

B.C. Oil & Gas Methane Emissions Research Collaborative

2019 – 2021 Research Plan

Introduction

Methane – the main constituent of natural gas – has a 25 times greater global warming potential than carbon dioxide over a 100-year period. The oil and gas industry is estimated to be approximately 17 percent of total B.C. emissions in the provincial greenhouse gas inventory¹ and is a large source of B.C. methane emissions.

The provincial and federal governments have goals for reducing methane emissions from upstream oil and gas operations. The Government of B.C. has a reduction goal of 45 per cent by 2025, relative to 2014 levels, while the Government of Canada has set a reduction target of 40-45 per cent by 2025, relative to 2012 levels.

The B.C. Oil and Gas Commission, the Ministry of Energy, Mines and Petroleum Resources, and the Climate Action Secretariat of the Ministry of Environment and Climate Change Strategy have developed methane emission regulations to meet the methane emission reduction targets, and to ensure they are equivalent to recently announced federal regulations.

The regulations address the primary sources of methane emissions from B.C.'s upstream oil and gas industry, which are:

- Pneumatic devices, pumps, and compressor starters
- Equipment leaks
- Compressor seals
- Glycol dehydrators
- Storage tanks
- Surface casing vent flows

The B.C. Methane Emissions Research Collaborative (MERC) focuses research efforts toward managing and reducing the release of methane from oil and gas operations. It is a collaborative initiative of Provincial agencies² and stakeholders that will make recommendations on the design and implementation of key research deliverables that will be necessary in order to meet methane reduction goals and to monitor the efficiency and effectiveness of B.C.'s methane regulations. The membership list of the MERC Technical Advisory Committee is provided in Appendix A.

¹ 2017 Provincial Greenhouse Gas Emissions Inventory

<https://www2.gov.bc.ca/gov/content/environment/climate-change/data/provincial-inventory>

² BC Oil and Gas Commission (Commission), the Ministry of Energy, Mines and Petroleum Resources (MEMPR), the Climate Action Secretariat (CAS)

Methane Research – An Overview

Considerable research has been conducted over the last several years to characterize methane emissions across the oil and gas value chain, in particular during exploration and production activities. A list of recent relevant research was developed based on recent literature reviews conducted for Canadian-based research projects, and supplemented with known industry-led or government-supported research, as well as other North American studies (Appendix B). While this is not necessarily an exhaustive list of research conducted on methane emissions from the oil and gas sector in North America, it is indicative of the themes of major research initiatives that have taken place over the last decade and includes a cross-section of the main project types (e.g. facility level measurement campaigns, regional emissions assessments, technology assessments, etc.) and the research partners involved in the various studies. Researchers included those from academia, environmental NGOs, industry, governments and regulators, and technology providers. The majority of studies (over half) in this list are U.S. based. Approximately one-quarter of the studies are Alberta based, with studies in B.C. accounting for less than ten percent of the total. While the U.S. and Alberta based studies provide insights that are useful for B.C. generally, they may not always be applicable or relevant to use in decision-making due to the markedly different emission characteristics that can exist between basins and jurisdictions.

About two-thirds all of the research that has been done across jurisdictions falls into the category of methane inventory development and this can be further subdivided into (1) baseline establishment (2) characterization of emission sources and (3) top down - bottom up inventory reconciliation. Traditional emissions inventories were often developed using bottom up methods – or those that relied on counts of specific equipment and components that were matched to known or standard emission factors for those equipment/component types. Top down estimates differ as they are often conducted over a large geographic area, and can use many different experimental methods, from flight campaigns to ground-level studies that use sensors on trucks to collect fence level measurements from different facilities looking at components across hundreds of facilities. The next most common tranches are leak detection and quantification methods and methane emissions mitigation technologies.

In B.C., about half of the studies to date relate to gas migration followed by inventory development (41 percent) and leak detection (12 percent). The majority of research campaigns that focused on inventory development, including top-down estimates and bottom-up estimates of emissions have found the existence of a small number of sources that are responsible for majority of methane emissions. These observations have given rise to various ‘rules’ set out in the literature – for example, the 5-50 rule, where it was observed that the largest 5% of methane emissions sources contributed to over 50% of total methane emitted³.

Research in B.C.

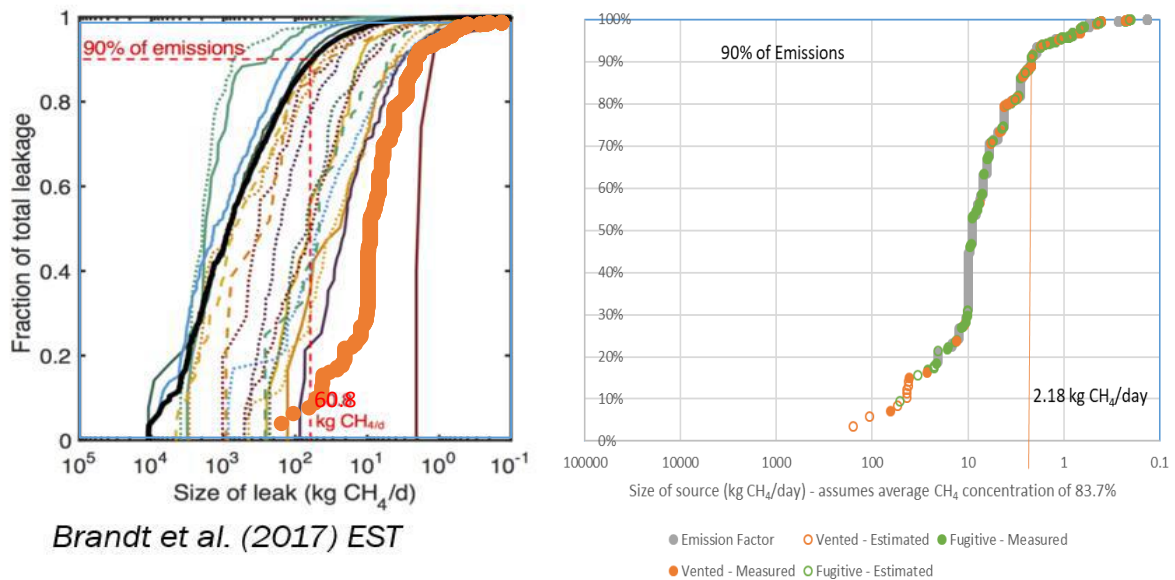
Direct comparisons between different studies can be challenging as, in some cases, the definitions used for source types differ. For example, the term ‘fugitive’ emissions can often refer to different sources of emissions depending on the researcher and jurisdiction being studied. The federal GHG reporting

³ Brandt, A.R., G.A. Heath, D. Cooley (2016). Methane leaks from natural gas systems follow extreme distributions. *Environmental Science & Technology*. DOI: 10.1021/acs.est.6b04303

program has a definition that refers to all sources of flaring, venting, and leakage emissions as ‘fugitive’ emissions⁴. This differs from the classification of fugitive emissions as unintentional leaks from equipment, and vented emissions as intentional emissions from specific equipment types. This latter definition is consistent with B.C.’s *Greenhouse Gas Industrial Reporting and Control Act* and the Drilling and Production Regulation under the *Oil and Gas Activities Act*. References to ‘fugitive’ and ‘vented’ emissions in this research plan are based on the definitions used in these provincial regulatory frameworks.

Emission distribution profiles from a recent field campaign in B.C. (the 2018 B.C. Oil and Gas Methane Emissions Field Study)⁵ were broadly consistent with those observed in other studies. The left panel of Figure 1 is from a meta-study that includes a compilation of results from numerous field campaigns in the U.S. which assessed different types of methane emission sources, including fugitive emissions (e.g. leaks) as well as vented emissions from various operating equipment, including pneumatic devices, pumps, compressor seals, and tanks³. Those results indicate that across all sources in the included studies, 90% of emissions result from devices with emissions greater than 60 kg CH₄ per day. The results from the B.C. Oil and Gas Methane Emissions Field Study are included as the orange line. The right panel includes results from the B.C. study with fugitive emissions and vented emissions indicated separately. The results from the B.C. study suggested that 90% of emissions resulted from sources greater than 2.18 kg CH₄ per day, significantly lower than those observed in the U.S. studies.

Figure 1 – Emission distribution profiles from recent U.S. research and results from B.C. Oil and Gas Methane Emissions Field Study



⁴ Reporting greenhouse gas emissions data: technical guidance 2018, available online: <https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/facility-reporting/reporting/technical-guidance-2018.html>

⁵ 2018 B.C. Oil and Gas Methane Emissions Field Study, available online: <https://bcogc.ca/public-zone/reducing-methane-emissions>

Note: Left panel includes results from meta-study looking at measured emissions profiles from various studies across North America and includes many different source types (fugitive emissions, pneumatic device and pump venting, compressor seals etc.)⁶. Orange line (left panel) is an approximation of B.C. field study results (including fugitive, vented emissions and estimates from pneumatic devices). Right panel includes emission distribution from BC field study results, and separates fugitive and vented emissions and pneumatic devices (using standard emission factors).

There are several classes of technology available to detect and measure methane emissions at different spatial scales, with new technologies and methods being developed. Table 1 below summarizes results from a recent research paper that assessed some of these technologies and provides minimum detection limits (i.e. the minimum rate at which the sensor can detect a source of emitted methane) that range from 0.024 kg CH₄ per day to 6,000 kg CH₄ per day ⁷.

A challenge with most current detection technologies is that they are unable to differentiate between fugitive emissions and vented emissions. As some vented sources are permissible under the current and proposed provincial regulatory frameworks, this differentiation is important in order to identify and repair potential leaks. For example, the largest single fugitive emission leak detected as part of the 2018 B.C. Oil and Gas Methane Emissions Field Study was approximately 51 kg per day (about 7% of fugitive emissions in study), with the next largest leak being two-thirds as much (34 kg per day, 4% of fugitive emissions in study)⁸. For this reason, as shown in Figure 2, satellite and some aircraft based technologies, with their currently high relative minimum detection limits, may not be effective at detecting fugitive methane emissions in British Columbia. However, they would be able to detect total emissions on site (i.e. if general venting emissions and releases from pneumatic devices are included) that exceed their detection limits. Some of these detection technologies and methods (including aircraft) have been used successfully in research programs in other jurisdictions, including Alberta to detect facility-level emissions from wellsites.

Table 1 – Comparison of Methane Leak Detection Technology Limits

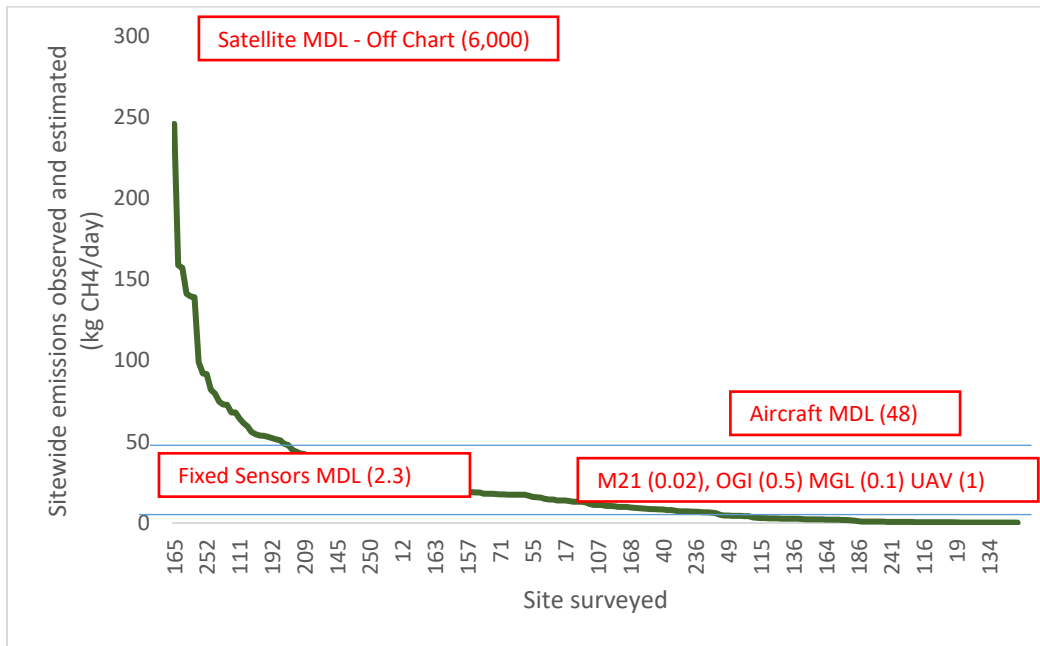
Technology	Minimum Methane Detection Limit (kg/d)
Method 21 (M21)	0.02
Optical Gas Imaging (OGI)	0.5
Fixed Sensors	2.3
Mobile Ground Laboratory (MGL)	0.1
Unmanned Aerial Vehicle (UAV)	1.0
Aircraft	48
Satellite	6,000

⁶Brandt, Adam & Heath, Garvin & Cooley, Daniel (2016). Methane Leaks from Natural Gas Systems Follow Extreme Distributions. *Environ. Sci. Technol.* 50, 22, 12512-12520.

⁷ Fox, Thomas & Barchyn, Thomas & Risk, David & Ravikumar, Arvind & Hugenholtz, Chris. (2019). A review of close-range and screening technologies for mitigating fugitive methane emissions in upstream oil and gas. *Environmental Research Letters*. 10.1088/1748-9326/ab0cc3.

⁸ Assumes average methane concentration of 83.7%

Figure 2 – Site level emission distribution profiles from B.C. Oil and Gas Methane Emissions Field Study



The relatively large sources of emissions within each study may be caused by a number of factors, though research suggests that the majority of these emissions are caused by abnormal process or operating conditions⁹. Other factors that may contribute to these large sources of emissions include equipment that is designed to emit significant amounts of natural gas (e.g. product tank venting) and episodic events such as condensate flashing and liquids unloading operations, or other sources such as unlit flares.

The presence of these sources can present significant challenges to identifying fugitive emissions or leaks from equipment in order to address them quickly. Further work is needed to accurately identify and mitigate emissions from the abnormal process or operating conditions. Separately, additional work may also be required to determine how these types of emissions sources might be better incorporated when designing and/or assessing the impacts of methane reduction policies. If the majority of observed emissions are expected to come from a small number of sources at a particular facility, or at a minority of sites within a larger sample (e.g. a region or jurisdiction), the distributional impacts of rules that apply to all sources or facility types will be more pronounced.

Just as there can be significant variation in observed emissions between facilities within a certain geographic area, there can be significant variation in emissions observed between different jurisdictions. These differences can be caused by a number of different factors, including the enforced regulatory

⁹ Zavala-Araiza, Daniel & Alvarez, Ramón & R. Lyon, David & T. Allen, David & J. Marchese, Anthony & Zimmerle, Daniel & Hamburg, Steven. (2017). Super-emitters in natural gas infrastructure are caused by abnormal process conditions. *Nature Communications*. 8. 14012. 10.1038/ncomms14012.

framework, resource characteristics, local geographic conditions, operator practices, and availability of infrastructure and technology. Table 2 includes the results from some recent Canadian studies in comparison to others conducted in the U.S.

Table 2 – Comparison of recent top-down research estimates of well-level methane emissions

Field	Survey method	Estimated rate (t/h)	Estimated rate (m ³ /d/location)	Source
Uintah, UT	Airborne	55	325	Karion et al, 2014
Lloydminster, AB	Airborne	22	290	Johnson et al, 2017
Barnett, TX	Airborne	60	121	Karion et al, 2015
Bakken, ND	Airborne	28	96	Peischl et al, 2016
Marcellus, PN	Airborne	20	91	Barklay et al, 2017
Montney, BC	Truck		34-37	Atherton et al, 2017
DJ Basin, CO	Airborne	19	27	Petron et al, 2014
Red Deer, AB	Airborne	2	26	Johnson et al, 2017

Note: Results for the estimated emission rates per location are based on a number of assumptions and should not be taken as representative of an individual site’s emission profile, but are included to demonstrate relative comparisons between different resource areas.

The estimates and results from the table above should only be considered snap shots of potential emissions from a particular point in time when the research was conducted, and caution should be used in using the information for direct comparisons between jurisdictions. As with the review of recent related literature presented above, there are often challenges with making definitive comparisons between studies as the definitions used may not always be consistent (e.g. definitions between fugitive and vented emissions) and the scope of each study may differ (e.g. single well sites versus facility-level comparisons). As such, the results should be taken as indicative of potential differences between operations in B.C. and other jurisdictions, but individual wells or facilities may have significantly different emissions profiles within each jurisdiction. Ultimately the comparison underscores the importance of area-specific research to assist with policy development.

Overview of Regulated Methane Source Types

The following section provides an overview of the emission sources and equipment covered by the B.C. methane emission regulations.

Equipment Leaks

“A leak is the unintentional loss of process fluid past a seal, mechanical connection or minor flaw at a rate that is in excess of normal tolerances allowed by the manufacturer or applicable health, safety and environmental standards. An equipment component in hydrocarbon service is commonly deemed to be leaking when the emitted gas can be visualized with an infrared (IR) leak imaging camera or detected by other techniques with similar or better detection capabilities.”¹⁰

¹⁰ Clearstone Update of Equipment Component and Fugitive Emission Factors for Alberta Upstream Oil and Gas Study (<https://www.aer.ca/documents/UpdateofEquipmentComponentandFugitiveEmissionFactorsforAlber-1.pdf>).

B.C. OGC fugitive emissions guidance¹¹ defines a repairable leak as including:

- any unintentional natural gas emission detected by an organic vapour analyzer with a concentration equal to or greater than 500 parts per million; and
- any unintentional natural gas emission detected by a gas imaging camera capable, under laboratory conditions, of detecting 1 gram per hour of pure methane at a distance of 3 meters between the camera and the emission and at a difference in air temperature and background temperature of no greater than 10 degrees Celsius.

Components that may leak and produce fugitive emissions include, but are not limited to:

- connectors;
- control valves;
- controlled storage tanks (thief hatches);
- meters;
- pneumatic devices;
- pump seals;
- pressure relief and pressure safety valves;
- unlit flares; and,
- valves (other).

Pneumatic Devices

B.C. OGC defines pneumatic devices as instruments that require a supply of pressurized gas to work. They include but are not limited to the following:

- actuators;
- positioners;
- regulators;
- switches; and,
- transducers.

They specifically exclude the following:

- compressor starters;
- pneumatic pumps; and
- online gas analyzers.

Pneumatic or pneumatic equivalent devices may have motive force supplied by natural gas, propane, instrument air, or electric power (from solar, generated by thermal electric generator (TEG) or power generator on site, fuel cell, or grid power).

Pneumatic Pumps

B.C. OGC draft guidance defines pneumatic pumps as those that require a supply of pressurized gas to work. They include but are not limited to the following:

¹¹ Fugitive Emissions Management Guideline, V.1.0: July2019. Available online:

<https://bcogc.ca/node/15539/download>

- diaphragm; and
- piston.

The type of chemical pumped may include but is not limited to the following:

- corrosion inhibitor;
- de-waxer;
- methanol;
- paraffin control;
- scale inhibitor; and
- scavenger.

They specifically exclude the following:

- energy exchange pump used to pump glycol (glycol dehydration unit);
- engine coolant pump;
- engine lube oil pump; and
- pump used for heat medium circulation.

Pneumatic or pneumatic equivalent pumps may be powered by natural gas, propane, instrument air, or electric power (from solar, generated by TEG or power generator on site, fuel cell, or grid power).

Compressor Starters

Compressor engine starters can be electric or pneumatic. They are used to rotate (turn or crank) the engine to initiate the engine's operation.

Compressor Seals

Reciprocating Compressors

Each cylinder on a reciprocating compressor has a packing case seal to prevent leakage of large volumes of high-pressure natural gas. All packing systems however, intentionally vent some natural gas either into the distance piece or through a vent line connected to the packing case, or both. The amount of seal gas venting depends on the cylinder pressure, the packing installation, and the amount of wear on the packing rings and compressor rod shaft. Over time, seal gas venting increase as wear progresses.

Centrifugal Compressors

Seals on rotating shafts prevent the leakage of high-pressure natural gas from centrifugal compressor casings. These seals can be either "wet" or "dry".

In wet seals, oil is circulated under high pressure between rings and around the compressor shaft to form a barrier that prevents the leakage of natural gas to atmosphere. Natural gas is entrained in the seal oil and is flashed off and the degassed oil is recirculated. The flashed gas can be either controlled or uncontrolled. If it is controlled, it is conserved or routed to flare. If it is uncontrolled, it is vented to atmosphere.

A dry seal is a mechanical seal.

Glycol Dehydrator

Glycol is used for hydrate control in natural gas refrigeration systems and to remove water from natural gas. When glycol comes into contact with natural gas it absorbs some methane. When the glycol is regenerated by dropping its pressure, by heating, and by contacting it with stripping gas, venting results. The venting may be either controlled or uncontrolled. If it is controlled, it is conserved or routed to flare. If it is uncontrolled, it is vented to atmosphere.

Storage Tanks

Atmospheric storage tanks (storage tanks), used in the upstream oil and gas industry to store liquids such as oil, condensate and produced water, may be either controlled or uncontrolled.

Uncontrolled: Tank vapours are intentionally vented to the atmosphere such as through a vent or an open thief hatch.

Controlled: Tank vapours are routed to a Vapour Recovery Unit (VRU) and are conserved (eg., recycled to compressor suction) or captured and combusted (eg., flare).

Data from the B.C. Oil and Gas Methane Emissions Field Study demonstrates that uncontrolled storage tanks can be a substantial source of routine emissions (two thirds of non-pneumatic venting emissions at wellsites and batteries¹². Vented emissions result from three factors: flashing losses, working losses, and standing losses.

Flashing: Emissions resulting from the flashing of light hydrocarbons, such as methane and volatile organic compounds, from the stored liquid when it experiences a pressure drop.

Working: Emissions resulting from working losses, vapours pushed out of the tank by rising liquid levels and by the agitation tank liquids.

Standing: Emissions resulting from the expansion of stored materials due to diurnal and seasonal temperature and pressure changes.

Several factors influence the vented volume and the most important factors are:

1. whether or not the tank is controlled or uncontrolled;
2. operating pressure in the separator(s) upstream of the storage tank;
3. tank throughput; and
4. material stored
5. malfunction of valves/instrumentation upstream of the storage tank.

Surface Casing Vent Flows

Surface casing is the first string of casing put into a well; it is cemented into place and serves to shut out shallow water formation and as a foundation for well control¹³.

¹² B.C. Oil and Gas Methane Emissions Field Study <https://www.bcogc.ca/node/15509/download>

¹³ <https://www.bcogc.ca/node/11467/download> (Oil and Gas Glossary and Definitions)

Surface casing vent flow means the flow of gas and/or liquid from the surface casing/casing annulus¹⁴.

MERC Research Plan development

Through initial meetings, TAC members developed a list of potential research questions of interest related to the six sources of emissions subject to requirements under B.C.'s methane regulations. The majority of questions discussed concerned improving our understanding of fugitive emissions (both in terms of site-level emissions and potential impacts on emissions inventories) and leak detection and repair program design, including the use of alternative or emerging technologies. A complete list of the research questions discussed is provided in Appendix C.

Through voting, TAC members determined the following questions to be the highest priority for the B.C. MERC to consider as part of an initial research plan:

Fugitives and leak detection and repair (LDAR)

- What is the effectiveness of Optical Gas Imaging (OGI) surveys and repair in reducing fugitive methane emissions at different inspection frequencies?
- Is there a more cost-effective method of conducting Leak Detection and Repair (LDAR) surveys? How will the regulator consider accepting alternative LDAR practices?
- What is the effectiveness of repairs on fugitive emissions? Do small leaks become big leaks? What is the rate of leak recurrence?
- How much of baseline or reference case emissions are fugitive emissions? Are there sources that are not well characterized? Are there sources not currently covered by regulatory requirements that form a significant portion of total fugitive emissions?
- Could a risk-based approach be effective in the management of fugitive emissions?
- What type of data is needed to evaluate current and alternative LDAR practices? What are the variables of interest to collect and analyze?
- How can we predict the likely effectiveness of an alternative LDAR method/program?

Storage Tanks

- What are the baseline or reference case emissions of methane from storage tanks? And what is the breakdown between fugitive emissions (unintentional releases) and vented emissions (intentional releases)?

Compressor venting

- How are emissions from compressors best measured/estimated? Are there new technologies for measurement? Are there differences in emissions by compressor type and/or size?

As work gets underway, additional questions may surface and priorities may change. For these reasons, the questions and prioritization will be re-evaluated on a regular basis.

¹⁴ <https://www.bccgc.ca/node/13316/download> (Oil and Gas Activity Operations Manual section 9.7.3)

Significance

The following factors were discussed as important to consider by TAC members when assessing potential projects. While they were not used to quantitatively assess project ideas, they were considered when projects were discussed by the TAC and aided in the ranking and prioritization of initial projects. It was recognized that not all factors would apply to each potential project.

- **Regulatory Check-in:** How relevant the research or project is to the Commission's committed to methane regulations regulatory check-in period (planned to occur prior to December 31, 2022).
- **Uncertainty:** How likely the project or research might reduce uncertainties or data gaps
- **Sector Adoption:** How likely the technology or research was to be adopted broadly by the sector
 - Considering scalability, safety, cost, reliability, and accuracy of the technology or practice
- **Funding Leverage:** How the project might leverage other funding sources or collaborations
- **Canadian Content:** Whether the research or project would provide an opportunity to collaborate with Canadian researchers, technology and service providers, and with indigenous groups

Subsequent discussions with the TAC brought forward some additional factors that could be considered when prioritizing projects in the future.

- **Cost:** How relevant the research or project is to reducing the cost of methane management while achieving the same or better emission reduction outcome.
- **Opportunity:** The magnitude of the potential methane emission reductions that could be achieved as a result of the research.
- **Stakeholder Priority:** Which of these questions are most important to various stakeholder groups.

List of initial projects

The TAC developed an initial list of research projects, based on the prioritized research questions above. All of these projects have been approved by MERC to proceed.

A Gantt chart was developed to show ongoing research projects in Alberta in comparison B.C. projects and is included as Appendix D.

Storage Tanks and Compressor Seal Gas Venting

Developing an improved understanding of storage tank and compressor seal vent associated methane emissions in British Columbia

Project description - A contractor working on behalf of the MERC will:

1. Determine what data currently exists in government/agency databases that could be used to develop a provincial inventory of storage tanks and compressor vents (reciprocating, centrifugal, rotary screw) and estimate their associated methane emissions under different operating conditions.
2. Identify relevant information available from other studies (in BC and elsewhere).
3. Identify gaps that exist in the data and suggest ways to address them.
4. Advise on whether or not a field study is needed to address data gaps.

5. Develop a preliminary provincial inventory of storage tanks and compressor vents and their associated emissions under different operating conditions including an uncertainty and gap analysis.

This project will improve stakeholder understanding of methane emissions from storage tanks and compressor seal vents - which were observed to be relatively large sources of methane emissions in the B.C. Oil and Gas Methane Emissions Field Study. While estimates have been derived for such emissions, a framework for accurate accounting in the format and with the detail that is needed has not yet been developed for British Columbia.

British Columbia Fugitive Emission Management Program Effectiveness Assessment

Project description – Comprehensive assessments of fugitive emission management programs have been limited in the past, which has led to uncertainty around their emission reduction outcomes. In order to ensure a robust assessment of the fugitive emissions management requirements in the B.C. regulations, the MERC is proposing that a study is conducted which will analyze the information that will be submitted as part of the regulatory requirements, along with additional field work if necessary. The project objective is to provide the Commission with the information it needs to assess how well its methane regulations are working at reducing fugitive methane emissions from equipment leaks relative to a pre-regulation baseline year (2012, 2014). If the regulations are not achieving enough reductions in methane emissions, the Commission needs to know the magnitude of reductions and costs that potential changes to the fugitive emissions provisions of the regulations could have. If the regulations are achieving the necessary reductions inefficiently, the Commission needs to know what changes could be made to the fugitive emissions provisions of the regulations to increase efficiency while maintaining effectiveness. The intent of this project is to review the effectiveness, efficiency, and cost of the survey methods that are included in the regulations. Alternative technologies and survey methods are out of scope.

The successful proponent will:

1. Design a study to assess the relative efficiency, cost, and effectiveness of equipment fugitive emissions detection and repair that includes specific comprehensive and screening survey frequencies and other pertinent factors on fugitive methane emissions in B.C. considering the following data sources:
 - a. annual permit holder data submissions to the BC Oil and Gas Commission (Commission); and,
 - b. other applicable sources of information, as appropriate.
2. If available data sources are insufficient to meet the project objectives, describe the proposed field work needed to meet the objectives.
3. Provide a report summarizing the methodology employed, proposed study design, budget, and schedule.

Alternative leak detection and repair program equivalency model development (LDAR-Sim)

Research into new methods of detecting and quantifying methane releases has risen in recent years due to regulations to limit these releases in various North American jurisdictions. In order for regulators to consider whether these new methods are acceptable alternatives to established regulatory requirements, assessments of program equivalence are required. Protocols to determine this equivalence have yet to be developed, but are expected to require some combination of controlled release testing, technology testing under real-world conditions, and computer modelling under different scenarios that consider local geographical, meteorological conditions, leak distribution and other conditions.

The University of Calgary has developed a research-level model, LDAR-Sim, to assess the equivalence of leak detection programs in different regulatory jurisdictions. This project is intended to further develop the model, with the intent, if it is successful and scientifically defensible, to adopt the model as a regulatory tool.

Top down, bottom up emissions inventory development

In many jurisdictions, recent research has shown that estimates of regional or site-wide methane releases developed using top-down methods (e.g. by aircraft, mobile ground laboratory) may be larger than estimates developed using bottom-up engineering estimates. Differences between the two types of estimates can be the result of a number of factors:

- omission of potential emissions sources in bottom-up estimates;
- inaccuracy or under-reporting of bottom-up emissions;
- abnormal operating conditions not accounted for in emission factors from different sources in bottom-up estimates; and,
- top-down estimates including measurements of episodic events that may not occur regularly throughout the year.

B.C. will develop an estimate of methane releases using a top-down methodology for comparison to bottom-up estimates. This will help identify whether there are sources of emissions (e.g. inactive wells) and/or equipment that could be better characterized for more effective emissions management. A snapshot of emissions prior to the regulations taking effect will be determined through a top-down assessment, which will provide an opportunity to assess reduction trends over time if another top-down survey is completed prior to the regulatory check-in period.

Appendix A - TAC membership

The TAC is currently comprised members of the following organizations:

BC Oil and Gas Commission
Ministry of Energy Mines and Petroleum Resources
Ministry of Environment and Climate Change Strategy - Climate Action Secretariat
Environment and Climate Change Canada
Natural Resources Canada
Geoscience BC
Alberta Energy Regulator

Appendix B – Literature Review

[Click link for spreadsheet.](#)

Appendix C - Research questions of interest to the TAC

Fugitive emissions and leak detection and repair (LDAR) programs

- What is the effectiveness of OGI surveys and repair at different inspection frequencies?
- Is there a more cost-effective method of conducting LDAR surveys?
- What is the effectiveness of repairs? Do small leaks become big leaks? What is the rate of leak recurrence?
- Is there a way to predict leaks?
- Could a risk-based approach be effective in the management of fugitive emissions?
- Is there a way to link operator best practices to reductions in fugitive emissions?
- What type of data is needed to evaluate LDAR practices? What are the variables of interest to collect and analyze?
- How can we predict the likely effectiveness of an alternative LDAR method/program?
- What are baseline emissions from fugitives?
- Which actions can improve equipment fugitive performance that are independent but complementary to leak detection? Can these actions be quantified in some way?
- What is the effectiveness of fixing leaks? What proportion of leaks can be repaired within a certain timeframe? Which cannot be repaired because of cost or resource constraints?

Storage tanks

- What are the baseline emissions from tanks? Breakdown between fugitives and vents?
- How are these emissions best measured/estimated? Are there new technologies for measurement? Confirm effectiveness of QOGI on tank vents.
- Are there best practices in design to reduce emissions from tanks (vents and fugitives)? What are the costs associated with these best practices?
 - Maintenance practices, technologies, other?

Compressor venting

- What are the baseline emissions from compressors? Breakdown between fugitives and vents?
- How are these emissions best measured/estimated? Are there new technologies for measurement? Are there differences by compressor type and/or size?
- Are there best practices in design to reduce emissions from compressors (vents and fugitives)? What are the costs associated with these best practices? Maintenance practices, technologies, other?
- How do emissions from compressor vents change over time?
- To what extent can compressor vents be tied-in or captured? Do these opportunities vary by compressor type/size/location/facility type?

Other

- What is the contribution of operating and/or maintenance practices to emission reductions? What is the mechanism to incent industry to adopt certain maintenance practices?
- Are there other alternatives for the quantification of fugitives?
- Can we improve our understanding of methane emissions from all sources? Can we reconcile top-down and bottom-up estimates?
- Are there any citizen science opportunities for detection of methane emissions?

[Appendix D- Gantt Chart](#)

Click link for spreadsheet.