required as demonstrated by facility process flow diagrams and/or unit operational performance data. Unit operational data may include engine operating hours, records of down time or other records to demonstrate that the engine fuel management system and/or the combustion of captured vent gases does not de-rate the engine or cause a significant increase in down time (and potentially increase compressor start gas emissions). The project proponent would need to show that the use of other units (engines) and/or supplemental fuels is not needed to compensate for increased parasitic loads, reduced fuel energy content and/or

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decreased engine power output. Functional equivalence may be demonstrated through an affirmation from the project developer or other qualified third party.

Regulatory Requirements: There are no regulations requiring the capture and destruction of vent gas emissions from the processes and/or units impacted by the project activity that have been quantified in the baseline as vented GHG emissions under SS B5b Venting of Emissions Captured in the Project. Further, the boundary of the project activity must not include the quantification of baseline GHG emissions from engine fuel combustion and vent gas emissions that are subject to regulation under the Alberta Specified Gas Emitter Regulation.

Flaring of Waste Gas in the Baseline: In cases where the baseline practice was the flaring or incineration of a waste gas stream that is now re-directed and used as supplemental engine fuel in the project activity, the project proponent may only claim GHG reductions due to fuel savings (either from reduced fuel usage to supplement the flare or displacement of the primary engine fuel source with a waste gas stream) based on the quantification procedures for the Flexibility Mechanism in Appendix A of the proposed protocol. The project proponent must demonstrate that the re-direction of the waste gases to the engine actually results in reduced flare fuel usage as evidenced by metered volumes of waste gas sent to flare/incinerator and/or volumes of supplemental fuel consumed or through engineering designs for the flare/incinerator unit.

B.12 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 fuel consumption per unit of production) for comparison between the project and baseline activities. In this protocol the common units of measurement are the specific engine RPM's and horsepower, used to determine fuel consumption of the unit between the project and baseline, and the volume of vent gases captured and combusted in the project versus baseline conditions.

In order for unit operation following the installation of engine fuel management and / or vent gas capture systems to be functionally equivalent to unit operation prior to installation the unit must provide the same function in both cases. Functional equivalence is achieved if the engine modification does not impair the functionality of the unit, process or overall facility such that additional energy inputs are required as demonstrated by facility process flow diagrams and/or unit operational performance data.

As such the project proponent would need to show that the use of other units (engines) and/or supplemental fuels is not needed to compensate for increased parasitic loads, reduced fuel energy content and/or decreased engine power output resulting from the project activity. Functional equivalence may be demonstrated through an affirmation from the project developer or other qualified third party. Additionally, the use of direct measurements of fuel consumption of the un-modified engine and the modified engine operating at the same set points (RPMs and loads) ensures that functional equivalence is maintained.

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As such, the relevant sources and sinks in both the project and baseline are for fuel extraction and processing, unit operation and capture of vent gases (or baseline venting of the emissions captured in the project condition). In particular, the volumes of fossil fuels consumed for unit operation and the heating value and composition of vent gases captured and combusted are compared.

Emission sources and sinks related to facility operation, venting and flaring of process emissions and site commissioning / decommissioning were excluded from quantification on the basis of functional equivalence between the project and baseline. Functional equivalence was established based on a comparison of the volumes of fuel consumed and the quantity / composition of gas flared or vented.

Emission reductions achieved from capture of vent gases will likely be of the highest magnitude in projects that implement this component of the system, followed by savings from reduced fuel consumption.

B.13 Flexibility Mechanisms

The inclusion of flexibility mechanisms is recommended in the proposed protocol to allow project proponents to address project specific issues that may require contingent methods of data collection or alternative quantification approaches. The project proponent will have to justify their application of any flexibility mechanisms within the proposed protocol such that the quantification approaches and data quality meet the minimum standards specified in the proposed protocol. The following flexibility mechanisms are recommended:

Change in the quantity of process emissions flared: In project configurations where there is a change in the quantity of process emissions flared as a result of the project activity the project proponent may use the proposed protocol's flexibility mechanism to quantify associated GHG emissions. This situation could occur when the baseline practice was the flaring of waste gas streams and the project condition involves re-directing the waste gas stream for use as supplemental fuel to reduce the fuel requirements for operating the flare. Alternatively, the project condition could also involve an increase in flaring whereby some gas streams previously vented to atmosphere are re-directed to flare in the project condition;

Brake Specific Fuel Consumption pre and post installation not measurable: For project scenarios where it is not possible to measure the brake specific fuel consumption before and after the installation of a new engine management system the project proponent may use fractional fuel savings data from other engines of the same make and classification. The project proponent should apply the protocol flexibility mechanism under the SS "B4 Unit Operation" in the proposed protocol to ensure that the estimation of the baseline fuel consumption is overly conservative across the full spectrum of engine speeds and loads. The use of this approach is contingent on there being sufficient data from at least 5 similar engines of the same make and classification operating with the same type of engine management system. For further details, refer to Appendix A of the proposed protocol.

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Multiple Installations: Engine fuel management systems and vent gas capture systems can be installed on a single engine or on multiple units at multiple sites. As such, the proposed protocol allows for flexibility in quantifying offsets from multiple installations; and

Site Specific Emission Factors: Site specific emission factors may be substituted for the generic emission factors indicated in the accompanying protocol document. The methodology for generation of these emission factors must be sufficiently robust to ensure accuracy.

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