Emissions Management RD&D & Technology Testing Capacity in Canada

Prepared For: Alberta Innovates and Natural Resources Canada

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This document was prepared by The Delphi Group on behalf of Alberta Innovates and Natural Resources Canada.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

Acronym	Definition
ACCTC	Alberta Carbon Conversion Technology Centre
AER	Alberta Energy Regulator
AI	Alberta Innovates
BCOGC	British Columbia Oil & Gas Commission
CAPP	Canadian Association of Petroleum Producers
CeDER	Centre for the Demonstration of Emissions Reductions
CH4	Methane
CHOPS	Cold Heavy Oil Production with Sand
CMCRI	CMC Research Institutes
CMOS	complementary metal-oxide-semiconductor
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
DV-CETC	Drayton Valley Clean Energy Technology Centre
EDF	Environmental Defense Fund
ENGO	Environmental Non-Governmental Organization
ERA	Emission Reduction Alberta
F/P	Federal-Provincial
FEED	Front-End Engineering and Design
FEMP-EA	Fugitive Emissions Management Program Effectiveness Assessment
FRS	Field Research Station
GHG	Greenhouse Gas
GPS	Global Positioning System
ISO	International Organization for Standardization
LDAR	Leak Detection and Repair
LNG	Liquified Natural Gas
MELA	Methane Emissions Leadership Alliance
MERC	Methane Research Collaborative
METEC	MONITOR Field Test Site
MONITOR	Methane Observation Networks with Innovative Technology to Obtain Reductions
MWA	Modern West Advisory
NAIT	Northern Alberta Institute of Technology
NGL	Natural Gas Liquids
NOx	Nitrogen Oxides
NRC	National Resource Council
NRCan	Natural Resources Canada
O&G	Oil and Gas

Acronym	Definition
PM2.5	Particulate Matter (diameter <2.5 micrometers)
PTAC	Petroleum Technology Alliance Canada
PTRC	Petroleum Technology Research Centre
RD&D	Research Development and Demonstration
RSCs	Reduced Sulphur Compounds
SAIT	Southern Alberta Institute of Technology
SCADA	Supervisory control and data acquisition
SENST	Smart Emissions Sensing Technologies
SLCPs	Short-Lived Climate Pollutants
SRC	Saskatchewan Research Council
StFX	St. Francis Xavier University
TRL	Technology Readiness Level
UAV	Unmanned Aerial Vehicle
UofA	University of Alberta
UCalgary	University of Calgary
UGuelph	University of Guelph
VOCs	Volatile Organic Compounds

1 EXECUTIVE SUMMARY

Federal and provincial governments are regulating emissions from Canada's upstream oil and gas industry as the country works towards its climate leadership goals. Producers are implementing emissions reduction projects throughout their operations to ensure compliance and to meet their environmental and social objectives. Technology developers continue to innovate and build new technologies that fill these needs. However, the timelines for meeting Canada's national climate change objectives and the associated regulatory requirements are rapidly approaching. Development and deployment of cost-effective, emissions reduction technologies require an ecosystem that can efficiently service these needs by supporting the product development lifecycle, including bench, pilot and field scale testing, baseline data & analysis, and verified performance reporting. Understanding the emissions management research, development & demonstration (RD&D) and technology testing capacity in Canada is critical to this process and will provide the necessary building blocks of an ecosystem that will service the needs of the market.

To that end, Alberta Innovates (AI) and Natural Resources Canada (NRCan) hosted a workshop in April 2018 to begin exploring Canada's emissions reduction RD&D and technology testing landscape. They then commissioned a research project to develop an understanding of the current state of the system and any gaps or opportunities to activate growth in the system's capacity. The research, compiled in this report, clarifies the key stakeholders involved in Canada's emissions management activities and collects information that paints a robust picture of the ecosystem. Through an extensive questionnaire designed for 26 organizations across four distinct stakeholder groups, data was collected that ultimately identified the two most critical pathways for AI and NRCan to consider when deciding on how best to support the national emissions management ecosystem: **Technology Testing** and **Data Systems**.

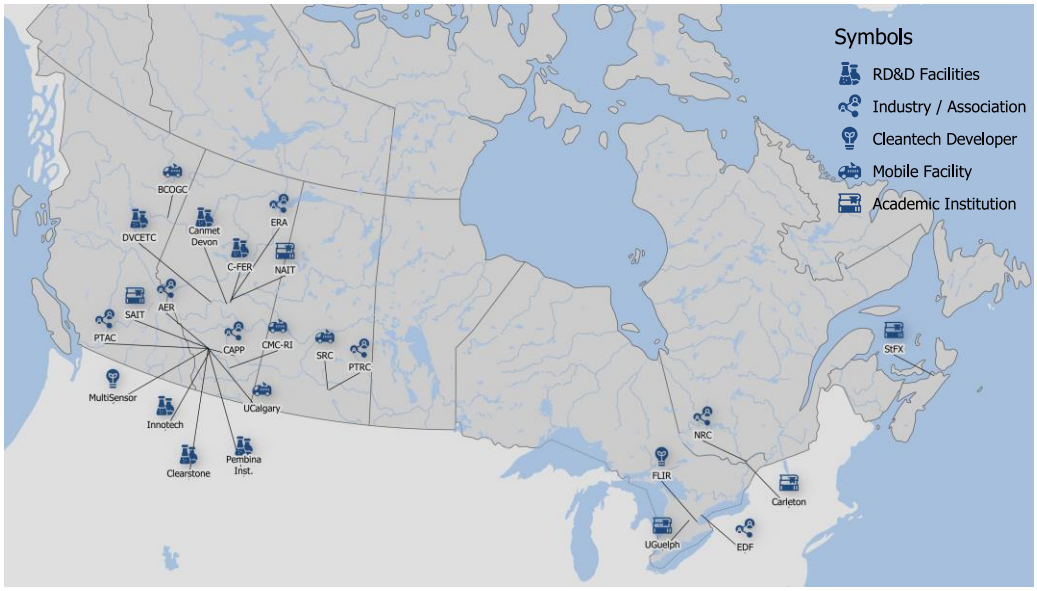

Figure 1-1: Stakeholders in Canadian RD&D and Technology Testing Ecosystem

The emissions management market is relatively new in the long life of the oil and gas industry and has seen significant development in recent years with increased focus on international commitments on climate change. New and innovative technologies are regularly entering the market but require extensive testing prior to field installation and ultimate commercialization. Once emission reduction technologies have been tested, data collection and quality control become the next most important components for both the achievement of policy and commercial objectives. The research identified that numerous organizations from academia, government, industry, innovators, and regulators are all active in some form of emissions reduction RD&D and technology testing and data management activities. However, emissions types and sources in the oil and gas industry are extensive, and each requires different process and/or technology solutions. These solutions must be developed in concert with regulatory requirements. This requires extensive testing across all source categories and requires a connected network of individuals and organizations with the appropriate physical infrastructure and methodological capabilities to manage the large volumes of data resulting from the testing and implementation activities.

The research suggests that Canada's current technology testing and data collection system is diverse both in the types of facilities that are performing testing/data collection and the types of technologies that are being developed and deployed. Many stakeholders are recognized globally for their leadership in the sector. However, the system currently lacks cohesion and there are still some gaps with respect to certain emissions source categories and types. Moreover, there are still gaps in data availability preventing shared understanding of the highest impact opportunities for emissions reduction.

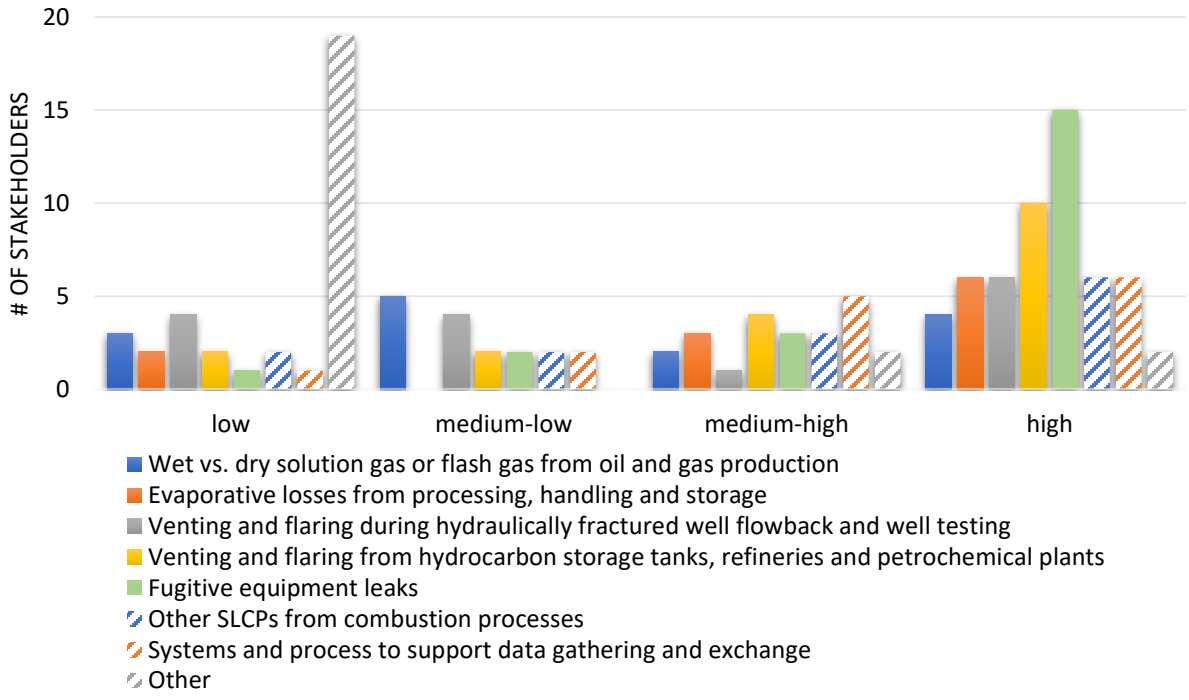

Figure 1-2: Stakeholder Emissions Management Priorities

Testing is happening in silos across the country at various academic institutions and independently by technology developers. Industry members have only recently been involved in large scale testing, which is a significant improvement to the system as field-level testing was identified by all stakeholder groups as a critical component to Canada's emissions management performance. However, the data collected through these testing initiatives is largely held under close cover, with only portions of it being shared through workshops and conferences. There are a variety of emissions models and quantification methodologies being applied across stakeholder groups that tend toward data gaps and inconsistencies. The market has recently made small steps to closer collaboration on data sharing, yet more opportunity exists to improve the quality and control measures applied to the data ecosystem. Fortunately, some of the gaps identified in the current system can be overcome with relatively minor investment of attention and resources (e.g. organizing information workshops, building an efficient and ongoing network of stakeholders to share information and build best practices, etc.) while others require a larger investment (e.g. building a centralized data hub, supporting development of physical infrastructure, etc.).

The research indicates that each of these solutions warrant consideration, as the benefits are tangible. However, the pathway to capacity building in Canada's emissions management RD&D and technology testing ecosystem must be navigated rapidly. High-grading the gaps to fill and opportunities to pursue needs to consider regulatory and environmental timelines and take a realistic view of what is achievable based on the current market capabilities. This report provides the framework to complete this work as the gaps and opportunities are identified along with the other system components that must be considered in concert with this research.

Ongoing stakeholder engagement and close collaboration are imperative to ensuring that technologies are field tested and that their performance is properly evaluated and communicated to the market. Given that a long list of well-informed stakeholders are currently involved in getting this work done, and that a solid foundation of work is currently underway from coast-to-coast, Alberta Innovates and Natural Resources Canada can act as both an enabler and leader of this evolving market that will promote the long-term sustainability of one of the nation's core industries and support the growth of a burgeoning national technology sector. The foundation for this leadership prospective is contained here, and the time for action is now.

2 INTRODUCTION

Alberta Innovates (AI) and Natural Resources Canada (NRCan) commissioned The Delphi Group and Modern West Advisory, Inc. to undertake a detailed mapping study of Canada's oil and gas emissions management landscape to better understand existing capabilities, assets (facilities, equipment, infrastructure), and expertise across the country, with a focus on research, development and demonstration (RD&D) and technology testing capacity.

> *Emissions innovation in Canada is advanced by governments, post-secondary institutions, private research organizations, industry associations, and oil and gas producers. Collaboration between these groups is already taking place, but a broader effort is needed to connect key players across the country to better align regulations and policy, emissions RD&D, and funding support, to achieve emissions reduction targets, while supporting the competitiveness of Canada's oil and gas and clean tech industries.*
>
> *- Alberta Innovates & Natural Resources Canada*

As part of their commitment to the Pan Canadian Framework for Climate Change, the governments of Alberta and Canada have set targets to reduce methane emissions and have implemented other regulations to reduce other short-lived climate pollutants (SLCPs). In support of these objectives, the federal and provincial governments have developed climate change regulations set to come into effect as soon as 2020. Ahead of these regulatory requirements, multiple government support mechanisms for research and development of emerging technologies throughout Canada's industrial landscape are in place. Further to that end, governments are considering how best to improve the overall system capacity of methane and other SLCP emissions research, technology development and demonstration (RD&D), and technology testing.

As part of these efforts, Alberta Innovates and Natural Resources Canada hosted a stakeholder workshop in April 2018, where stakeholders identified the need to perform a Canada-wide mapping exercise and gap analysis of facilities, infrastructure, assets, capabilities and expertise across the oil and gas emissions management value chain, with a focus on RD&D and technology testing capacity to address the impacts of methane and other SLCPs. **The feedback received at the workshop included identification of the need to build capacity and enhance coordination across the oil and gas emissions management ecosystem to accelerate emissions reduction technology deployment and support of cost-effective regulatory compliance.**

The following report completes this work and the results of this exercise will inform federal-provincial initiatives on building capacity, supporting collaborative RD&D and technology testing projects, and fostering an integrated network for improved emissions management to help Canada achieve its emissions reduction targets. The objective of this work is to inform the advancement of a Front-End Engineering and Design (FEED) study to develop cost estimates and initial plot plans for any required new or expanded facility/infrastructure or equipment necessary to deliver on RD&D and technology testing priorities and strategic outcome objectives. The opportunities presented here will help Canada advance its global leadership in oil & gas emissions management through an efficient national network to ensure

all the components within the system have the capacity to support the achievement of the country's international climate goals.

This mapping exercise and gap analysis includes an assessment of the following components:

- Existing facilities across Canada advancing air emissions measurement, reporting, verification and reduction RD&D and technology testing/validation;
- Stakeholders including post-secondary institutions, Federal/Provincial governments, labs and innovation agencies, provincial regulators, industry and industry associations, and private research organizations;
- Identification of facility assets, equipment, and expertise, as well as facility limitations;
- Identification of facility linkages to other organizations within the oil and gas emissions management value chain;
- Facility funding models and governance structures;
- Existing databases and data platforms for emissions data and reporting, including associated data sharing arrangements, data providers/users, and limitations associated with analytical capabilities, intellectual property, data access, and data security; and
- Key gaps based on existing facilities, infrastructure, assets and expertise, and opportunities for capacity building to improve the emissions testing landscape in Canada.

2.1 Background

2.1.1 Report Objectives

Research into Canada's emissions RD&D and technology testing capacity undertaken as part of this report is built on the following objectives: (a) understanding emissions reduction technology market potential, (b) identifying pathways to commercialization, and (c) supporting industry deployment of low-cost solutions.

The following components are core considerations for building this capacity:

1. **Development** of new infrastructure
2. **Enhancement** of current facilities
3. **Formalization** of the current data ecosystem
4. **Acceleration** of technology deployment in-line with policy/regulatory considerations
5. **Interconnection** with ecosystem funding mechanisms

These criteria are important to the report objectives because decisions need to consider the timelines on which outcomes are achieved. Notably, short-term (1-2 years) and long-term (3+ years) needs within the ecosystem are variable and therefore capacity building decisions should balance immediate/current system impacts, and future system needs. For example, system impacts on RD&D and technology testing outcomes are variable between **development** of new facility infrastructure and

policy/regulatory considerations. Further, **enhancements** of the current ecosystem may provide medium-term returns, and **formalization** may tender the most immediate system benefits (e.g. data collection infrastructure). Each part of the RD&D and technology testing system, along with the outcome timelines, need careful consideration given the objective of supporting Canada's target under the Paris Climate Accord.

These considerations above will help AI and NRCan evaluate **how best to bridge the gap between emissions RD&D and technology testing activities already underway in the country and the infrastructure, data collection, assessment, and management systems required** to achieve the following objectives:

1. Establish a fully **integrated national network** for improved emissions management in Canada, while supporting the competitiveness of Canada's oil and gas and clean tech industries;
2. Accelerate the **deployment and adoption** of cost-effective solutions to achieve emissions reductions and regulatory compliance through outcomes-based RD&D, field-scale testing and validation of technologies;
3. Position **Canada as a leader** in providing global emissions management solutions;
4. **Attract** investors and innovators to Canada.

Further to the above information, it is important to understand the **regulatory landscape** (current and prospective), the **national emissions inventory,** and the **current funding mechanisms** available to support emissions management RD&D and technology testing activities in Canada. This information, in concert with the data collected in this report, and an understanding of the technologies available to the system[1], will provide a complete view of the current capacity of the emissions management ecosystem, and thereby clarify the most effective capacity building opportunities faced by Alberta Innovates and Natural Resources Canada.

[1] See PTAC, MELA, and SRC for exhaustive lists of emerging and readily available technologies.

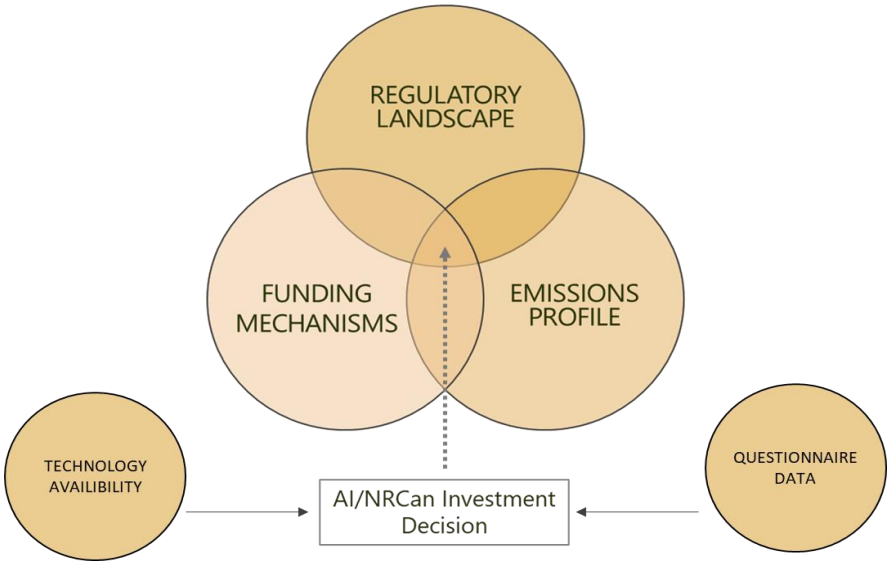

Figure 2-1: System Impacts

Optimal capacity building opportunities require close evaluation of any overlaps in regulatory design, funding mechanisms and emissions sources to identify the core focus areas. Within these focus areas, the emissions source categories where existing technology and innovation infrastructure is dedicated can be explored to determine if there is a need to **enhance specific technology pathways** with structural supports or investment dollars from government. The information captured in this report will clarify whether the emissions management RD&D and technology testing ecosystem is supporting the core focus areas of regulation and technology development appropriately and will more effectively identify system gaps and future capacity building opportunities.

2.1.2 Canada's Climate Change Regulatory Landscape

Federal and Provincial regulations are aiming for a greenhouse gas emissions reduction target of 30% below 2005 levels by 2030 with an interim methane emissions reduction target in the oil and gas sector of 40% to 45% below 2012 levels by 2025. As a result, many provincial jurisdictions are considering different policy and regulatory options to support Canada's commitment under the Paris Agreement. Each policy, and the associated regulations, influence the areas of need for support in building innovation, technology development, field testing, technology deployment, and data management systems. For example, as flaring, venting, methane, NOx, and VOC's have become regulated over the years, the market has adapted with advancements in technology, monitoring, and reporting. A brief overview of the multitude of Federal and provincial acts and regulations are listed in Figure 2-2~~Figure 1-2~~ below.[2]

[2] This list is not exhaustive as some emissions related regulations are tied to other pre-existing regulations.

Figure 2-2: Canadian Federal & Provincial Climate Related Regulations

It is important to understand the objectives of each of these regulations (and others as deemed relevant) and the timelines on which they are based prior to determining ecosystem support options for AI and NRCan to consider in the emissions management landscape in Canada.

For example, when comparing the final Federal and Alberta draft[3] methane regulations, there are four similar methane source categories being regulated in both jurisdictions as identified by the coloured boxes in Figure 2-3~~Figure 1-3~~. Venting, pneumatics and fugitive emissions are also the largest three sources of emissions in the national inventory (see Figure 2-6~~Figure 1-6~~). Understanding the details of these regulations within each of these source categories (e.g. reduction & reporting requirements, timelines, etc.) will help drive capacity building identification (e.g. measurement, equipment upgrades, testing requirements, etc.).

[3] The final Alberta methane regulations were released during report writing and were not incorporated into the document given time constraints for report production.

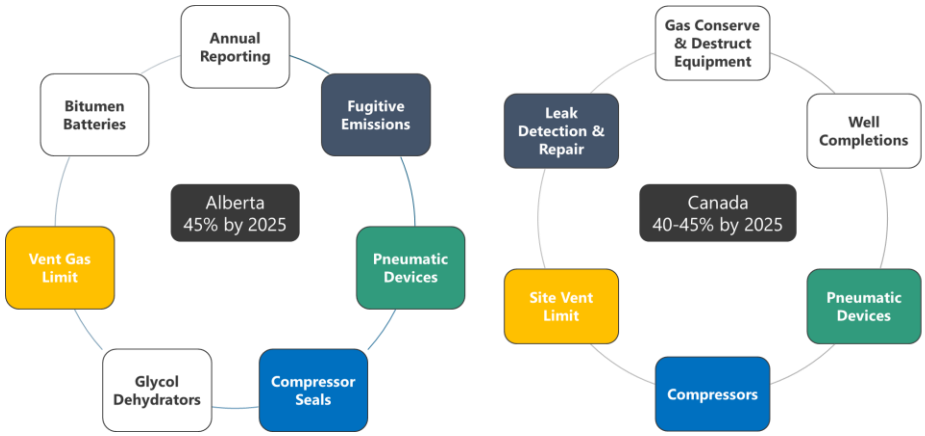

Figure 2-3: Regulated Methane Emissions Source Categories, Alberta and Federal

The Federal and Alberta methane regulations have created a market for methane emission reduction measurement, monitoring, and mitigation technologies. With the multitude of methane source categories now being regulated, the oil and gas industry needs to **implement** immediate **emissions measurement** and **data management systems** to better understand its inventory and regulatory risk profile, then to complete low-cost compliance measures. As a result, significant public and private funding and other support mechanisms for RD&D and technology development have been invested into these activities over the most recent couple of years. For example, the final Federal and draft Alberta regulations indicate that "alternative screening" leak detection technologies are eligible as a compliance mechanism, assuming equivalent outcomes. Little more detail is known at this time; however, it provides a window of opportunity for new and emerging technologies to fill the void of uncertainty. Consequently, the market is seeing an influx of technologies being developed in this area (e.g. truck mounted sensors, drones, fixed wing aircraft, and satellites). Each of these technologies requires extensive testing and data controls.

There is some urgency, however, for industry to determine what these "alternative" technologies are. The timelines associated with methane regulations in Canada are immediate, as both the Federal and Alberta provincial regulations are set to come into effect as soon as 2020.

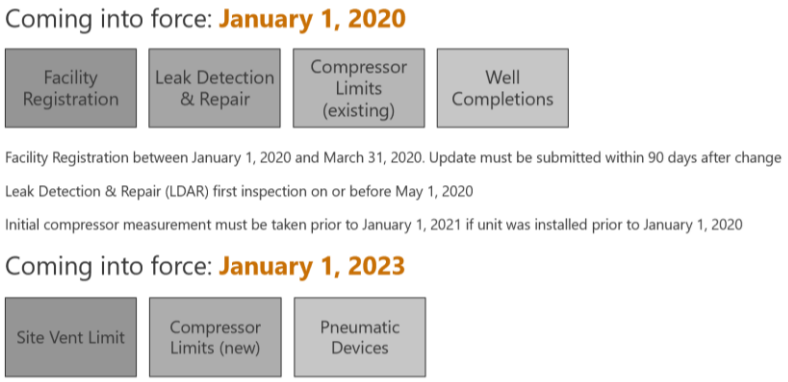

Figure 2-4: Environment & Climate Change Canada Methane Regulation Timelines

Further to these short timelines, Alberta has indicated it will implement a mandatory review process in the 2021/2022 timeframe to evaluate the effectiveness of the regulation and to consider regulatory adjustments resulting from emerging emissions management technologies. Specifically, they will consider making changes to regulations if there is evidence of available lower-cost emission reduction and/or leak detection/screening alternatives. **A robust repository of emissions reduction technology performance data will be paramount to this process.** This drives the need for immediate commencement of emissions planning and reporting to the relevant regulators/government, therefore deployment of data collection and management systems are on critically short timelines.

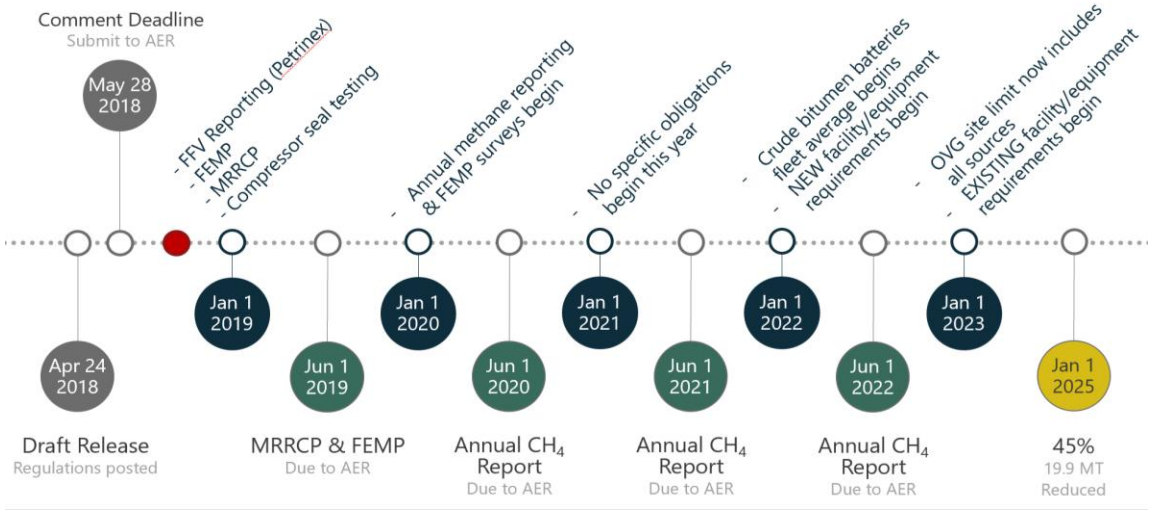

Figure 2-5: Alberta Draft Methane Regulation Timelines

2.1.3 Canada's National Emissions Inventory

In consideration of these new methane emissions regulations, evaluating the National Emissions Inventory provides insight into the areas of opportunity for capacity building in the emissions management ecosystem in Canada. Although emerging research is suggesting that some source categories are not accurately reflected in the inventory resulting in limited ability to assess impact of increased innovation, each of the methane emissions source categories shown in Figure 2-6~~Figure 1-6~~ have different challenges and opportunities for mitigation on different timescales.

Methane regulations in Canada have largely been designed with an understanding of **reduction achievability** and **data reliability** to assess compliance impacts and cost implications to industry. Future capacity building into the emissions RD&D and technology testing landscape should consider similar parameters. Notably, some **source categories have more readily available solutions and require fewer technology advancements than others**. Other source categories have a higher variance in quality of baseline data (estimates are used to calculate the national inventory over measured volumes) and therefore require advancements in **measurement technologies** more than **mitigation technologies**. Capacity building in the Canadian emissions testing facility system must consider these factors on both a **short and long-term timeframe** as growth in deployment of mitigation technologies will achieve

reductions today, while deployment of emissions measurement and alternative technologies will improve our ability to quantify source categories and see benefits farther into the future.

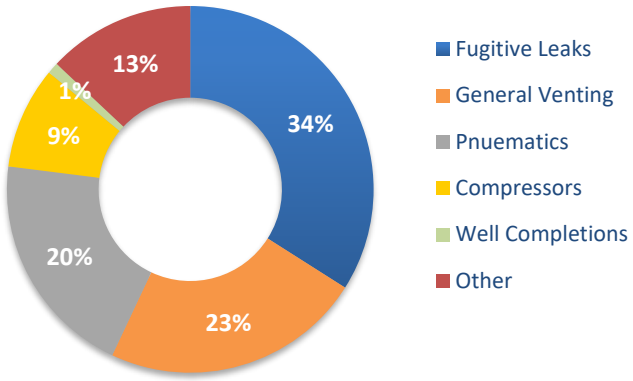

Figure 2-6: Canada's 2014 National Methane Emissions Inventory[4]

The three largest sources of methane emissions in Canada, "General Venting", "Fugitive Leaks" and "Pneumatics" are also the sources with the most data uncertainty. Venting from tank tops is highly uncertain as measurements are challenging and modelling is often used to estimate volumes. Fugitive leaks are more well-known but the inventory is largely incomplete as only partial data is currently available due to a lack of regulatory requirements to collect the information. Pneumatic device emissions are also highly uncertain as both measurements and inventories are incomplete. Further, there exists a variance in Canada's estimated venting and fugitive emissions profile identified by multiple reports recently completed by academia and other stakeholders[5]. Nonetheless, **these shortcomings alone present an opportunity to expand emissions measurement capacity** in Canada and provide a view of the source categories requiring the most attention regarding technology development (measurement and mitigation) and deployment to ensure low-cost emission reductions are achieved.

Of note here is that the largest emissions source in Canada (fugitive leaks) is also the most contentious area of the regulatory development process and largely the most uncertain data component of the national inventory. Consequently, federal and provincial regulations have allowed for some flexibility in the alternative testing methodologies, however the details characterizing these methods/technologies remain unclear[6].

[4] From Environment and Climate Change Canada

[5] Recent studies of Canada's GHG emissions include those completed by EDF, University of Toronto, AER, Clearstone Engineering and Greenpath, among others.

[6] University of Calgary noted in response to this study that it has been commissioned to complete a study that helps to identify "equivalency" in alternative leak detection technologies.

2.1.4 Funding Mechanisms

A review of the current funding mechanisms that support the emissions management RD&D and technology testing capabilities in Canada will further inform the decision about where and when collaboration and capacity building can be implemented.

Table 2-1: Overview of Current Funding Mechanisms in Canada As of December, 2018[7]

Oversight	Mechanism	Funds Available
Alberta Innovates	Climate Change Innovation & Technology Framework (CCITF)	$94 MM
Alberta Innovates	Clean Technology Business Innovation Voucher Program	$3 MM
Energy Efficiency Alberta	Custom Energy Solutions	$2 MM
Energy Efficiency Alberta	Green Loan Guarantee	$400 MM
Energy Efficiency Alberta	Methane Emission Reduction Program	$5 MM
Environment and Climate Change Canada	Low Carbon Economy Challenge	$500 MM
Government of Alberta	Carbon Competitiveness Incentives Regulation	Offsets – Market Price
Government of Alberta	Alberta Energy Innovation Fund	$1.4 B
Government of Alberta	Methane Emissions Reduction Program	$250,000 per facility, per fiscal year[8]
Government of British Columbia	Clean Infrastructure Royalty Credit Program	$19 MM
Government of British Columbia	Part 3 Agreement for Low Carbon Fuels in British Columbia	$Offsets – Market Price
Innovation, Science and Economic Development Canada	Accelerated Growth Service	$NA
Natural Resources Canada	Clean Growth Program	$155 MM
Natural Resources Canada	Energy Innovation Program	$49 MM[9]
OGCI Climate Investments	Oil and Gas Climate Initiative (OGCI)	$20 MM

The funding programs described by the partial list in

Table 2-1~~Table 1-1~~ are deployed in varying jurisdictions with oversight from either national or provincial governments. The success of any program depends on the speed and accuracy with which the investment dollars are sent out the door. To that end, AI and NRCan can review each program's success to date to help inform their capacity building design criteria. Understanding program shortcomings will ensure the same issues are not repeated. Additional work may be required to identify details of each program and overlay the current targeted investment areas with the National Emissions Inventory, the Canadian regulatory landscape, and the gaps identified in this report to determine core capacity building opportunities. For example, a probing question to ask is: "How much time and how many resources are

[7] This is not an exhaustive list and does not necessarily reflect funding that is specifically earmarked for emissions management RD&D and technology testing.

[8] For oil and gas facilities operating in Alberta that do not exceed 40,000 barrels of oil per day.

[9] Over 3 years from April 1, 2016 to March 31, 2019

being allocated into research, development and demonstration versus actual deployment of readily available technologies and how is the performance data being collected?".

2.1.5 Stakeholder Benefits

The final piece of background information to consider relates to understanding the core stakeholders within the ecosystem and the benefits to each group based on their needs. **Identifying common interests will ensure that capacity building is maximized and affecting core system needs.** A summary of these benefits is included in Table 2-2~~Table 1-2~~ below. This information is used as guidance for the review of the questionnaire information collected in this report.

Table 2-2: Stakeholder Benefits of Emissions Testing Capacity Investment

The background information presented in this section may require further research to paint a complete picture of system impacts. However, this information is useful for the current report when completing a gap analysis and opportunity assessment of the emissions management RD&D and technology testing capacity in Canada. Connection to these five components will be made throughout the report, when appropriate.

3 METHODOLOGY

The following table demonstrates five key criteria used as guidance for the development of the questionnaire completed for this report as well as a list of key identifiers used as guidance during data analysis.

Table 3-1: Questionnaire Guidance

	Criteria		Analysis
A	**Geographical**: National Distribution	→	Linkages (Current & Prospective Interconnection)
B	**Emissions**: Types & Sources	→	Field Data & Systems & Access
C	**Technology**: Types & TRL Levels	→	Current vs. Emerging
D	**Facilities**: Types (Physical or Non-Physical)	→	Capabilities & Limitations
E	**Funding**: Sources & Coverage	→	Investment Objectives & Opportunities

A. What is the **geographical** distribution of emissions testing facilities in Canada and how can they be linked to improve the efficiency of the ecosystem?

B. What type of **emissions** coverage does the system currently have? What is the state of the data collection infrastructure?

C. What **technologies** are being tested and how? How is the system servicing readily available technologies versus emerging technologies? Current technology requires baseline measurement while emerging technology requires field testing – identify these variances in the system.

D. Details of the current emissions testing **facilities** infrastructure will help determine the limitations of the current ecosystem and provide insight into the opportunities for improvement.

E. How are the current testing facilities funded and where are there opportunities to leverage current **funding** or fill gaps in the funding coverage?

The steps taken to complete a detailed, Canada-wide mapping exercise and gap analysis of facilities, infrastructure, assets, capabilities and expertise across the oil and gas emissions management value chain are outlined in this section. The process is demonstrated in Figure 3-1~~Figure 2-1~~. The top (orange) half of the figure represents the project set-up and data collection phases, while the lower (blue) half represents the assessment and report portion of the project. Collaboration with Alberta Innovates and Natural Resources Canada throughout the project duration ensured the process was in-line with expectations and needs.

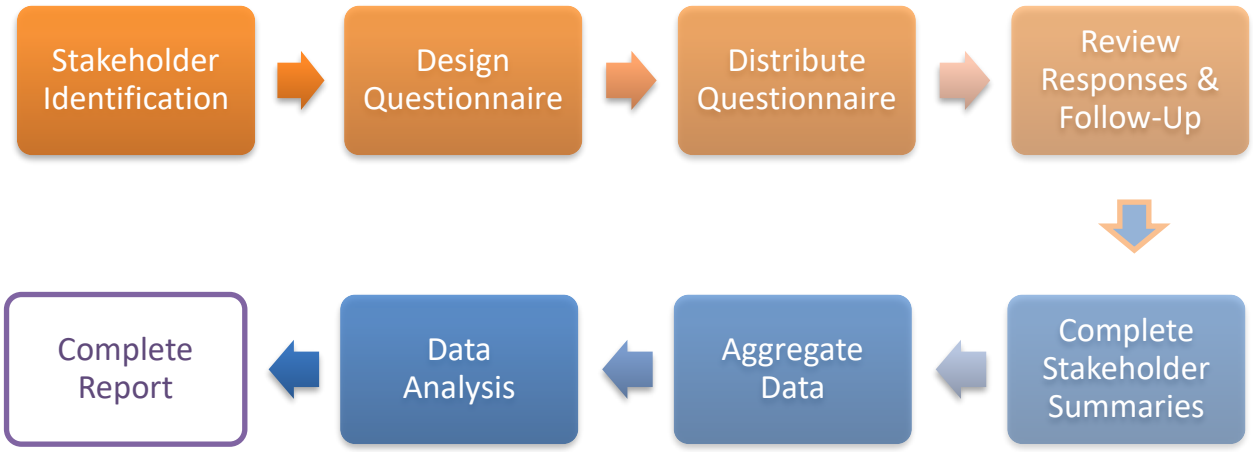

Figure 3-1: Project Process

Stakeholder Identification – Stakeholders were identified through discussions between AI, NRCan, Delphi and Modern West Advisory, based on relative knowledge, experience, and connection to the emissions management RD&D and technology testing landscape in Canada.

Design Questionnaire – A web-based questionnaire was designed that allowed for easy access to stakeholders, multiple individual responses within each organization, and intelligent logic to determine question types during questionnaire completion. This method improved the likelihood of accurate responses based on the type of stakeholder completing the questionnaire. A complete list of the questions used in the questionnaire is presented in APPENDIX A ~~Appendix~~ B.

Distribute Questionnaire – Stakeholders were contacted via email and in-person to distribute and review questions and concerns each stakeholder might have ahead of completing the questionnaire. Follow-up emails were sent no later than 72 hours following initial questionnaire distribution.

Review Responses & Follow-Up – Each questionnaire response was reviewed upon submittal to ensure completeness. Where responses were deemed "light", follow-up emails, phone calls, and in-person meetings were initiated to maximize data collection.

Complete Stakeholder Summaries – The information collected via the questionnaire was compiled with some edits into stakeholder-specific "summary reports". Each of these summary sheets is presented in APPENDIX E ~~Appendix C~~.

Aggregate Data – The raw data was extracted from the questionnaire responses and converted to graphical representations for improved analysis and interpretation. Early trends were identified, and some stakeholder follow-up was conducted to test the trends, ensure questionnaire responses were properly interpreted, and to maximize data analysis. Key aggregated data is presented in Sections 3 and 5~~4~~ of this report, while the remaining data points are presented in **Error! Reference source not found.**~~Appendix D~~ and the accompanying Excel file.

Data Analysis – The questionnaire responses, summary sheets, aggregated data, and stakeholder follow-up feedback were evaluated for trends, gap analysis, and opportunity identification.

Complete Report – The above data, along with the information provided in Section 2.1 above~~1.1 above~~, were compiled into this report for consideration by Alberta Innovates and Natural Resources Canada.

The methodology applied to the research for this report culminates in an analysis of the **capacity** and **gaps** identified in the current Canadian emissions RD&D and technology testing landscape as well as needs identified by stakeholders to help determine **recommendations** in areas of need.

4 RESULTS

Upon receipt of the questionnaire responses, analysis was performed using both quantitative and qualitative methods. When possible, graphical analysis was employed to identify trends that are useful for informing capacity building decisions in the emissions RD&D and technology testing ecosystem in Canada.

Following the comprehensive stakeholder identification and questionnaire development process, SurveyGizmo links were distributed in October 2018 to 27 individuals from 26 different organizations (two surveys were sent to the National Resource Council). A total of 26 responses were received, including those that were complete or partially complete. Partially complete responses include those where large portions of the questionnaire were left blank and additional information was not received after multiple attempts to follow up with the stakeholder. Only one questionnaire received no response (Environmental Defense Fund). Overall, 23 of 27 responses were collected in time to be included in the quantitative analysis of this report, representing an 85% response rate. Three of the remaining four questionnaire responses are included in the summary documents, but not in the graphical analysis contained within this report. The list of stakeholders who received the survey, along with indication of the status of their response, is provided in Table 4-1~~Table 3-1~~ below. Further information on the stakeholder identification process can be found in APPENDIX A ~~Appendix A - Stakeholder List~~.

Table 4-1: Final Questionnaire Response Included in Analysis, by Stakeholder Group

	Industry / Association		Post-Secondary Institution		Clean Tech Developer		RD&D Facility
C	Alberta Energy Regulator (AER)	P	University of Alberta (UofA)	C	FLIR	C	Natural Resources Canada CanmetENERGY
C	BC Oil & Gas Commission (BCOGC)	C	University of Calgary (UCalgary)	C	Kairos Aerospace	C	C-FER Technologies
C	Canadian Association of Petroleum Producers (CAPP)	C	Carleton University	C	MultiSensor Canada	C	Clearstone Engineering
P	Petroleum Technology Research Centre (PTRC)	C	University of Guelph (UGuelph)			C	CMC Research Institutes (CMCRI)
I	Environmental Defence Fund (EDF)	C	Northern Alberta Institute of Technology (NAIT)			C	Drayton Valley Clean Energy Technology Centre (DV-CETC)
P	Emission Reduction Alberta (ERA)	C	Southern Alberta Institute of Technology (SAIT)			C	Innotech Alberta
P	National Research Council (NRC)	C	St. Francis Xavier University (StFX)			C	Saskatchewan Research Council (SRC)
C	Pembina Institute						
C	Petroleum Technology Alliance Canada (PTAC)						

C = Complete Response; P = Partial Response; I = Incomplete Response

Notes:

a. The lack of responses is not anticipated to significantly skew the results as they only represent 15% of all respondents.

b. Responses from University of Alberta, EDF, NRC-lab and PTRC were not received in time to be included in the graphs and tables provided in this section.

4.1 Emissions Management RD&D and Technology Testing Network Map

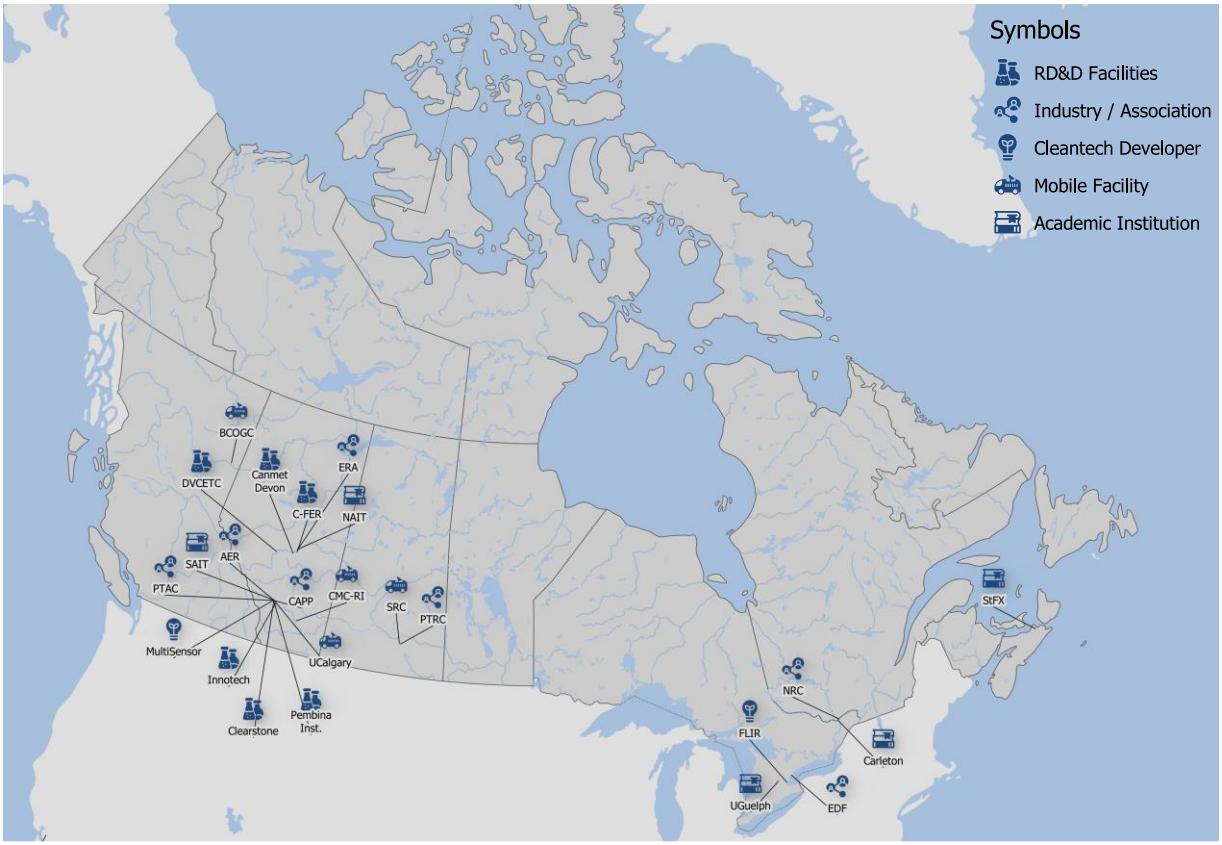

Figure 4-1: Map of Canada's Emissions Management RD&D and Technology Testing Ecosystem.

4.2 Facility Features

The following section contains key data points and graphical representations of the aggregate responses relating to stakeholder facilities. The remaining graphical analysis is featured in **Error! Reference source not found.**~~Appendix D – Additional Results Visuals~~. Relevant graphs, tables, charts and qualitative assessments are included below along with the relevant Survey Gizmo questions used to complete the analysis (blue font).

4.2.1 Physical Facility

Q6: Does your organization have a physical facility where you undertake emissions management RD&D?

16 of the respondents (70%) identify themselves as a physical facility where they undertake emissions management RD&D. All seven of the Industry/Association classified stakeholders indicated that they do not have a physical facility.

While many respondents identify as a physical facility, it should be noted that there is significant variance amongst these facilities, notably in capacity to serve the emissions testing market (e.g. equipment on site, controlled testing versus field testing, cost, eligible technologies/methodologies to be tested, etc.), and in the type of physical testing infrastructure on site. It is clear when analyzing the full set of responses that the definition of a physical facility was subjective amongst respondents. Although not included directly in the questionnaire, reading the responses indicate the following information: three stakeholders have mobile emissions testing units (SRC, UCalgary, CMCRI[10]), other stakeholders have outdoor labs (Canmet, Carleton, CMCRI, InnoTech) or indoor labs (C-FER Technologies, InnoTech, StFX, UGuelph, FLIR), whereas others complete research in third-party labs or facilities (C-FER Technologies, SAIT, NAIT, Kairos, MultiSensor, Clearstone).

This variety in facility types contributes to a range of capabilities in the Canadian emissions management network/system, however, some additional clarity is required to fully understand the actual number of physical facilities in Canada. Notably, some stakeholders share the use of physical facilities and/or indoor testing labs, demonstrating that facility collaboration is a model currently in use. For example:

- University of Calgary uses the Field Research Station (FRS) at CMCRI's site in Alberta;
- CAPP employs the University of Calgary mobile testing units for their FEMP-EA initiative;
- CanmetENERGY and Carleton share the Large Scale Flaring Lab at Carleton University in Ottawa;
- CanmetENERGY has custom designed flow controllers at the Carleton flare lab that can replicate field flare fuel chemistries (C1-C10) from Canadian and international sites for local testing of technologies for domestic and export applications;
- Clearstone Engineering uses SAIT's research lab in Calgary;
- MultiSensor is currently completing testing at SAIT and previously at the Natural Gas Technologies Centre[11] in Montreal.

These shared facility/data collection relationships should be evaluated more closely to discuss strengths and opportunities for improvement as this work may identify capacity building opportunities.

[10] BCOGC also indicated that they have mobile testing equipment but did not classify this equipment as a physical facility.

[11] http://www.ctgn.qc.ca/en/ After responses were collected it was evident that this is a facility that was missed in the stakeholder group identified for this research.

Capacity Building Considerations

With at least 13 physical emissions RD&D and technology testing facilities already in Canada, there is an opportunity to support collaboration between these and other engaged stakeholders. A better understanding of the current **collaboration structures** in place, associated costs and limitations (e.g. seasonal), and most importantly, the **data sharing** agreements amongst stakeholders (e.g. how does data flow from one stakeholder to the next) will support informed choices on capacity building. Some other questions to consider include:

- How can the current facility sharing agreements be leveraged to be more inclusive or to more widely distribute usage and to manage the collected data on site?
- Are there limitations to government funded facilities versus privately funded facilities?
- Does the definition of "emissions testing facility" require clarification?
- What are the limitations to access (location, cost), testing capabilities (physical attributes, system needs based on emerging technologies), and **data sharing**?
- How will **data sharing** limitations be overcome? All relevant stakeholders require access to field level data in order to make well-informed decisions. However, risks to open data sharing hinges primarily on Industry's concern over performance liabilities, as well as Post Secondary Institutions' willingness to share unpublished information. Physical facility sharing is only one component of prospective collaboration models.

4.2.2 Focus Areas

Q9: What types of emissions does your organization focus on? Are you involved in their quantification, characterization, or transportation?

There are a wide variety of emissions tested throughout the emissions management RD&D and technology testing ecosystem in Canada. Figure 4-2~~Figure 3-2~~ below demonstrates the overall activity of each stakeholder group by gas type.

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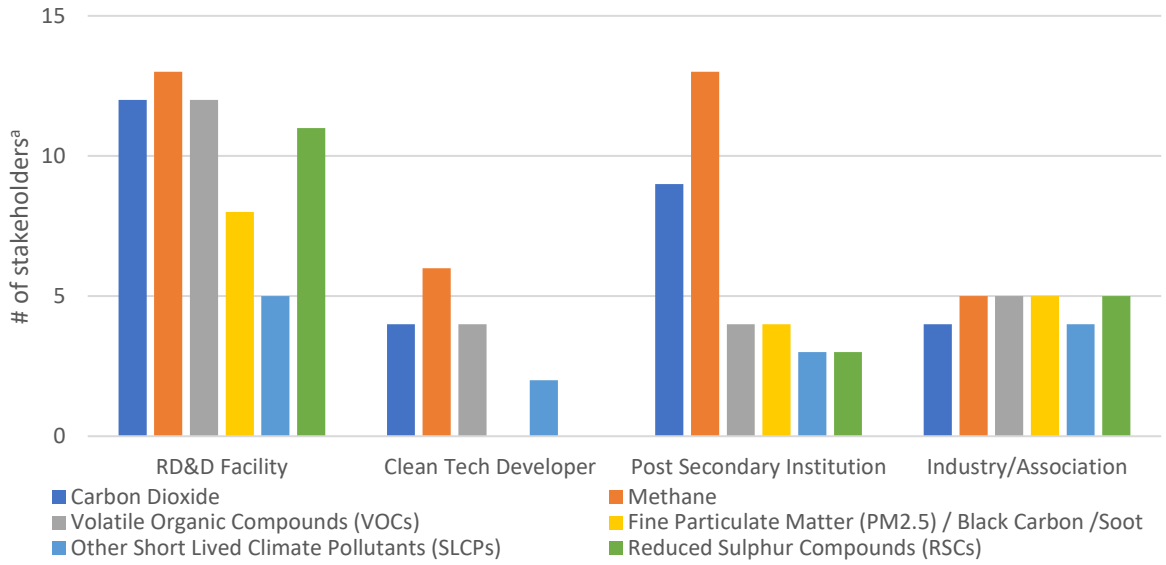


Figure 4-2: Emissions Focus by Organization Type

Notes:

a. The number of stakeholders (y-axis) can be greater than the number of respondents because stakeholders are able to select whether they are involved in the characterization, quantification, transportation, or other activity for each emission type.

b. "Other" emission types identified in the responses include: ammonia (MultiSensor).

Methane is the most prevalent emissions focus area irrespective of Stakeholder Group, followed by **CO_2** and **VOCs**.

GAP: Reduced Sulphur Compounds (RSCs), Particulate Matter 2.5 and other Short-Lived Climate Pollutants (SLCPs) are less of a focus area for the respondents. This is most apparent within the Clean Tech Developer group, who did not indicate that they were involved in any RD&D activities related to RSCs and PM2.5 (note: this only included three total stakeholders). BC OGC is the only stakeholder that is involved in monitoring PM2.5 and other types of gas releases from oil and gas activities (with a focus in Northeast BC). The Industry/Association group indicates uniform RD&D for across all emission types.

Capacity Building Considerations

The emphasis on **methane emissions** is largely a result of the incoming methane regulations at the federal and provincial levels. These regulatory requirements are creating the market for emissions reduction measurement and mitigation technologies. However, it should be noted that other climate change regulations in Canada are interconnected with methane emissions reduction activities and reporting requirements specified in the regulations. For example, benzene, SLCPs, NO_x and VOCs are each associated with Federal and/or Provincial regulations outside of the methane regulations. Compliance activities related to one emissions source may directly affect performance regarding another emissions source (e.g. NO_x and CH_4 in compressor engine management). Capacity building in Canada's emissions management RD&D and technology testing capacity should consider this interconnection.

Further, the national inventory has been identified as having a significant gap when it comes to methane emissions from oil and gas operations. Therefore, it is not surprising that the current emissions testing ecosystem is focused in this area, especially given readily available emission reduction technologies currently available to industry. However, it is widely known that a higher quality and quantity of data is needed for industry, regulators, government, and ENGOs to find alignment on where those opportunities exist and what the associated cost is. This shortcoming also correlates with the number of funding mechanisms providing investment dollars into methane emissions measurement and reduction activities in Canada, and development and deployment of emerging clean technologies.

Table 4-2~~Table 3-2~~ identifies the RD&D focus relative to quantification, characterization, and transportation of different emissions types for each stakeholder. **Quantification** is defined as determining the volume of emissions being released, **Characterization** is defined as emission speciation and properties, and **Transportation** is defined as dispersion of gaseous and particulate emissions. This table also highlights the technology readiness levels (TRL) of stakeholders. TRL descriptions are captured in Appendix E.

The information collected here indicated that Quantification and Characterization of methane and carbon dioxide are the most prevalent focus areas of RD&D activities across stakeholder groups. PTAC, SRC, Clearstone, CanmetENERGY, and Carleton University are the stakeholders most engaged in Quantification, Characterization and Transportation activities (inclusive of the most diverse set of gases).

GAP: Transportation testing is the least prevalent activity in each category. Exploring the ecosystem's need for further activity in this space will provide better insight into the need for capacity building.

Table 4-2: Quantification (Q), Characterization (C), and Transportation (T) RD&D by Emission Type

		CO2			CH4			VOC			Particulate			SLCPs			RSCs		
Stakeholder	**TRL**	**Q**	**C**	**T**	**Q**	**C**	**T**	**Q**	**C**	**T**	**Q**	**C**	**T**	**Q**	**C**	**T**	**Q**	**C**	**T**
Alberta Energy Regulator	9																		
BC Oil and Gas Commission	9							✓			✓						✓		
CanmetENERGY	1-9	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓				✓	✓	✓
CAPP	5-9	✓			✓			✓			✓			✓			✓		
Carleton University	1-8	✓	✓		✓	✓		✓	✓		✓	✓		✓	✓				
C-FER Technologies	3-8							✓											
Clearstone Engineering	1-9	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	
CMC Research Institute	3-7	✓	✓		✓	✓											✓	✓	
DV CETC	Respondent has identified this as not applicable due to lack of funding support for these activities.																		
Emissions Reduction Alberta	6-9				✓														
Environmental Defense	No Response Yet																		
FLIR	9	✓	✓		✓	✓		✓	✓					✓	✓				
InnoTech	5-8		✓	✓		✓	✓		✓	✓								✓	
Kairos Aerospace	8				✓	✓													
MultiSensor Canada	3-9	✓	✓		✓	✓		✓	✓										
NAIT	4-9																		
NRC	2-8																		
Pembina Institute	None Provided																		
Petroleum Technology Research Centre	None Provided																		
PTAC	1-9	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SAIT	6-7				✓	✓	✓												
Saskatchewan Research Council	3-8	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
StFx University	1-8		✓	✓	✓	✓	✓											✓	✓
University of Alberta	No Response Yet																		
University of Calgary	1-9	✓			✓			✓			✓								
University of Guelph	1 – 3; 7 - 9	✓		✓	✓		✓												
TOTAL COUNTS	**N/A**	**10**	**10**	**5**	**15**	**12**	**8**	**11**	**8**	**5**	**8**	**5**	**3**	**5**	**5**	**2**	**7**	**7**	**4**

Notes:

a. Totals do not represent activity within the same TRL or even oil and gas activity area. This is used to provide an approximate estimate of emissions type RD&D focus within the ecosystem.

4.2.3 Third-Party Testing

Q12: Does your organization provide third-party testing/validation/certification of technologies?

Q13: What type of technologies can you validate and at what scale?

Q14: Please provide a brief description of associated procedures/equipment used.

Overall, nine out of the 16 stakeholders (those considered to be physical facilities) perform third-party testing, validation, or certification of technologies. This includes five of the seven RD&D Facility classified stakeholder organizations and four Post-Secondary Institutions. It should be noted that the third-party testing capabilities at Post Secondary Institutions is limited given they are not dedicated third-party testing facilities and they are often looking to complete some of their own testing at other facilities given the limitations at their locations and their stated need to complete field-scale rather than lab-scale testing. The Clean Tech Developer category is comprised of the technologies requiring third-party testing, therefore none of them provide testing to outside parties. The Industry/Association group of organizations are typically the recipients or enablers of the testing results. Oil and gas producers are looking for these testing results when considering technology deployment, while government and regulators require the results to design appropriate policy, regulations, and funding mechanisms.

Table 4-3: Summary of Stakeholders Providing Third-Party Testing

Stakeholder		High level description of third-party testing capabilities

1	SASKATCHEWAN RESEARCH COUNCIL (SRC)	• Can test and validate technologies geared toward measurement, reduction, capture and conversion for low- and high-volume emission sources
		• Validate existing and emerging technologies at the bench, pilot, and field scales
		• Emission modeling services are available in-house
		• At the field scale, the mobile CeDER trailers are equipped to test and validate most types of emissions reduction systems at industry sites, including:
		  ○ Vapour Recovery/Treatment: Vapour Recovery Unit; Vapour Recovery Tower
		  ○ Flare/Combustion Solutions: Utility and Smokeless; Flares; Incinerators
		  ○ Capture/Convert Technologies: CNG/LNG/NGL; Gas to Liquid; Gas to Power
		  ○ Monitoring Systems: Static and Mobile Systems; UAV Systems; LDAR Programs
		  ○ CeDER laboratory and mobile facilities are modular, meaning that the instrumentation and equipment required for each project can be tailored to the technology being tested

2	ST. FRANCIS XAVIER UNIVERSITY	• Assess measurement methodologies • On occasion they work with technology developers to validate their techniques, and have done so for truck-based detection, and are currently working with drone, aircraft, and satellite tech developers to help them build their validation experiments • Often work with controlled release, but also real infrastructure/emissions as defined by opportunity
3	CMC RESEARCH INSTITUTES	• Primarily pilot and field scale, but also for some modeling / simulation studies • CMCRI has had discussions with Saskatchewan Research Council about potentially hosting their CeDER validation facility at its FRS
4	CARLETON UNIVERSITY	• Provides third-party testing / validation / certification of technologies in the form of bench, pilot, field, and modelling (analytics) • Extensive combustion emissions measurement capabilities, optical measurement instruments for gas-phase and aerosol/particulate species, field measurement equipment, unique experimental facilities, and analytics expertise

5	C-FER TECHNOLOGIES	• Provides verification services through the full spectrum from modeling and simulation to field demonstration:
		  ○ Computation Fluid Dynamics modeling to understand fluid movement and heat transfer
		  ○ Bench-scale tests to evaluate the performance of system components
		  ○ Full-scale laboratory tests to simulate technology performance in real-world conditions
		  ○ Pilot and field trial design and monitoring using custom-built instrumentation systems
		• Develops purpose-built testing equipment to simulate the flow, temperature, pressure, load and environmental conditions that the system must operate in.
		• Has specialized instrumentation systems and data processing to characterize the performance of the technology

6	CLEARSTONE ENGINEERING LTD.	• Equipped to provide validation services for all types of methane and some types of SLCP emission measurement and control technologies • Have a laboratory and research centre located in Calgary that features over $2 million in specialized testing, measurement and analysis equipment • Offer solutions at the bench, pilot, field and modelling/simulation levels • Developed a variety of software tools for modelling selected types of emission sources • Developed their own SCADA solutions and have their own proprietary system for performing process simulations

7	INNOTECH ALBERTA	• InnoTech Alberta's Vegreville Facility:
		  ○ Testing and validation of point sensors, tunable diode laser apparatus, emissions mapping tools and pipeline leak detection technologies
		• Alberta Carbon Conversion Technology Centre (ACCTC):
		  ○ Demonstration scale facility located adjacent to Shepard Energy Centre with blower and piping infrastructure to feed flue gas from the natural gas fired power plant to the ACCTC.
		  ○ ACCTC contains 5 outdoor test bays with total area of 125,000 ft^2. Each test bay is individually metered for natural gas use; electrical services and utility water use as well as a 400bbl (63.5m3) double-walled tank to hold liquid waste streams

8	NAIT	• Validate technologies related to industrial sensors (emissions monitoring in the field), process engineering (e.g. treatment of natural gas at the wellhead) carried out at the bench scale in NAIT's labs
		• Associated procedures/equipment used:
		  ○ Moisture sensors (inline measurements)
		  ○ Natural gas sensors (environmental and inline)
		  ○ Bench scale prototypes for testing natural gas desiccants and sweeting technologies
		  ○ Design and testing of field pilot equipment for testing membranes to treat raw natural gas

9	UNIVERSITY OF CALGARY	• Capacity to test methane sensing technologies designed for small (e.g., close-range/component-level devices) and very large (e.g., satellite systems) *leaks* • SENST's mobile testing equipment can be deployed anywhere with road access. Mobile sensing systems perform differently according to weather, terrain, and landcover

**More information regarding each stakeholders' validations of technologies and their scale and description of associated procedures/equipment used, please refer to each stakeholder summary sheets, available in APPENDIX E ~~APPENDIX E.~~

Capacity Building Considerations

It has been indicated throughout this study that oil and gas producers are critical to the emissions testing needs of the ecosystem due to the significant **gap in field-level testing** available to technology developers. Currently, some meaningful collaboration is occurring in regard to third-party testing. Post-Secondary Institutions are joining with Industry and Clean Teach Developers to test technologies in the field, then using appropriate academic modelling to evaluate the results (CAPP's FEMP-EA program, for example). The constraints to this work include the speed at which Industry can make facilities available to the program in concert with the capacity of the universities completing the analytics and the speed at which technologies can be deployed into the field. Furthermore, this program is focused on fugitive emissions technology and source identification only, which leaves many other parts of the emissions management system left to complete small-scale testing at the bench or pilot phase.

The FEMP-EA program also sheds light on a common obstacle to an effective RD&D and emissions testing ecosystem – **data sharing**. This is currently an issue that CAPP is working through with the participating universities and other organizations involved or keenly interested in the program (e.g. tech developers, regulators, etc.). Notably, there are data sharing risks and therefore constraints between academic institutions, technology providers, industry participants, and government/ regulators. This reiterates the need for close stakeholder collaboration throughout the process of these types of programs.

When looking at the best estimates of the national emissions inventory, it is no surprise that fugitive emissions are the focus area of CAPP and its members. But there is also an identified need for further testing on **tank emissions** (disaggregation between fugitive & vented volumes) along with **pneumatic device** performance and their associated emissions profile. While some funding initiatives like those offered by Alberta Innovates, Emissions Reductions Alberta, and Energy Efficiency Alberta are providing incentives to fill some of these testing/identification data gaps, there is a growing concern amongst stakeholders that the pace of testing for emissions quantification and emerging clean technologies may not be in line with the rapidly approaching regulatory requirements now in place in Canada for methane and some other short lived climate pollutants.

4.2.4 Emission Management Priorities

Q15: What emissions management priorities is your organization currently addressing?

The following figures provide a view of emissions management priorities for each of the organizations that responded to the questionnaire. Figure 4-3~~Figure 3-3~~ to Figure 4-6~~Figure 3-6~~ illustrate the emissions priorities for each stakeholder group and Figure 4-7~~Figure 3-8~~ illustrates the aggregated emissions priorities of all stakeholders.

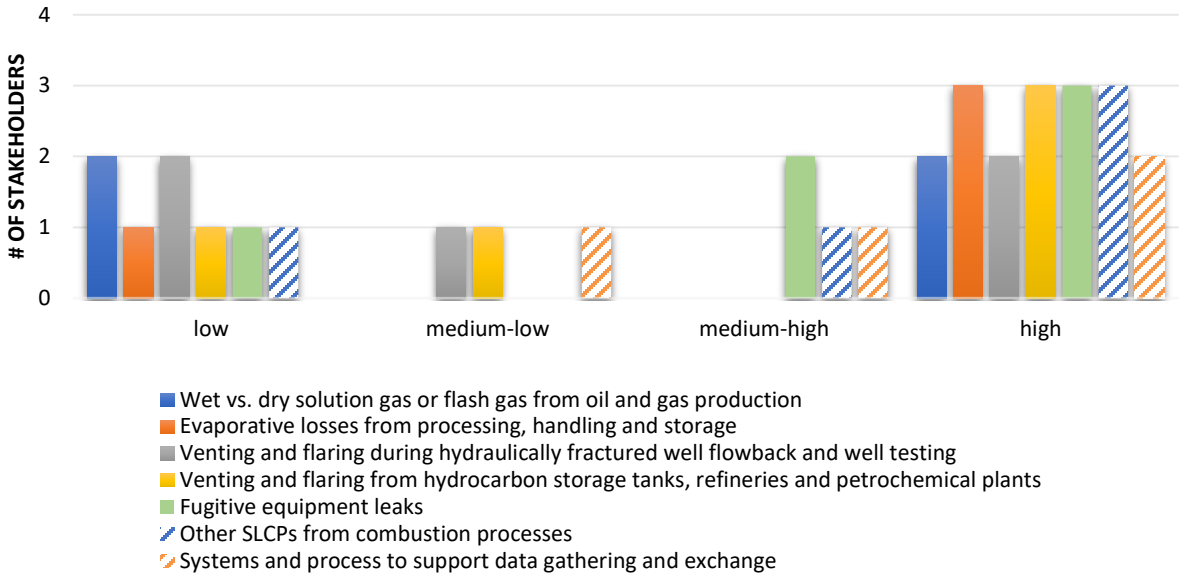


Figure 4-3: RD&D Facility Emissions Management Priorities

Notes:

a. "Other" priorities for RD&D Facilities include: leak prevention and detection in upstream and midstream operations; projects to reduce emissions by improving equipment and process efficiency (C-FER); technologies to reduce or utilize surface casing vent flow emissions; methane emissions from water wells and other facilities; natural background emissions; technology cross-validation using multiple methods (CMCRI).

Identification of the stakeholder priorities in this graph provides insight into areas where accelerated technology development and demonstration may be possible. **Therefore, additional research is required to identify a subset of the most promising technologies in these priority categories and to further investigate capacities from a techno-economic perspective.** The results of such analysis could be used for future capacity building considerations and decisions regarding the use of these technologies.

"Wet vs. dry solution gas or flash gas from oil and gas production" and "venting and flaring during hydraulically fractured well flowback, and well testing" are the most polarized categories of the emissions management priority areas, with about half of the RD&D Facilities ranking them as a high priority and the other half ranking them as a low priority. Overall, "fugitive equipment leaks" was the category identified most often as a priority area (six times) while "venting and flaring from hydrocarbon storage tanks, refineries and petrochemical plants" was second most frequent (five times) along with "other SLCPs from combustion processes".

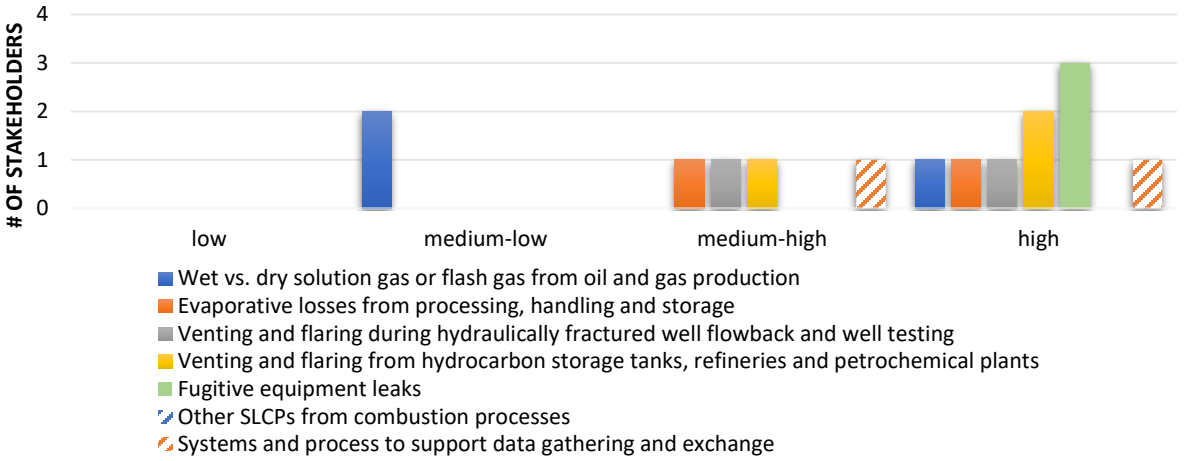


Figure 4-4: Clean Tech Developer Emissions Management Priorities

Notes:

a. "Other" priorities for Clean Tech Developers include: Leak inspection as well as intermediate and long-term emissions monitoring, including monitoring of intermittent methane sources (MultiSensor).

The three Clean Tech Developers have all identified "fugitive equipment leaks" as the highest priority for their emission management RD&D work, with "venting and flaring from hydrocarbon storage tanks, refineries and petrochemical plants" as a close second, which is consistent with the two highest priority areas identified by the RD&D Facility stakeholder group.

Only "wet vs. dry solution gas or flash gas from oil and gas production" was considered lower than a medium-high priority.

GAP: "Other SLCPs from combustion processes" was not considered an applicable priority area for any of the three Clean Tech Developer respondents. This is partially due to the fact that only one Clean Tech Developer identified as being involved with SLCPs. Given the small sample size used for this report, it may be worth completing additional research with a broader range of Clean Tech Developers to corroborate this gap.

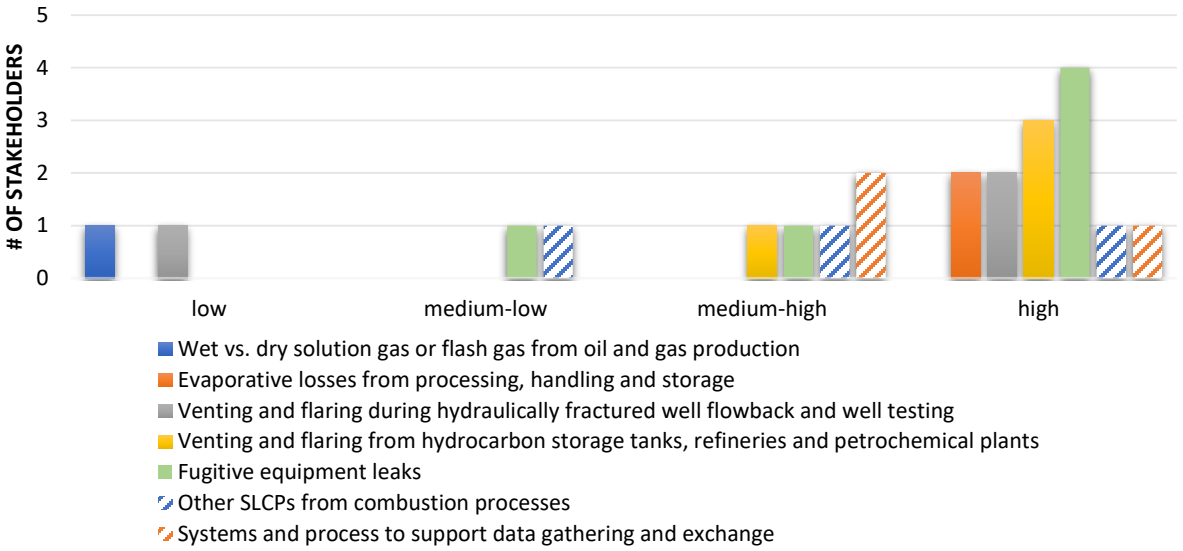


Figure 4-5: Post Secondary Institution Emissions Management Priorities

Notes:

a. "Other" priorities for Post-Secondary Institutions include: quantifying emissions from mining facilities that come directly from land and tailings ponds, not necessarily from on-site equipment (University of Guelph); and contributions to regulatory and standards development (Carleton).

b. Numerous Post-Secondary Institutions identified priority issues as N/A. For example, NAIT focused on developing natural gas conditioning technologies that did not fit the priority area options provided in this questionnaire.

Similar to Clean Tech Developers, Post-Secondary Institutions consistently identified "fugitive equipment leaks" as a high priority for their emission management RD&D work, with "venting and flaring from hydrocarbon storage tanks, refineries and petrochemical plants" as a close second.

GAP: Most Post Secondary Institutions did not consider "wet vs. dry solution gas or flash gas from oil and gas production" and "evaporative losses from processing, handling and storage" as applicable priority areas for their organization. It may be valuable to understand why these areas are low priority as this type of research may identify opportunities for system capacity building.

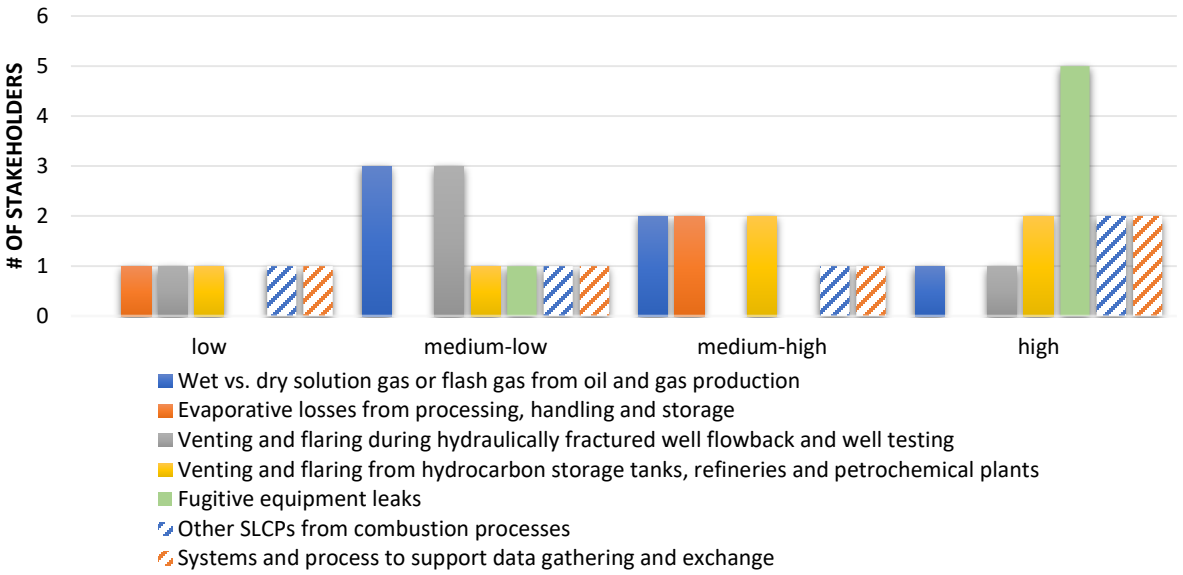


Figure 4-6: Industry/Association Emissions Management Priorities

Notes:

a. The BC Oil & Gas Commission stated that their organization is focused on all aspects of emissions management for the O&G sector and selected N/A for all available response options.

Industry/Association stakeholders most frequently identified "fugitive equipment leaks" as a high priority for their organization, by a significant margin over the other options. Given the diverse nature of stakeholders within this category (producers, technology enablers, and regulators), this information is indicative of where the short-term focus is within the emissions management ecosystem, as industry and regulators in particular, are most focused on immediate, cost-effective emission reductions in the field. Other priority areas were more evenly spread across the industry associations.

GAP: "Evaporative losses from processing, handling, and storage" was selected the least often as a priority for Industry / Associations.

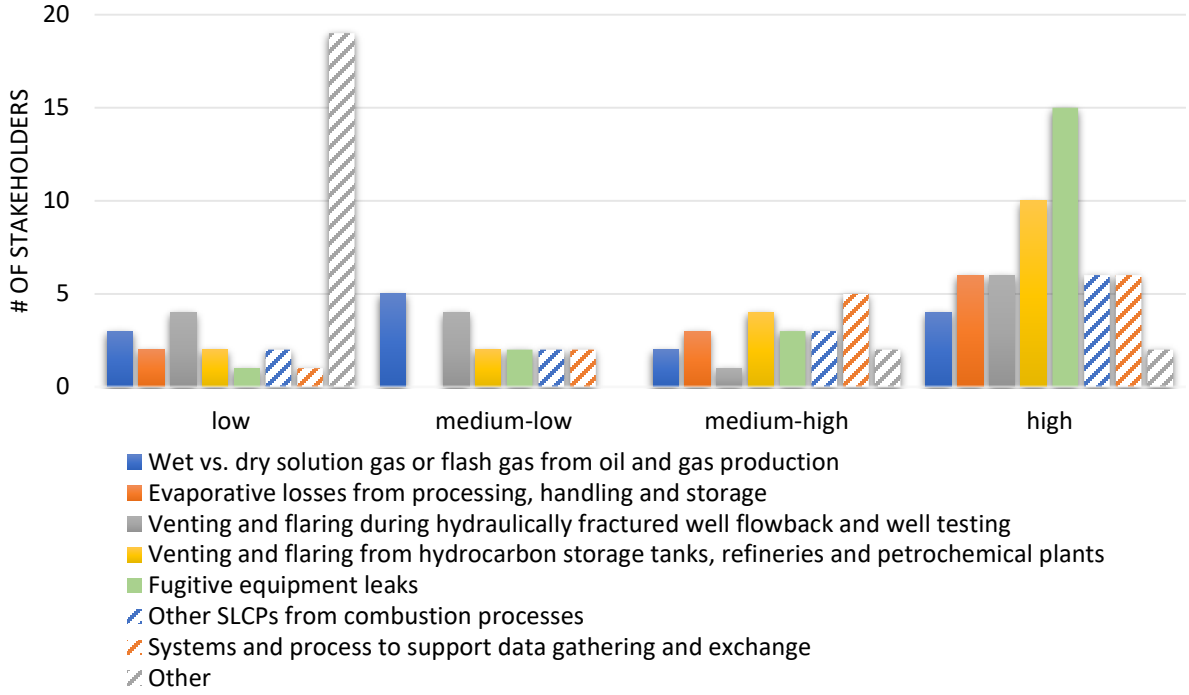


Figure 4-7: Aggregated Emissions Management Priorities for All Stakeholders

Notes:

a. Other emission management priorities have been identified for organization type figures above. In general, other priorities are not considered top priorities for each of the respondents.

When aggregating all responses from participating stakeholders, “fugitive equipment leaks”, and “venting and flaring from hydrocarbon storage tanks, refineries and petrochemical plants” were most frequently identified as a top priority. “Systems and process to support data gathering and exchange” and “other SLCPs from combustion processes” are next most frequently considered a priority emissions management focus area, followed by “evaporative losses from processing, handling and storage” and “venting and flaring during hydraulically fractured well flowback and well testing”.

Although there are priority areas that are currently receiving more attention, collectively, stakeholders have indicated they are focusing on all of the priority options provided in the questionnaire. This suggests that there are few, if any, emissions management RD&D and technology testing categories that appear to be overlooked amongst the stakeholders perhaps other than “leak prevention and detection in upstream and midstream operations”. As such, many stakeholders indicated other priority areas that were not provided as options in the questionnaire responses, but for the most part these were ranked as lower priorities. On one hand, this might suggest that the most relevant priorities were identified in this question, but if other options were provided, perhaps the results may have looked slightly different.

Capacity Building Considerations

The prioritization of "fugitive equipment leaks", and "venting and flaring from hydrocarbon storage tanks, refineries and petrochemical plants" by the stakeholders suggests that there may be more collaboration and technology advancement opportunities in these two areas to address GHG emissions in Canada in the short-term compared with the other areas. Getting a complete understanding of the **data collected** by the organizations involved in the testing of these categories will enable a more complete understanding of the emission reduction and capacity building opportunities across Canada. Furthermore, **measurement and quantification methodologies** are important to understand as they may vary across stakeholders.

Specific areas where collaboration and data sharing are viable could be identified through **regular workshops** (i.e. quarterly) where stakeholders active in these areas present their activities, results, and methodologies in a controlled environment. This would allow for stakeholders to release only the information they are willing and able to share but will also keep all stakeholders fully abreast of the most current research and results. It will enable close collaboration amongst stakeholders by bringing them together for focused discussions and networking, and will enable the ongoing identification of the most promising technologies/activities in GHG emissions reduction in Canada.

4.2.5 Source Categories

Q16. What emissions source categories is your organization currently addressing?

"Fugitives & LDAR", and "storage tank emissions" are most frequently identified as emissions source categories stakeholders are addressing. In general, this is consistent with the top priority areas ("fugitive emission leaks" and "venting and flaring from hydrocarbon storage tanks, refineries and petrochemical plants") identified in Section 3.1.4 above.

The categories are listed below from most frequently addressed to least frequently addressed. Perhaps not surprisingly, a similar trend was discovered with three of the four stakeholder groups, where Clean Tech Developers, Post-Secondary Institutions, and Industry/Associations generally prioritize source categories in a similar manner. Only RD&D Facilities had a somewhat erratic allocation within the source categories, perhaps indicating the diverse capabilities of emissions testing capacity in Canada. Also of note, is that Industry/Association stakeholders identified "compressors" and "pneumatic devices" as 2 of their top 3 most frequently addressed emissions source category (along with "storage tank emissions"), but on aggregate, those categories do not rank in the top five.

"Purging", "bitumen batteries", and "gas destruction" emissions source categories are not addressed as frequently in part because no Post Secondary Institution respondents are currently focusing on these emissions source categories. When consolidated, "other" emissions source categories rank higher than five of the pre-designated emissions source categories. However, these low-frequency categories are disparate and represent mostly unique emissions sources.

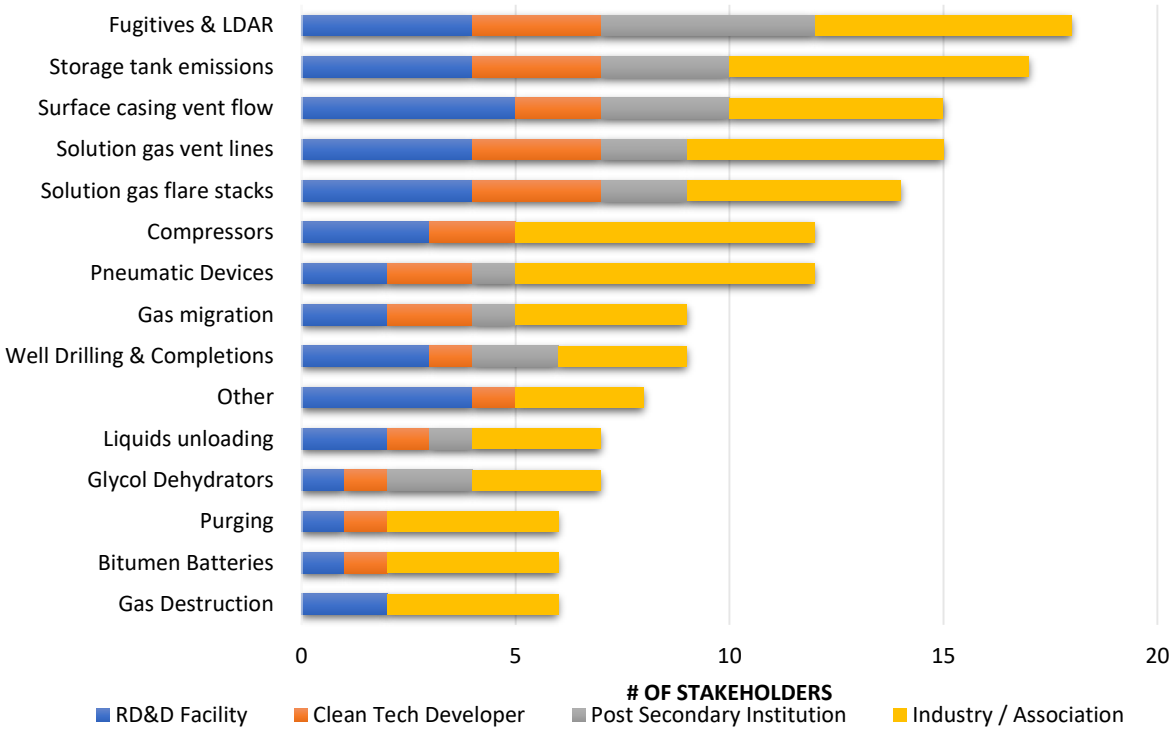


Figure 4-8: Emissions Source Categories Addressed by Stakeholders

Notes:

a. "Other" emissions source categories stakeholders are currently addressing include: pipeline leaks, steam utilization (C-FER); refinery and petrochemical flaring (Canmet); background natural emissions, noble gas tracers and migration indicators, natural gas in groundwater and water wells (CMCRI); landfill emissions, agricultural emissions, methane emissions from coal mines (Innotech); tailings ponds and mine face surfaces at oil sands facilities (Clearstone); meter leaks, plant maintenance (FLIR); distribution gas leaks (MultiSensor); engines (NRC, BCOGC, AER, ERA); and tailing ponds & oil sands mine face (PTAC).

GAP: Liquids unloading, glycol dehydrators, purging, bitumen batteries, and gas destruction emissions source categories may be considered gaps as they are not as frequently addressed by stakeholders. However, these emission source categories are believed to be lower sources of methane/SLCP emissions (relative to the other categories), which may explain why they are less frequently addressed by stakeholders.

4.2.6 Technology Readiness Levels (TRL)

Q17. What Technology Readiness Level (TRL) stage(s) does your organization focus on?

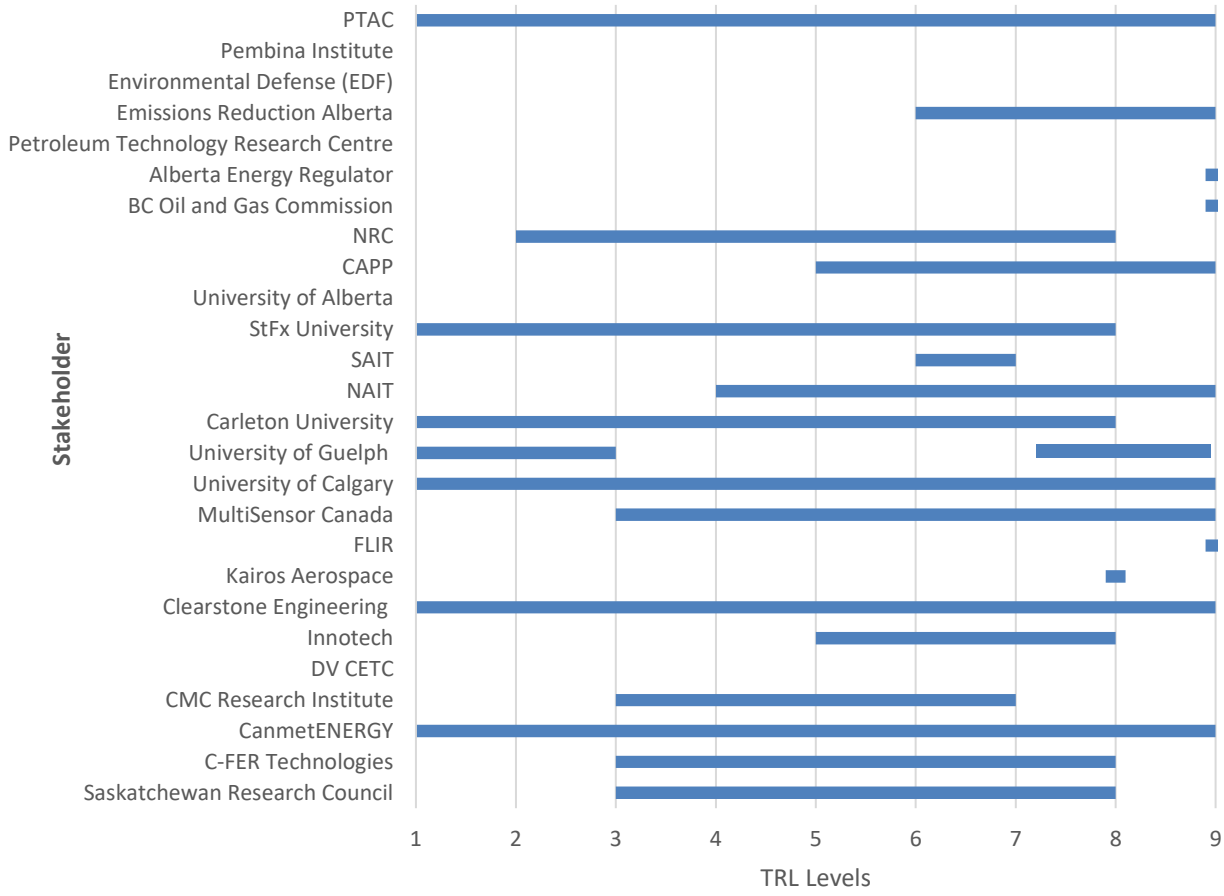


Figure 4-9: Focused TRL Levels by Individual Stakeholders

The stakeholder participants for this project maintain broad coverage throughout the TRL scale with the primary focus area within TRL Levels 3-8 (14 of 26 stakeholders). TRL Levels 7 and 8 are the most commonly covered, while TRL Levels 1 and 2 are the least covered, which may be the result of the stakeholders identified for this project as well as a bias towards technologies that will achieve emission reductions sooner than later. Pembina, PTRC, the University of Alberta, and the Drayton Valley CETC indicated that they do not cover any technologies on the TRL scale, although for U of A and PTRC this is likely due to incomplete responses received. FLIR, the AER, and the BCOGC were the only three organizations that are strictly focused on TRL 9 given that FLIR is an established technology and the regulators primary focus is on compliance which requires readily available technologies. Although it should be noted that the AER is keenly interested in the development of emerging technologies and how they might impact their regulations in the future. They are active participants on several committees for

emissions testing and technology info-groups like the CAPP FEMP-EA program and PTAC, respectively.

4.2.7 Business Model

Q32: Describe your organization's business model.

Figure 4-10~~Figure 3-11~~ demonstrates the business models of individual stakeholders. In the questionnaire, respondents could select "Fee For Service", "Government R&D Funding", and "Private Funding" as the only three options. However, most of the stakeholders chose all three of them or wrote "Combination" in response to this specific question. Therefore, a forth option, "Combination of the Three" was added to demonstrate how many stakeholders identified their business model as some sort of combination.

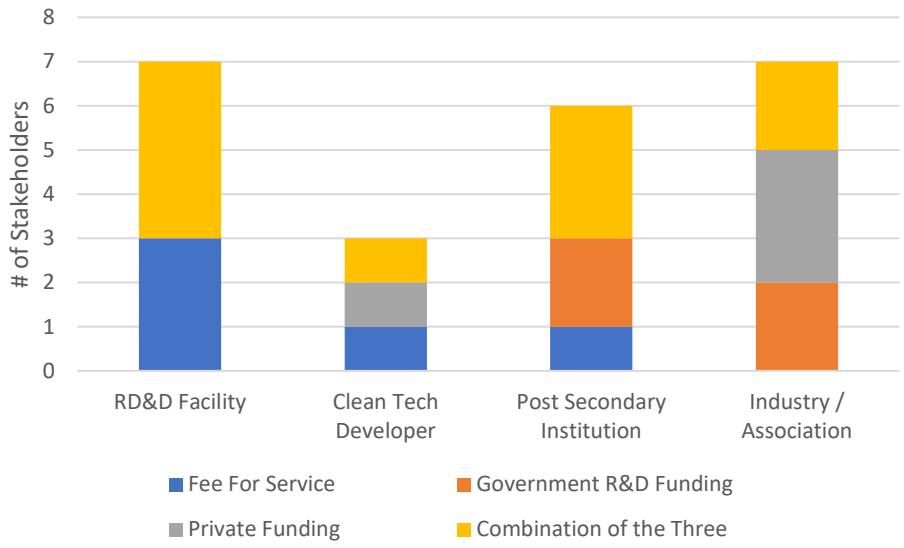


Figure 4-10: Self-Identified Business Model

GAP: "Combination of the Three" is the only category that is consistent amongst stakeholder groups. It may be helpful to have additional conversations with the questionnaire respondents (and notably the RD&D Facility stakeholders) that designated "Combination of the Three" as their Business Model to gain a more complete understanding of the disaggregation between the three sources of funding. Similarly for Post-Secondary Institutions, as this information will be useful when evaluating where capacity building opportunities exist within the system (and in order to avoid funding overlaps). This finding is perhaps indicative that other factors are more important to building the capacity of the emissions RD&D and technology testing ecosystem given that multiple business models can be used to support each of these organizations successfully.

4.3 Assets

4.3.1 Specialized Equipment

Q21: What specialized equipment/technologies does your facility currently use?

Figure 4-11~~Figure 3-12~~ displays the specialized equipment/technologies in use by respondents. These specialized equipment/technologies have been organized from highest to lowest frequency.

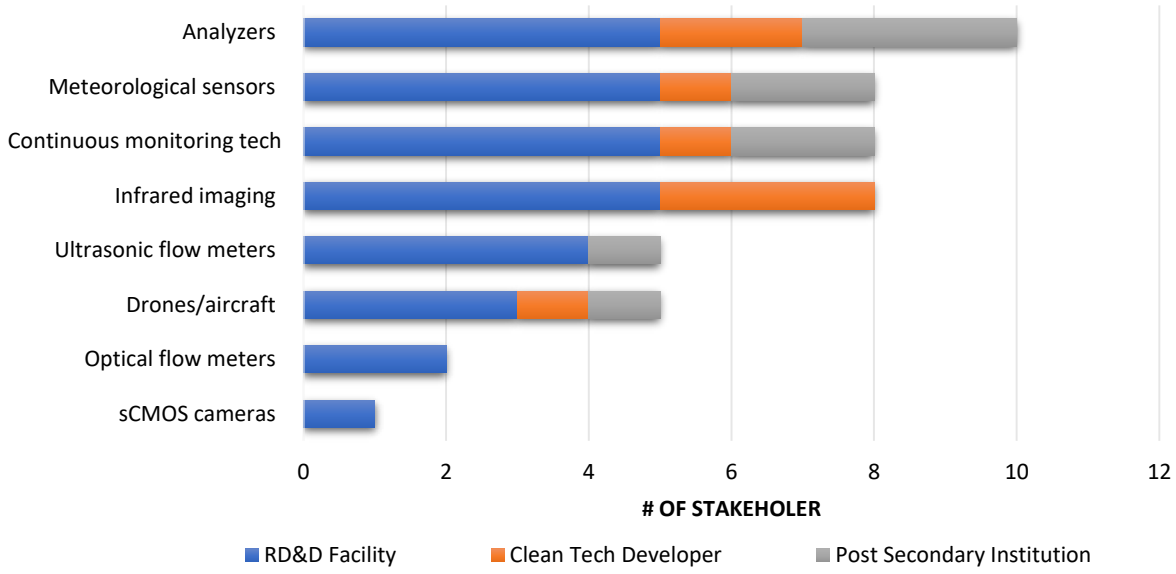


Figure 4-11: Specialized Equipment/Technologies Used by Different Stakeholders

Notes:

a. "Other" specialized equipment/technologies identified by stakeholders: Pipeline leak simulation; facilities for in soil and on water liquid releases; Special Environments Laboratory providing full-scale simulation of equipment in explosive, corrosive or toxic gas environments; High-temperature flow loops for testing equipment for thermal oil sands operations and waste heat (C-FER technologies); purpose built TDLAS based continuous measurement and speciation; purpose built laser based technologies for soot characterization and quantification of the atmospheric radiative climate forcing of black carbon PM2.5 soot particles from flaring (CanmetENERGY); Cavity Ring-Down Spectrometry Picaro; Dual Frequency Comb Laser Interferometry; Gas Chromatography Mass Spectrometry (CMC Research Institute); Data loggers, wireless transmitters, SCADA systems; Temperature, pressure, distance, GPS coordinates, weight, and liquid level measurement systems; Calibration systems (Clearstone Engineering); Custom optics; Custom detectors (MultiSensor Canada); Portable release system; Vehicle-based R&D platform (U of C); Computational Server for Atmospheric Modelling (U of G); Black carbon measurement technologies; Tunable diode laser spectroscopy systems; Field deployable spectrometers (Carleton University); validate sensors in the industrial space (NAIT); Emission flux chambers for gas migration, floating, etc; Vehicle-based emissions technology (StFx University).

The results in Figure 4-11~~Figure 3-12~~ above do not include Industry/Association stakeholders as this question was found to be irrelevant to them, and for the most part, any emissions testing they participate in involves collaboration with one or multiple of the other stakeholder groups.

Capacity Building Considerations

A significant number of "other" specialized equipment/technologies indicates that the format of the question did not capture enough of the market and that perhaps further assessment should be completed to identify future focus areas regarding specialized equipment. This information does, however, indicate the diverse nature of equipment requirements within the emissions RD&D and technology testing ecosystem in Canada and that opportunity may exist to leverage the available equipment throughout the system. Building an equipment/technology map based on the emission type (CH_4, NO_x, etc.) and emissions source category (pneumatics, tanks, etc.) could help identify these leveraging opportunities. It may also be valuable information to the stakeholder groups as a resource for them to identify the equipment required for different testing methodologies and to demonstrate the equipment already in-use.

4.3.2 Access

Q22: What types of operating facilities does your organization have access to (examples provided below)? Do you own the asset(s) or is it owned by a third-party? Please identify relevant third party (ies).

Table 4-~~4~~5: Facility Access by Stakeholder

	RD&D Facility			**Clean Tech Developer**			**Post Secondary Institution**			**Industry / Association**		
	HA-O[12]	HA-3[13]	NO Access	HA-O	HA-3	NO Access	HA-O	HA-3	NO Access	HA-O	HA-3	NO Access
CHOPS	0	3	3	0	2	1	0	1	4	0	3	0
Gas Batteries	0	4	2	0	2	1	0	3	2	0	4	0
Multi-Well Oil Batteries	0	4	2	0	2	1	0	3	2	0	4	0
Gas Plant(s)	0	3	3	0	2	1	0	1	4	0	4	0
Single Well(s)	1	3	2	0	2	1	0	3	2	0	4	0
Uncontrolled Tank Farms	0	2	4	0	1	2	0	1	4	0	4	0

Notes:

[12] Has Access- Owned by Organization

[13] Has Access- Owned by Third Party

a. "Other" operating facilities that Clean Tech Developers have access to include: underground storage, gathering and transmission lines, gate stations, municipal distribution networks (MultiSensor); and a mining facility (UGuelph).

Only one of the stakeholders identified access to an owned operating facility (CMCRI). This reiterates the importance of ensuring producers (field facility owners) are actively participating in the emissions management network/system in Canada. Post-Secondary Institutions and RD&D Facilities were most vocal about the challenges they face regarding access to operating facilities, and the data supports this identified gap. Carleton University identifies lack of forward-thinking industry partners willing to provide site access as the main gap prohibiting exploration of new and innovative ideas, for example. Similar massaging was received from other stakeholders such as NRC and Kairos who indicated that bridging the gap to technology deployment requires accessing the field for testing emissions reduction technologies.

Capacity Building Considerations

The entire emissions management RD&D system **relies on field facility access** to complete accurate and exhaustive technology testing.

- The National Emissions Inventory requires better field level data to improve accuracy;
- Clean Tech Developers require field level data to prove out their technologies;
- Regulators require field level data to write sound regulations;
- Industry members require field level data prior to committing to deploying new technologies at their facilities.

Some of this work is currently achieved by a few of the funding mechanisms currently in the system (e.g. EEA's Methane Emissions Reduction Program) while others enable collaboration amongst stakeholder groups by providing conditional funding based on partnerships (i.e. Clean Tech Developers and Post-Secondary Institutions co-applying for funding).

Enabling the collaboration/connection between industry and all other stakeholder groups is a critical requirement to growing Canada's emissions management system capacity. There are a multitude of options to consider in order to elicit participation from industry (e.g. royalty breaks at participating facilities; directed funds to capital costs; etc.), however, there are also logical constraints to allowing free flowing access to operating facilities (e.g. safety and process disruption). Balancing these issues is the key component to bridging this current emissions testing system gap.

4.3.3 Real Gas Sources

Q24: Does your emissions quantification work involve real gas sources or controlled-release of gas?

Closely connected to Q22 above, it is important to identify the system capacity to quantify "real" and "controlled" gas sources. Quantification of real gas sources is described as field-based measurements on actual equipment at O&G facilities. Quantification from controlled sources is described as work done on simulated sources at the lab, bench, or pilot scale.

The results found that 12 of 16 physical facilities use real gas source emissions (based on access to third party facilities), while 11 of the 16 facilities involve the controlled release of gas. Nine of the physical facilities are capable of both real and controlled quantification testing options with the remaining facilities performing just one of the options. Only three stakeholders that have emissions management RD&D

facilities are not set up to provide either real gas or controlled release of gas for emissions quantification (C-FER, DV CETC, and NAIT). It is important that the emissions RD&D testing system have access to both real and controlled emissions sources, as technologies at different TRL Levels require different testing. However, it is worth noting that several stakeholders have developed mobile testing units in order to better capture field level data (providing a wider variety of testing environments).

Capacity Building Considerations

Enabling access to real and controlled gas sources presents an opportunity to improve the capacity of the emissions testing system in Canada. Currently, the cost of completing testing at some of these third-party facilities is proving to be a barrier. St.Fx University made note of this in follow-up conversations, given the long distances their team and equipment is required to travel to access other facilities in Canada, plus the fee-for-service costs of many of these facilities can be high. Numerous stakeholders have completed testing at the METEC facility in Colorado, and many of them believe this facility is sufficient to serve the needs of controlled release testing for leak detection technologies, however, cost and other issues remain limiting factors for use (e.g. environment, proximity to urban infrastructure, cross-border technology, etc.). Consequently, an avenue for capacity building may be to support travel and facility usage fees.

Another opportunity for capacity building in the ecosystem may be to enable **data sharing** between stakeholders completing the testing and quantification at real and/or controlled emission sources. Improving the distribution of results can streamline testing needs within the system and can improve the pace at which knowledge is shared, and perhaps the speed at which technologies move along the deployment pathway.

Additional notes on gas sources:

- Most stakeholders indicated that they have access to city roads and fresh water, while only few have proximity to academic institutions or RD&D center/testing facilities.
- More than 80% of the facilities that conduct emissions quantification work using real gas or the controlled release of gas are able to adjust the content of gas used in the system.
- “Other” amenities and services accessible to stakeholder facilities include: explosion proof testing facilities (C-FER); 200 ha research space, 40,000 sqf state-of-the-art multipurpose facility for technology development and validation equipped with all utilities (natural gas, steam, clean electricity, cooling and chilled water), real life flue gas from natural gas boiler, up to 2 tpd (CMCRI); close proximity to academic institution, < 1km (DV CETC); machine shop, 3D printing, electronics lab (Clearstone).

4.4 Expertise

4.4.1 Contribution, Databases, Publications

Q20: Is your organization involved in any techno-economic analysis for emissions mitigation solutions?

Q28: Describe your organization's contribution to emission management RD&D, testing and/or technology evaluation.

To determine the potential success of emerging technologies or the competitiveness of currently available technologies, it is imperative that the environmental and economic trade-offs of development and use be identified. Therefore, the ecosystem's current ability to conduct techno-economic analyses is of paramount importance for capacity building decisions and ultimately to ensuring the deployment of emissions reduction technologies.

Formatte

Figure 4-12~~Figure 3-12~~**Error! Reference source not found.** provides the level of stakeholder involvement in techno-economic analysis for emissions mitigation solutions. Techno-economic research/analysis can be described as "an evaluation of mitigation technologies considering both environmental and economic performance (cost, energy consumption, emissions performance)".

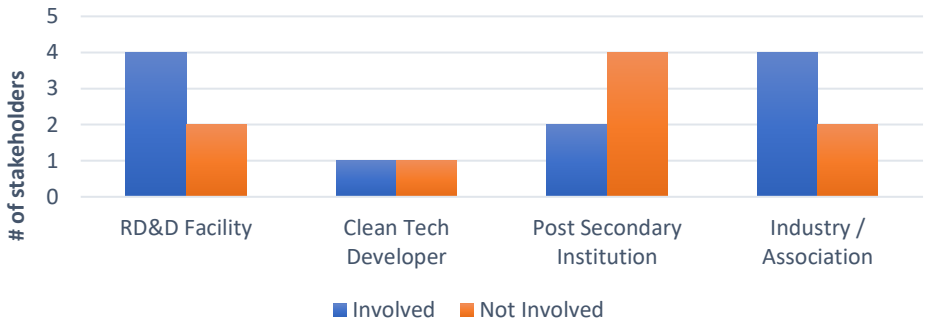


Figure 4-12: Level of stakeholder involvement

Over half (55%) of the stakeholders complete techno-economic analysis for emissions mitigation solutions. Note that three stakeholders identified that techno-economic analysis was not applicable to their organization (DV-CETC, FLIR, and CAPP). They did not provide an explanation as to why. This is particularly surprising in the instance of CAPP because their members rely so heavily on techno-economic analysis when considering capital allocation for environmental performance projects. Further discussion with CAPP may prove helpful.

GAP: It is unknown whether or not similar **quantification methodologies** are being used for the techno-economic analysis applied by each stakeholder. This may cause some variances in the system that could affect development and deployment of certain technologies. Quantification methodology is critical to the emissions management ecosystem in Canada as it is the basis for determining policy, regulatory specifications, funding support, and industry acceptance. It is identified as a key source of concern regarding Canada's National Emissions Inventory, for example, and can lead to trepidation by industry stakeholders which hampers technology deployment (data believability is critical).

Capacity Building Considerations

Data sharing where techno-economic analysis is concerned could be a potential contributor to financial savings for some stakeholders (avoiding the potential repeat of quantification) and acceleration of technology development and deployment by allowing access to the completed work to more stakeholders. These data sharing opportunities, along with the potential development of **quantification standards**, could take the form of a data **"clearinghouse"** overseen by government agencies and supported by stakeholders throughout the emissions management RD&D and technology testing ecosystem in Canada. However, as noted in this section, proprietary information may be a significant limiting factor to the creation of a data clearinghouse.

Error! Reference source not found.~~Figure 3-13~~ indicates that Post Secondary Institutions are least active in techno-economic analyses. However, these institutions could benefit from the results of techno-economic analysis conducted by other stakeholders such as Industry/Associations to better focus their R&D efforts towards technologies with higher deployment potentials. In addition, data availability (e.g. proprietary information) where technology development is concerned is one of the main challenges that Post Secondary Institutions struggle with when conducting techno-economic analyses, and technology testing. Therefore, facilitation of data sharing to make data available to academia could play an important role in development of technologies and accurate techno-economic analyses.

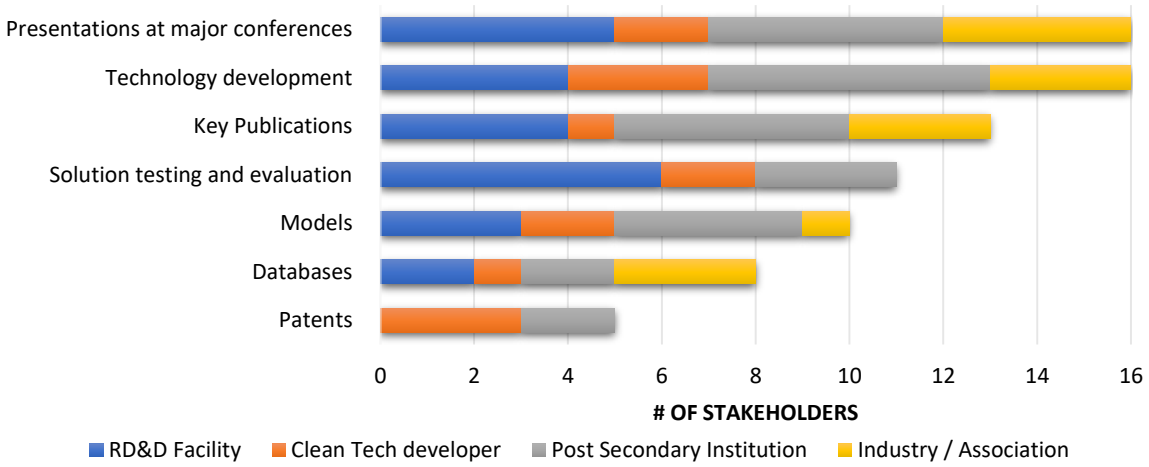


Figure 4-13: Contributions to emission management RD&D, testing and/or technology evaluation across different stakeholder

Notes:

a. "Other" contributions identified by stakeholders to the emission management RD&D space includes: standard development (C-FER); an international research team (CMCRI); Support for SMEs and larger technology manufacturers researchers and regulators (Innotech); emission factor and speciation profile development (Clearstone); commercialization of products (MultiSensor); expert technical advice and analytics (Carleton); provide technology advice, assistance and services to SMEs to help them grow their innovation capacity, and develop and commercialize technologies in the global marketplace (NRC IRAP).

GAP: These responses suggest that **databases** and **patents** are the areas where stakeholders are least contributing to emissions management in Canada. **Resolution of data-sharing obstacles** could improve the likelihood that stakeholders will jointly contribute to a database (or databases) that participants in a national emissions management network could all benefit from.

Capacity Building Considerations

The questionnaire identified "presentations" and "key publications" as two of the top three contributions currently ongoing in the emissions testing ecosystem. This supports the capacity building consideration identified earlier in the report – regular workshops to allow for ongoing and targeted data sharing between key stakeholders. Some of these additional key individuals and organizations have been identified through the questionnaire responses. The work completed here has therefore built a list of stakeholders that can serve as a baseline network to further collaborate on capacity building in the emissions RD&D and technology testing system.

4.5 Data

4.5.1 Data Types (Access and Collection)

Q 73: What type of data does your organization collect/have?

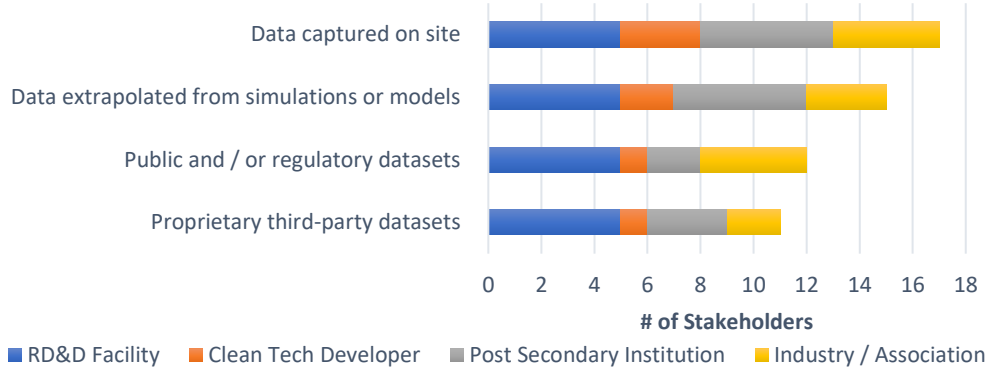


Figure 4-14 : Type of data collection across different stakeholders

Notes:

a. "Other" data types that stakeholders collect include: research data sets (UCalgary); and R&D strategic plans, business plans, R&D projects, business development strategies undertaken by clients (NRC).

All RD&D Facilities, except for C-FER and DV-CETC, access/collect all the data types and datasets, as demonstrated by Figure 3-17 above (five of seven RD&D Facility stakeholders). Simulations and models are widely used in the system today and are likely to remain a critical component in the future, as a required part of the technology development process. Where the analysis of this question becomes particularly interesting is in considering whether or not there is a link between the "public and/or regulatory" and "proprietary third-party" datasets, and the more widely recognized "on-site" and "simulation/model" datasets. Is there cross-over between the data provided in any of these four datasets that might indicate focus areas for quantification methodology standardization?

GAP: The highest number of stakeholders capture data on-site. However, not all of the stakeholders have quality assurance/quality control (QA/QC) measures in place to validate the data that is captured and used for performance and/or techno-economic analysis. Whether or not standardized QA/QC measures could be implemented, at minimum for data validation, could be considered for capacity building in the ecosystem.

4.5.2 Data Sharing Arrangements

Q 76: Do you have any data-sharing arrangements with other organizations? Please identify relevant organizations. Are the data sets open/sharable?

Q77: What are the limitations of the data you collect or use?

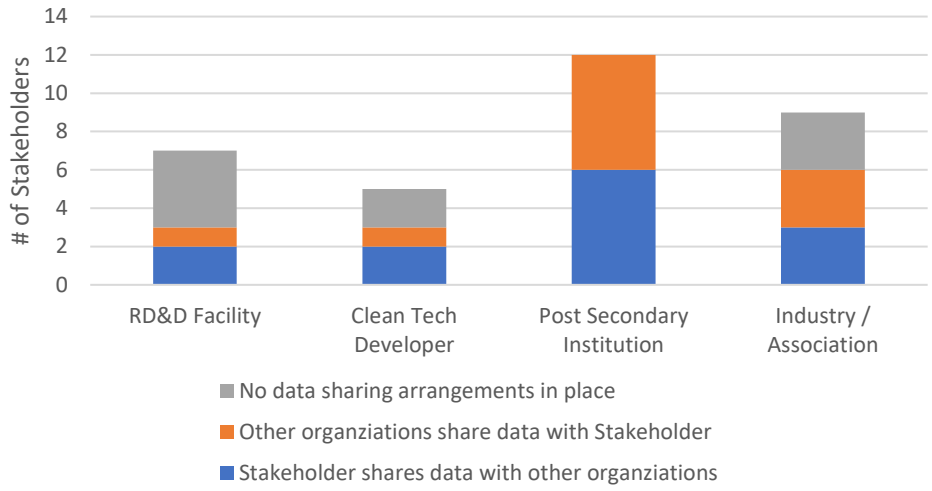


Figure 4-15: Data sharing arrangements by stakeholder type

Not surprisingly, Post Secondary Institutions identified the largest number of data sharing arrangements in both relevant categories. The next closest stakeholder group to have identified multiple data sharing arrangements was the Industry/Association group, but their numbers are only half of those of Post-Secondary Institutions. Among them, SRC has an emissions reduction technology database containing information on almost 400 emission reduction technologies within TRL Levels 3-8. SRC indicated their tool for quantifying emission reductions and cost analysis for each of these technologies is shareable for a fee. Overall, 65% of all the stakeholders either share or receive data with other organizations. This presents an opportunity to consider a national data hub, given significant data sharing already taking place within the ecosystem.

Capacity Building Considerations

It is expected that the majority of the **data sharing** arrangements in the Industry/Association category are all recent given the concerted focus on emissions management over the past two years. One stakeholder specified that they have data sharing arrangements under a non-disclosure agreement (NDA). It is suspected that other organizations would have NDAs in place. The details of those arrangements could help identify some of the barriers needing resolution in the instance of a national data-sharing network.

4.5.3 Software

Q 78: What software, data processing, modelling, and analytical tools does your organization use? Are any of these in-house tools, and if so, are they shareable?

Most stakeholders indicated the use of "software for emissions calculations" and "data processing and reporting software". This could in large part be due to the fact they are broader categories compared to "tank simulation" and "dispersion models". There are multiple "other" tools stakeholders identified in their responses.

GAP: Quantifying emissions from tanks has been identified as a current challenge in the system. Clearstone Engineering and Canmet ENERGY are the two stakeholders that have developed and been using tank emissions simulation software, but, given that CAPP has identified **tank emissions** as one of the key opportunities for industry to reduce methane at a low-cost to ensure regulatory compliance and to support Canada's emission reduction goals, further consideration should be made to the use and quality assurance of tank emissions simulation software. This is particularly important given the challenges faced when trying to quantify tank emissions on site.

Capacity Building Considerations

The majority of stakeholders stated their tools are not shareable. This highlights the challenge with **proprietary data**. Models currently used for emissions quantification (by industry, regulators, technology providers, etc.) have proven to be highly variable, leading to a variance in emissions reductions allocated to certain technology types and ultimately influencing the estimated emission reductions (and associated costs) achievable under new regulatory requirements. Improving the shareability/collaboration of emissions quantification tools/models currently within the system will enable a more efficient and effective emissions management RD&D and technology testing environment in Canada.

Table 4-~~5~~6: Stakeholders' Software, Data Processing, Modelling, and Analytical Tools

		Tank simulation software			Dispersion modelling software			Software for emissions calculations			Data processing and reporting software		
Stakeholder	**Stakeholder Group**	**Developed Internally**	**Used Internally**	**Shareable**	**Developed Internally**	**Used Internally**	**Shareable**	**Developed Internally**	**Used Internally**	**Shareable**	**Developed Internally**	**Used Internally**	**Shareable**
Saskatchewan Research Council	RD&D facility					✓		✓	✓		✓	✓	
C-FER Technologies													
Canmet ENERGY		✓	✓					✓	✓		✓	✓	
CMC Research Institute						✓						✓	
DV CETC													
Innotech													
Clearstone Engineering		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Kairos Aerospace	Clean Tech developer							✓			✓		
FLIR								✓					
MultiSensor Canada					✓	✓		✓	✓		✓	✓	
University of Calgary	Post-secondary Institution				✓			✓					
University of Guelph					✓		✓	✓		✓	✓		✓
Carleton University								✓	✓		✓	✓	
NAIT													
SAIT												✓	✓
StFx University					✓	✓		✓	✓		✓	✓	
University of Alberta													
CAPP	Industry/ Association												
NRC													
BC Oil and Gas Commission						✓						✓	
Alberta Energy Regulator			✓			✓		✓			✓		
Petroleum Technology Research Centre													
Emissions Reduction Alberta													
Environmental Defense													
Pembina Institute													
PTAC												✓	
Total Count		2	3	1	4	7	2	11	6	2	9	9	3

Notes:

a. "Other" tools that stakeholders use include: emission reduction technology database and Geospatial data management system (SRC); pipeline release modeling (C-FER); process simulation software, data collection applications, statistical analysis packages (Clearstone); machine vision software (MultiSensor); black carbon measurement software, inventory analysis tools, extensive experimental control tools / software (Carleton)

5 DISCUSSION

5.1 Overview of the Ecosystem

Stakeholder groups were identified based on a preliminary understanding of the emissions management RD&D and technology testing capacity in Canada, and were further categorized into four stakeholder buckets, as described in Section 3~~2~~, for the purpose of being able to draw comparisons between stakeholder views, and to be able to aggregate data more easily**Error! Reference source not found.**. However, on completion of the research, it was determined that the system can be further disaggregated in a manner that clarifies where the capacity building considerations are along the system. Figure 5-1~~Figure 4-1~~ demonstrates this view.

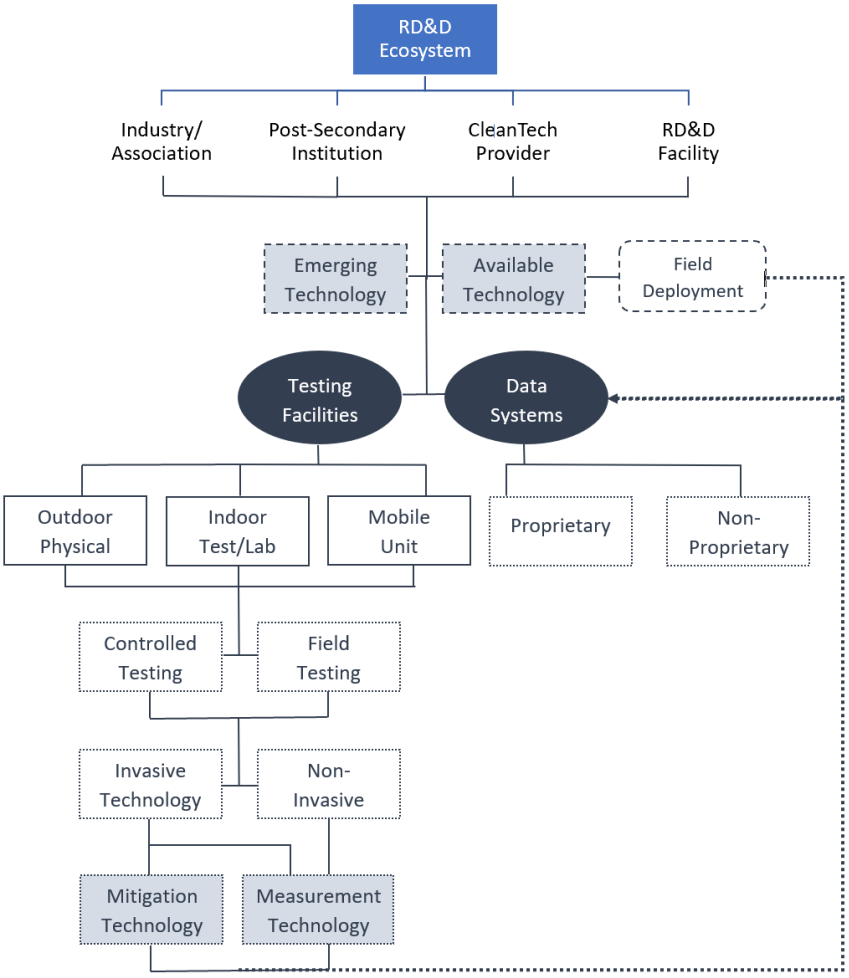


Figure 5-1: Overview of the RD&D testing ecosystem

Following the identification of the four stakeholder groups, the next layer differentiates between **Emerging Technology** and **Available Technology**. Given that one of the key objectives of this report is to enable deployment of emissions reduction technologies, some system capacity building considerations can be made in order to move technologies from the former category to the latter. Emerging technologies require support for development, pilot and field level testing, while available technologies require commitment and collaboration primarily from oil and gas producers, plus appropriate incentives (if any) to ensure rapid deployment throughout the multitude of producing fields in the country.

Although there are a small number of funding mechanisms and other support structures available for technology deployment (ERA, EEA, etc.), it is likely that additional support could be useful to enable **field deployment** of Available Technology. Once these available technologies are deployed, performance evaluations need to be carried out and preferably reported into a centralized data hub with appropriate QA/QC measures accessible to a wide array of stakeholders. The ability to share field level data and performance results/quantification is critical to maximizing the development and deployment of these technologies.

It is widely identified by stakeholders that the system would benefit from aggregation of field performance data of available/implemented technologies. However, this information is likely to be proprietary to the producers implementing the technology in their fields and/or the Clean Tech Developer providing the technology. Consequently, there may be some benefit to a central location for this information to be accessed/shared in some manner. This will allow a greater number of stakeholders the benefit of reviewing technology performance data and it will encourage the "race-to-second" that is so prevalent in the oil and gas industry. Once field data is collected and performance reviewed, a technology is more likely to see greater deployment.

Following the Emerging vs. Available technology layer, the emissions management RD&D and technology testing ecosystem can be divided into two distinct "tracks": **Testing Facilities**; **Data Systems**. These tracks have been identified as the most critical capacity building decision point in the system as each track contains separate opportunities to grow Canada's leadership in emissions management RD&D. Testing Facilities largely comprise physical emissions testing infrastructure, while Data Systems refers primarily to the collection of technology performance testing data as well as quantification methodologies used for emissions reduction identification.

5.1.1 Testing Facilities

5.1.1.1 *Outdoor Physical; Indoor Test/Laboratory; Mobile Unit*

Initially, this work set out to focus on the physical facilities in Canada associated with emissions management RD&D and technology testing. Through the process, the research identified three more specific categories of physical testing facilities: **Outdoor Physical; Indoor Test/Laboratory; Mobile Unit**. Each of these designations contain different capacity building considerations. For example, the primary need identified by stakeholders is field level testing for methane leak detection quantification and alternative technologies. To address this need, the system would require additional **Outdoor Physical** facilities or upgrades as the system does not currently contain sufficient availability in this regard. However, given the limitations of physical testing facilities (e.g. inability to manufacture field conditions; the lack of flexibility with surrounding environmental conditions; etc.), the somewhat

limiting costs of Canadian-based facilities, and the accessibility of the METEC facility in Colorado, further growth of Outdoor Physical facilities may not be needed, unless a collaborative model is developed that will provide field level testing conditions (which is what CAPP created with the FEMP-EA program currently underway).

There are a number of effective **Indoor Test/Laboratory** facilities across Canada located primarily at Post Secondary Institutions. Expansion of this infrastructure could improve emissions management capacity in Canada, however, through conversations with Post Secondary Institutions and Industry stakeholders, there is an indication that this opportunity is only modest (e.g. additional equipment and staff). Where the larger capacity building opportunity lies is within a data management system that could aggregate the data collected at these facilities. As mentioned, this presents some significant challenges, but stakeholders across the board were open to considerations for how to improve the data sharing capacity of the current ecosystem. An initial mechanism AI/NRCan could implement would be regular workshops (e.g. quarterly) specific to data sharing. This will allow for the dissemination of information while allowing stakeholders (data holders) the ability to present only the information they are currently able to share.

Numerous **Mobile Units** exist in the current emissions management system with the most active being those from Saskatchewan Research Council (SRC), University of Calgary, and St.Fx University. Some support to expand deployment of these units may be helpful to the system as they each have the ability to test equipment in field conditions. Performance data sharing remains a constraint of these units, as the data remains proprietary or is available for a fee. Vehicle mounted units are limited by travel time, which can only be overcome with additional units injected into the system. Furthermore, **calibration equipment** to accompany these Mobile Units was noted as a gap to be filled[14]. This is also a relatively low-cost funding consideration but would improve the efficiency of these mobile testing units by allowing a greater number of tests to be completed while the mobile units are in the field by removing the need to calibrate equipment off-site. This is particularly important given the long distances travelled in order to reach a variety of facility locations in different formations (which is important to ensuring data variability).

Saskatchewan Research Council completed an exhaustive analysis of testing facility options prior to identifying the CeDER mobile unit as the system they would build. This is reflective of the effectiveness of these mobile units and should carry some weight in considering future system growth. Further discussions with SRC may prove beneficial to better understand their evaluation process and understand the barriers they identified to alternative testing facility solutions.

5.1.1.2 *Controlled Testing; Field Testing*

As touched upon above, there are two types of testing requirements identified as critical to emissions management RD&D that comprise the next layer of the ecosystem: **controlled** and **field** testing.

[14] David Risk, St. Francis Xavier University

Controlled testing, while secondary to field testing, is still a critical component to the emissions management ecosystem. It allows for early stage testing of emerging technologies and baseline performance quantification. Additionally, the data collected from controlled testing requires appropriate collection and evaluation. The system currently lacks a centralized hub for this data management to occur, and for the most part it is the responsibility of the technology testing entity to collect and evaluate this information. Deploying this information into the stakeholder ecosystem is a critical and immediate need, and while it is currently happening, it is limited in scale and requires stakeholders to seek out collaboration opportunities. Supporting and enabling this collaboration is a significant capacity building opportunity.

Throughout this research, **field testing** was identified as one of the most critical components of the emissions management ecosystem and the top gap currently in existence. It is required for the successful development and eventual deployment of emissions reduction technologies. Expanding the system capacity to enable field testing largely depends on oil and gas producers to provide access to sites. This can happen if Industry and Clean Tech Developers build more collaborative partnerships to collect field level data (this is happening in pockets, but not on a large scale as many Clean Tech Developers state this gap as the largest barrier to their technology moving to deployment). This capacity can also be expanded in the instance that AI/NRCan or other government agencies formally collaborate with an actively producing field site(s) in partnership with a producer willing to commit a location to emission testing. Outside of this option, Mobile Units become the next most reliable opportunity to achieve field testing. However, mobile testing units have a distinct limitation related to the types of technologies that can be tested given that they do not complete testing on-site, but rather from a distance to the actual facility. Therefore, capacity building opportunities need to consider another layer specific to the types of equipment/technologies that require field testing: **invasive** and **non-invasive** technologies[15].

Within the controlled versus field testing ecosystem layer, it is important to ask: *Can the current controlled testing capacity of the system keep pace with the speed at which new technologies are needed and are entering the market?*

Understanding the timelines associated with technology development (along the TRL scale), testing requirements, regulatory compliance obligations, and market deployment will identify pockets for capacity building. For example, what are the most stringent aspects of Alberta's methane regulations and what technologies and/or data are needed for industry to achieve low-cost compliance prior to 2025? What is the status of those technologies and what is required to enable their deployment? How can the system be certain that the data collected is credible? Is the system focused on testing technologies that address the largest emissions sources? Given the resource constraints within the system, should capacity building focus on improvement of emissions inventories (field data), development of emerging technologies, or deployment of readily available technologies?

This type of work can be completed in close collaboration with a group of relevant stakeholders, many of whom are identified in this report.

[15] These terms were coined by Laura Johnson at the Alberta Energy Regulator during the course of interview follow-up for this project.

5.1.1.3 *Invasive Technology; Non-Invasive Technology*

There are a different set of barriers to overcome based on this classification. **Invasive** technologies require installation directly on-site and can be classified as either a mitigation or measurement technology. These technologies require an Outdoor Physical facility to complete testing and are mostly restricted to on-site field testing at an actively producing site. They require close collaboration with the operator of the facility as there may be health, safety, and/or process issues that can hinder the testing of the technology. For some technology types, facility shut-downs are required for installation, which leads to extended lag time to complete the testing given the limited number of facility shut-downs that occur annually.

Building a formal network of producers and technology developers to ensure they are frequently made aware of technology types as they become available for field testing, and the installation requirements for each technology (e.g. facility type, process block, facility shut-down, etc.) could improve the chances of gaining traction on technology deployment. This would allow for a quicker timeline to installation as the likelihood of finding a producer with an upcoming turnaround, for example, is improved through a connected network. A closer look at MELA and/or PTAC's Methane Hub would be a good place to start.

Non-invasive technologies do not require site access, can be field tested off-lease, and primarily include measurement, not mitigation technologies. The ability to test non-invasive technologies is more flexible than for invasive technologies, and much of this work is already taking place through University of Calgary, St.Fx University, CAPP/PTAC, SRC, CMCRI, and multiple Clean Tech Developers (Kairos and many others not interviewed for this report). Where the system could improve in regard to non-invasive technology testing is in data sharing and equal exposure for all emerging technologies to gain access to field locations for performance testing.

As previously mentioned, calibration is identified as a gap in the non-invasive technology testing system. It is important to ensuring reliable measurements are taken and will allow for more expeditious execution of testing. At present, some measurement technologies require calibration ahead of each test. However, the calibration equipment is not mobile and therefore calibration must occur at an Indoor Test/Laboratory facility.

5.1.2 Data Systems

Similar to Testing Facilit~~the Testing Facility~~ track above, there are two distinct types of data that each possess different risks, opportunities and decision points for capacity building: **Proprietary; Non-Proprietary**.

5.1.2.1 *Proprietary; Non-Proprietary*

Propriety data is a barrier to a fluid emissions management system because it cannot be completely overcome with any targeted investment. Should a centralized data hub be considered by Alberta Innovates and Natural Resources Canada it would have to consider the full value of that hub in the absence of confidential data from ongoing research by Post Secondary Institutions and Clean Tech Providers. Further discussion with these stakeholder groups would be beneficial to understand any other opportunity to overcome this barrier.

One suggestion received was to host periodic **workshops** where stakeholders with propriety data have the opportunity to present their research/findings in a controlled environment. Speakers can choose which information to communicate/distribute while still providing insight into the work. Hosting these targeted workshops on a regular basis, with a consistent format, will streamline data sharing opportunities and will enable an ongoing connected network.

Non-proprietary data represents an area with significant opportunity for capacity building. There are multiple data points across the ecosystem, and at any point in time multiple technologies are (a) under development or (b) being tested or (c) being deployed. Within each of these three categories another sub-set of data accumulates based on technology types, then bench, pilot and field testing, and finally performance monitoring upon implementation. Each technology provider, testing facility, university, or industry member completing emissions measurement and technology testing possesses important data. All of this data is important to developing a complete picture of the emissions management system and opportunities for capacity building in Canada.

A **centralized hub** for data collection is an important consideration for building the capacity of Canada emissions management system. A key component of this opportunity is to develop a work plan that identifies who will administer the hub, how data will flow in and out of the hub, and most importantly, who will evaluate the data for completeness, accuracy, and relevance. This data hub is different from a stakeholder network in that the focus is on data and performance evaluation and enabling access to information that will allow a stakeholder network to make informed decisions.

5.2 Stakeholder Priorities

The questionnaire submitted to stakeholders contained questions pertaining not just to their individual organization but also to the broader emissions management RD&D and technology testing capacity system. Given that the participating stakeholders are immersed in emissions management, they can provide well educated insight into the current and prospective future state of the ecosystem in Canada.

Q82: What key emissions management RD&D areas should we be paying more attention to?

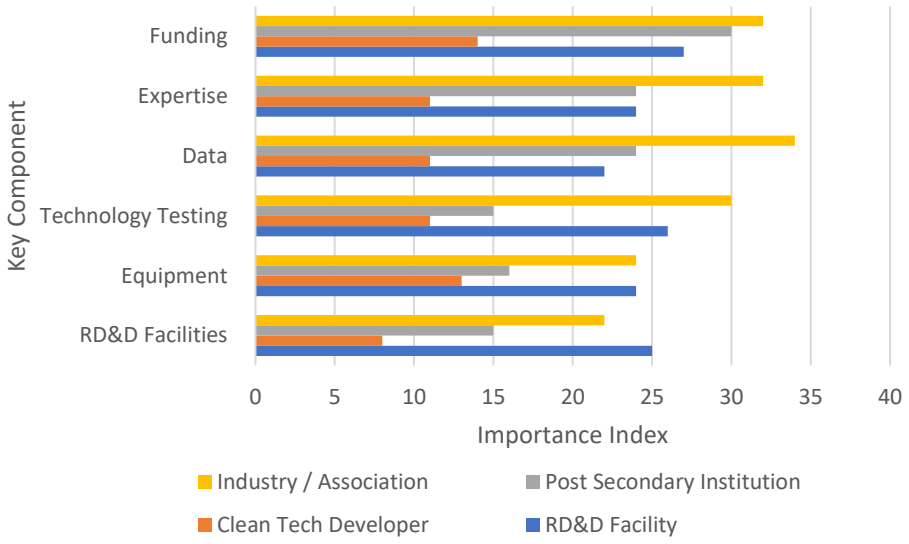


Figure 5-2: Ranking of the Key Components of Canada's Emissions Testing RD&D Network

Notes:

a. "Other" key components identified by stakeholders includes: stable and predictable policy and regulatory alignment, and meaningful attempts to meet Paris climate goals (CMCRI); ground truthing capability, reporting / publicity, performance assessment (MultiSensor); coordination (UCalgary); site access for testing / measurements (Carleton).

b. In order to be able to rank the key components of Canada's emission management RD&D network, an importance index was created. Low Importance option was weighted 1 and High Importance was weighted 5 while Low-Medium Importance, Medium Importance, and Medium-High Importance were weighted 2, 3 and 4 respectively. This weighting system was then used to be multiplied by the responses that chose each option. For example, the "30" level of importance of "funding" for the Post Secondary institution was calculated knowing 6 of the stakeholders ranked funding as High Importance, which in this index system has a weighting of 5. It should be noted that as the number of stakeholders in each organization type is different, it is better to compare the stakeholder types with each other rather than looking at the whole system.

For RD&D Facilities, funding and technology testing was ranked the highest key components of the network. Clean Tech Developers gave funding and equipment higher ranks while Post Secondary Institutions indicate funding, expertise and data are the key component of the network.

Industry/Associations have chosen data, funding and expertise as the key components. This response clearly identifies one of the unavoidable shortcomings of this work – each stakeholder will have their organization's best interest in mind throughout the response process, which is why we see "funding" as the only common component identified between all stakeholder groups.

Industry/Associations identified "data" as the most important component of the system. Given that it is the Industry stakeholder group that is required to both provide access to their field locations to collect critical data as well as the stakeholder group responsible for implementing the emissions reduction technologies, it should receive more consideration than some of the other responses received for this question.

5.2.1 Today

Q 80: What does a successful emissions management RD&D tech testing Centre/Network look like to you, that meets your organizations needs/objectives? Describe key features that would address your needs and fill the gaps that you consider to exist in the current emissions management/technology testing ecosystem?

5.2.1.1 *Stakeholder Views on the Characteristics of a Successful Network*

Attributes and characteristics of a successful emissions management RD&D and technology testing system were identified by stakeholders. This section summarizes the responses received from respondent stakeholders in a consolidated format.

Desired Features of an RD&D Centre/Network:

- Enable successful development and commercialization of technologies, grow in revenues, employees and increased R&D spending;
- Rapidly develop, test and deploy emissions technology to comply fully with relevant regulations, while at the same time driving costs of compliance down and providing an additional industrial development base that Canada can exploit from an international export standpoint;
- Allow for flexible comparison of a wide range of solutions that takes into account the large variance in source-type, scale and location of methane emissions;
- Compare different technology methodologies and approaches to advance the ecosystem;
- Be capable of releasing liquid and gas hydrocarbons in a controlled manner to:
    - Evaluate performance of detection and quantification technologies;
    - Train personnel on the proper use of these technologies; and
    - Develop best practices for installation, deployment and operation.
- Range of Pasqual stability classes available (opportunity to sample overnight);
- Varied geologies, varied infrastructure on site, spans pressure ranges relevant to operational sites, includes controlled releases through hole sizes of relevance at relevant pressures, with in-line mass flow meters to provide ground truth;

- Offers multiple scenarios, including a selection of sites with intentional venting, flaring, and leak profiles;
- Multiple facilities located close to each other to enable multiple emissions profiles to be assessed in a short duration;
- Both above and below ground leak testing;
- Mobile and fixed testing components as this allows early stage technologies to be tested safely in a fixed facility while higher TRL level technologies can be tested under real world conditions in the field;
- Accessible to a wide range of stakeholders with good accommodation facilities nearby;
- Organized and communicative; and
- Flexibility to accept third party release options.

Suggested Focus Areas of an RD&D Centre/Network:

- RD&D that is driven by an outcome objective for 100% hydrocarbon resource recovery that is cost effective;
- Comparison of emissions detection, quantification and reduction technologies in a transparent and **data-driven** way;
- Develop more players in the *'independent validation and verification'* space;
- Integration of various promising technologies into an operational system;
- Comparison and **benchmarking** of technologies as well as blind testing.

Structure of the Proposed RD&D Centre/Network:

We received contrasting responses from the stakeholders on the structure of a prospective centralized facility or network. Few of the Post-Secondary Institutions wished for a collaborative network to support Canada's RD&D ecosystem, while Industry/Associations and Clean Tech Providers felt collaboration is a critical component. Similarly, Industry/Associations largely felt a physical facility similar to METEC would be beneficial while Post Secondary Institutes generally felt the value of a new physical facility was not there. The stakeholder's views on a centralized Test Centre/Network are listed below:

- A successful emissions management RD&D network would be a network and specifically not a physical centre. Proposed network needs to be extremely nimble, to respond quickly to opportunities, and to take significant risks on projects and ideas that are ambitious enough that the outcome is unknown;
- METEC is quite a good example for this purpose, except METEC is only focused on the upstream. It will be fruitful to have these capabilities for testing to be expanded for midstream and downstream activities;

- Not necessary to build another new facility for developing/validating emissions related technologies. The infrastructure exists within Alberta Innovates, SRC, and other labs and industrial organizations. A network of producers, funders, and existing tech validators would be a better idea; and channeling the funds to existing facilities and for field testing.

Quote from the Canadian Association of Petroleum Producers: *CAPP sees the unavailability of a controlled release test facility like METEC and a field test facility as the biggest gaps in the way of a successful emissions management RD&D facility in Canada. CAPP sees the development of a Canadian emissions testing facility as extremely time sensitive. We would emphasize the importance of developing an RD&D centre before the end of 2019. With the AER planning for a regulatory review to take place in 2021/2022 it is extremely important to properly test both emerging and currently available technologies primarily as it pertains to fugitive emissions testing. The sooner this type of facility can be functioning, the sooner industry can work with tech providers to field test the appropriate emissions reduction equipment and involved stakeholders can determine the lowest cost solutions to ensure reductions are achieved and regulatory requirements are met.*

Quote from the University of Calgary: *SENST recommends not attempting to duplicate METEC in Canada as they already have the systems in place, so it would be better to partner rather than recreate METEC North. They specifically have designed their test system at the University of Calgary to address the limitations of METEC - the ability to test in different environmental conditions (terrain, landcover, road density, etc.) and the ability to generate large emissions for aircraft and satellites. METEC cannot generate larger emissions due to location (near residential) and infrastructure. Their system has been developed to fill this gap.*

<u>Capacity Building for an RD&D Centre/Network</u>:

- Crucial to avoid duplication of investment in testing facilities to ensure effective utilization of existing infrastructure and best return on tax dollars;
- Incentivize oil and gas producers to support **pilot testing** of new emissions reduction technologies, through carbon credits or other funding mechanisms;
- More investment in infrastructure without deep consideration of needs, objectives, regulations, and science will create large inefficiencies in the system. It is necessary to work backwards from the needs and outcomes to define what infrastructure or new investments are required to fill gaps;
- Future capacity building should focus on SMEs to enhance business growth and create jobs;
- Future funding and capacity building should be directed towards science to devise **testing programs** and determine the infrastructure required to support tech development and emissions reduction;

<u>Policy / Compliance / Regulations Considerations of an RD&D Centre/Network</u>:

- Deploy a tool to determine what "cost-effective" compliance looks like (e.g. FEAST model);
- Need to have regulators **specify procedures for validating** the performance of technologies. Need to define operating requirements for technology developers so that they can focus on the critical industry needs;
- Policy/regulation targets should be revised to 100% resource recovery that is cost effective, to enable RD&D ecosystem to thrive and eliminate gaps in achieving cost effective compliance with policies.

Collaboration Opportunities for an RD&D Centre/Network:

- A scientific **advisory committee** to outline testing needs, objectives, and protocol;
- Stakeholders in the emissions management ecosystem to come together to assess and adopt **best available technologies and practices**;
- Forward thinking industry partners willing to provide **site access** to explore new measurement technologies;
- **Conferences and forums** focused on technologies, testing, lessons learned, successes & failures;
- **Workshops** to inform industry of ways to comply with emerging regulations, and what new technologies are emerging in the next 24 months (help them develop near-term and intermediate-term strategies). In addition, workshops that enable hands-on experience with emissions management tools and techniques;
- AI/NRCan to oversight a **forum** of experts to compare different technologies, address strengths and weaknesses and, define best practices;
- Technology equivalency and **access to partner organizations** are key for private technology developers;
- Peer-reviewed work and **reports** and publications;
- Complete transparency in the industry's reporting on reduction targets is critical;
- **Connected network** of centres where multiple emission sources can be provided without duplication of resources. Shared expertise and a single data sharing model respecting proprietary data;
- Enable access to testing centres where real sources can be accurately simulated and/or controlled. This is especially important for performance of fundamental RD&D, such as work on developing an improved understanding of emission mechanisms;
- Continued access to academic/jurisdictional RD&D Centre infrastructure (e.g. national or provincial) such as the assets described at the NRCan/Carleton University and University of Western Ontario facilities, and strategic collaborative access to Canadian based upstream, midstream and downstream oil and gas facilities.

5.2.2 Future

Q 79: What are your organization's short-term development plans (over the next 1-3 years)? Will you be expanding current capabilities and/or physical assets or expanding into new areas of study? If so, please describe.

5.2.2.1 *Short Term Development Plans*

Not all stakeholders described their short-term development plan.

- **FLIR** is planning to hire. But the scale and growth would partly depend on the federal and provincial elections in the coming years, specially between now and May 2020;
- **NRC IRAP** intends to continue providing technology advice, assistance and services to SMEs to help them grow their innovation capacity, and develop and commercialize technologies in the global marketplace;
- PTAC recently created the **Methane Emissions Research Collaborative** (MERC) to focus research efforts on managing and reducing the release of methane from oil and gas operations. The initiative of provincial agencies and stakeholders will make recommendations on the design and implementation of the key research deliverables that will be necessary to meet methane reduction goals. MERC is developing a three-year work plan that includes:
    - A review of the state of research relating to oil and gas methane emission measurement and reduction nationally and internationally;
    - A plan for the identification of research and projects that will inform and support the development of provincial policies and regulations to meet current and future methane emission reduction goals;
- **University of Calgary, SENST** will be entering a very aggressive period of controlled release testing and piloting from 2019-2022. The focus will be on 'alternative' mobile methane sensing systems: drones, vehicles, aircraft, and satellites. They have partnerships with tech developers in all four types of platforms and would like to enhance their testing equipment by adding sensors, controls, and masts. They noted that annual funding cycles limit their ability to hire and train dedicated technical staff as students are too transient (new infrastructure components to improve their portable release system);
- **CAPP** will be focused on the FEMP-EA project, committed to understanding efficiency, effectiveness, and cost of alternative leak detection technologies and methodologies;

Quote from NATURAL RESOURCES CANADA CANMETENERGY: *A key feature that would address needs and fill gaps in Canada is a strategic national plan (not to be confused with a federal plan) that is in the strategic interest of Canada and that integrates energy, environmental, economic and social sustainability and has near, medium and long term objectives that are shared and supported among industry, government, academia and Canada's very innovative tech sector. Some of Canmet's ongoing international success can be attributed to a level of policy and regulatory certainty and strategic integrated planning within the jurisdictions that it works in (e.g. China's current 13th five-year plan that integrates energy, environment, economy and social license; Mexico's constitutional energy and economic reforms that contain clear environmental and social sustainability objectives for energy sector growth). Aspirational goals of RD&D in Canada should not be limited to developing cost effective technology or methodology pathways to compliance with a regulation after the regulation has been developed*.

5.3 Stakeholder Gap Analysis

Q 83: What are the missing tools/capabilities required to achieve your organization's emissions management objectives?

Q 84: Key gaps: What are the key gaps in RD&D/tech development to achieving cost-effective compliance with emissions management policies and regulations? What additional work is required to address this issue and what does that entail?

5.3.1.1 *System Gaps Identified by Stakeholders*

Research Capabilities:

- Ability to develop affordable **small-scale solutions** for application in marginal or mature oil fields;
- Facilities that can **simulate full-scale releases** under controlled conditions to enable demonstration of detection and quantification technologies and set up a technology baseline;
- Demonstration and **benchmarking** of equivalent fugitive emissions detection technologies;
- RD&D facilities enable integration of multiple technologies onto the same operating platform for detection and quantification;
- Engineering tools that aid in demonstration and selection of emission control technologies. For example: tools that enable techno-economic evaluations and quantify emission reductions;
- Cost-effective super emitter identification;
- More emphasis on economics of detection and mitigation;
- Currently available monitoring technologies are not truly continuous - they don't operate at night typically and they sample for only a short duration;

- METEC is limited in their capabilities, especially with them focusing on only upstream. Therefore, a testing facility with bigger scope would be a successful test center. For example: including SF_6 which is a GHG with high GWP;
- Highly Qualified Professionals: Lack of local expertise and requirement of competent economists in addition to scientists/engineers to aid in techno-economic assessment of technologies.

Data/Data Sharing:

- Oil and gas operators should be more open to sharing data from case studies to benefit the entire emissions management ecosystem and enable **benchmarking** of technologies;
- Real time monitoring data captured through fixed sensors and data arrays:
    - Emission reductions will be more accurate and cost-effective when operators can access real-time, **accurate site level measurement** to deal with day to day operations. The current emission inventories are based on incomplete estimates, inaccurate data and they believe the actual emissions can be 3 or 4 times higher than what we estimate, simply because the estimations rely on old/poor methodologies;
- Data accuracy and cost-effective super emitter identification:
    - Actual data can change the economics of the project as there might be higher real emissions compared to estimates and by addressing these larger emissions it will act as a larger revenue source for the operators, either through capturing the gas or other monetary projects such as offsets;
- Networks need to be a **multi stakeholder collaboration**. In the past, PTAC shared results/data with only industry and excluded ENGO or academia. A live measurement system with transparent process, where the **data are credible and publicly shared**, will be essential to build trust across stakeholder groups.
- Data sharing among stakeholders in the ecosystem is a major hurdle:
    - Post-Secondary institutes are constrained by their need for publishing research findings;
    - Research facilities are limited by NDAs with their funding industry partner;
    - Technology developers will not be willing to share their proprietary information; and
    - Industry associations limit data sharing to their members.

Centralized Facility / Collaboration / Communication / Network:

- Lack of a central facility for **coordinating testing, third-party certification, or testing protocols**;
- Real use cases help clarify what works better than spec sheets. A centralized facility which can **benchmark, and share experience** gained with all stakeholders;

- Knowledge gap among industry peers on various technologies (features, pros and cons) that are currently available to help them achieve methane reduction goals;
- **Improved communication** on capabilities of individual stakeholders across the emissions management ecosystem;
- Government-industry collaboration in the emissions management system ecosystem.

Policy / Compliance / Regulations:

- Lack of policies that align with market opportunities. Currently, Canada is great at developing technologies but doesn't adopt them;
- Aligning testing requirements to regulations and vice versa: the current federal regulations do not specify how new and emerging, 'alternative' technologies can gain regulatory approval. A process should be developed and coupled to specific test requirements, processes and protocols;
- Compliance with emissions management policies and regulations is currently defining the outcome objectives for RD&D in this space. The revised AER directives are written primarily using existing LDAR techniques and industry will comply with these, as they currently do. Success will depend on the alignment of federal and provincial regulations such that they achieve climate policy goals. It is not a technology or science issue it is an alignment of regulation and industrial practice to policy goals issue;
- RD&D that is driven by compliance with emissions regulations, relegates Canada's innovators to reactively developing solutions for a waste management space, instead of a resource management space. Waste management approaches often seek to identify pathways to waste as much as is allowed by regulation, whereas resource management approaches seek to minimize and drive to zero, the slippage of resources from our systems;
- Lack of harmonization of the rules around performing LDAR across provinces.

Quote from CMCRI: *CMCRI classifies emissions policy / RD&D initiatives into two broad groups. The LDAR approach and the general characterization of total atmospheric emissions. The standard industrial LDAR approach deals with equipment inventories, pipes, valves and their leaks. LDAR approaches tend to focus on equipment and its replacement or repair. This tends to be the domain of industry and the focus of AER directives. The more general characterization of total atmospheric emissions, using measurements and source identification in the atmosphere tends to be the focus of the universities. Whether industry will take an interest in this approach remains to be seen. It may provide the best estimate for understanding total emissions, but it can have issues for source identification, depending on technology used and data models employed. Currently proposed AER Directives and their amendments treat all of these methods as "alternatives". How to reconcile the two approaches remains elusive.*

Funding:

- Requirement for combination (hybrid) funding support from: industry, technology providers and government agencies (federal /provincial); and
- Funding mechanisms to be non-dilutive, non-refundable and independent.

5.4 Limitations

The following limitations were noted during the course of the research completed for this project:

- Some questionnaires were not thoroughly completed. As a result, a complete data set may not have been accumulated. Stakeholders were given a limited amount of time to complete the questionnaire and limited preliminary dialogue with stakeholders was completed ahead of the Survey Gizmo link being distributed. Consequently, some stakeholders only provided basic, high-level information or skipped questions entirely. This was particularly noticeable in the "Emission Management RD&D Testing Capacity in Canada" section of the questionnaire.
- Thorough follow-up with stakeholders was limited. As a result, a complete data set may not have been accumulated. The project scope and tight timelines did not allow for extensive follow-up conversations with each responding stakeholder. It was discovered through some follow-up, in-person interviews that new and relevant information was available and ultimately collected. This was particularly relevant to discussions with the University of Calgary, CAPP, Saskatchewan Research Council, MultiSensor Scientific and Saint Francis Xavier University.
- Building a questionnaire for a wide array of stakeholders was challenging. Given the four types of stakeholders identified for this research, and the varying levels of knowledge/activity in the emissions RD&D testing ecosystem each stakeholder group possessed, it was difficult to build a mechanism that captured the interests and needs of all 26 participants. This led to some questionnaires being incomplete and required the construction of a lengthy questionnaire.
- Ensuring participant bias did not influence questionnaire results & report analysis. As discussed early on in the project scoping exercise, and readily discovered throughout the interview and questionnaire process, stakeholder bias was abundant. Each stakeholder has specific needs for their own facility/operation, and when possible, they would take the opportunity to address these needs. This may have had an influence on the gap analysis and opportunity assessment seen in this report.
- Data analysis provided insight into the quality of questions provided to stakeholders. It was discovered through the process of the research that some questions were more effective than others at eliciting appropriate information. Understanding this dynamic would have been helpful at the outset of the question identification in order to improve the quality of questions delivered to stakeholders. This realization, however, was very helpful to the follow-up interviews that were completed.

- Additional research would generate a more thorough evaluation of the RD&D emissions testing ecosystem in Canada. Through the report writing process it became apparent that additional research on the interconnection between policy timelines, regulatory obligations, funding mechanisms, and technology development would be very informative. Further engagement with producers, funding providers and technology developers would also be helpful to extend the understanding of market needs. Time and resource constraints were limiting factors.

5.5 Risks

There are multiple risks to an effective (and relevant) national emissions test centre or network. These risks vary according to which type of capacity building contributions have been made into the system. For example, "Development" and "Enhancement" investments (into physical facilities) carry financial risks associated with construction delays, demographic limitations, and ongoing funding throughout the usable life of the facility. "Formalization" investments contain risk and limitations related to data collection, system development, and data security, among others. A more complete list of risks to a successful national emissions test center are noted in **Error! Reference source not found.**~~Table 4-1~~.

Table 5-1: Risks to Success of National Test Centre or Network[16]

1	Data Confidentiality	6	Data Verification/Validation
2	Ownership/Operatorship Bias	7	Technology Validation Expertise
3	Partial Participation	8	Infrastructure Development Timelines
4	Maintain Ongoing Relevance	9	Policy/Technology/Funding Disconnect
5	Regulatory/Political Uncertainty	10	Ongoing Funding

1. Data Confidentiality – Access to data collected from field and/or lab testing is typically limited to those stakeholders that are directly involved in the emissions quantification work being completed. For Post-Secondary Institutions there are constraints related to work publication; for technology providers the limitations pertain to development and performance confidentiality; for industry the concern relates to competitive and regulatory compliance concerns. For each of these reasons a data hub "facility" would be limited to publicly available data, which would limit the type and quality of data collected and analyzed.

2. Ownership/Operatorship Bias – Data quality assurance will be critical to ensuring that the information collected by some centralized hub is free from bias, and that errors are minimized. This requires distinct expertise as the data is highly technical and significantly variable.

3. Partial Participation – The credibility of a centralized "facility" or data hub is diminished if only a subset of the total ecosystem stakeholders participate in the network. Partial participation leads to incomplete

[16] This list does not necessarily represent the views of the respondent stakeholders

datasets and reduces the data sample size collected by the network, for example. Further, the network needs to be exhaustive to ensure that all relevant datasets are collected, reviewed, and reported on.

4. Maintain Ongoing Relevance – This risk is somewhat related to Partial Participation as system credibility is crucial to maintaining ongoing relevance of the network. This requires sound QA/QC measures, widely recognized/respected experts maintaining the system, and taking both a short-term and long-term view to emissions management RD&D and technology testing (e.g. focus broader than methane, which is the current immediate priority). It requires a sound business model, unbiased datasets and a collaborative model inclusive of all relevant stakeholder groups, among other meticulous details requiring ongoing maintenance.

5. Regulatory/Political Uncertainty – This risk cannot be controlled by a centralized network but does pose a concern with respect to availability of government funding and regulatory requirements. A change in government can influence the funds available to a centralized hub and diminish the relevance of a network should regulatory requirements be changed.

6. Data Verification/Validation – As mentioned in risk #4 above and identified by multiple Post Secondary Institutions, data verification/validation is critical to ensuring a well-functioning emissions RD&D and technology testing "facility". Data quality standards and common methodologies would be important considerations in this regard.

7. Technology Validation Expertise – Knowledge and experience of emissions reduction quantification is paramount to an effective centralized network in order to ensure the highest data standards are maintained throughout the lifecycle of the datasets as they enter and are extracted from the "hub".

8. Equipment and Infrastructure Investment Timelines for implementing investments to build emissions RD&D and technology testing capacity must coincide with and be able to support regulatory compliance timelines in order to achieve Canadian emissions reduction targets.

9. Policy/Technology/Funding Disconnect – As communicated in this report, it is important to thoroughly understand the interplay between policy/regulations and emerging vs. available technologies and targeted funding. Without this understanding an inefficient system can be developed which could result is wasteful spending and minimized credibility.

10. Ongoing Funding – A centralized data hub or testing facility is a long-term investment that needs to withstand political and other changes that could jeopardize the viability of the system. Securing the appropriate funding for the timescale required to build a solid, credible "facility" may prove challenging, especially in today's oil and gas market.

6 CONCLUSION

Alberta Innovates (AI) and Natural Resources Canada (NRCan) have commissioned Delphi and Modern West Advisory to undertake this detailed mapping and gap analysis study of Canada's oil and gas emissions management landscape to better understand existing capabilities, assets (facilities, equipment, infrastructure), and expertise across the country, with a focus on research, development and demonstration (RD&D) and technology testing capacity. This report contains the data and analysis completed resulting from the work plan, other critical system information that broadly affects the emission testing landscape in Canada (e.g. regulations, funding programs, etc.), as well as the needs expressed by key stakeholders to help determine capacity building focus areas. The gap analysis and recommendations contained herein will help AI and NRCan evaluate how best to bridge the gap between emissions testing activities already underway in the country and the infrastructure, data collection and assessment, supports, and management systems required for accelerating emissions reduction technology deployment.

The identified opportunities take several forms, whether it is development of new facility infrastructure or enhancements of the current ecosystem or formalization of a network of actively involved stakeholders, among others. Understanding that each of these opportunities present themselves on different timelines with different levels of involvement from stakeholders will ensure that appropriate measures are pursued that will have the most immediate impact on the emissions management ecosystem. Notably, capacity building must consider factors on both a short and long-term timeframe as growth in deployment of mitigation technologies will achieve reductions today, while deployment of emissions measurement and alternative technologies will improve our ability to quantify source categories and see benefits farther into the future.

Throughout the report, additional work is identified that will further enhance the research compiled by AI and NRCan to date. For example, there are multiple funding mechanisms already in place that support the emissions management system in Canada's oil and gas industry. Ensuring that future capacity building measures support or enhance these initiatives and avoid program overlap, additional work may be required to overlay the current targeted investment areas with the National Emissions Inventory, the regulatory landscape, and the gaps identified in this report in order to build a robust and effective system that will attract innovators and investment to Canada.

The framework of Canada's emission management ecosystem was expanded in this report beyond the four stakeholder groups identified to complete the questionnaire. This new system chart lays out the two primary capacity building "tracks" available to AI and NRCan: Testing Facilities; Data Systems. Each track contains separate opportunities to grow Canada's leadership in emissions management RD&D and technology testing. Testing Facilities largely comprise physical emissions testing infrastructure, while Data Systems refers primarily to the technology testing and performance data collected, as well as the quantification methodologies and models used by various stakeholders.

Ultimately, the entire emissions management RD&D system relies heavily on field facility access to complete accurate and exhaustive technology testing. The National Emissions Inventory requires better

field level data to improve accuracy. Clean Tech Developers require field level data to prove out their technologies. Regulators require field level data to write sound regulations. Industry members require field level data prior to committing to deploying new technologies at their facilities. Enabling the system to fill this requirement is a critical consideration, as is building the collaboration capacity between industry and all other stakeholder groups.

Another opportunity for capacity building in the ecosystem pertains to data sharing between stakeholders completing the testing and quantification at real and/or controlled emission sources. Data availability is a challenging issue to address, however, expanded access to technology performance and techno-economic analysis, as well as standardized QA/QC controls would be helpful. Resolution of the data sharing obstacles will dramatically improve the performance of a national emissions management network.

Finally, understanding the timelines associated with technology development, testing requirements, regulatory compliance obligations, and market deployment barriers will identify pockets for capacity building. Given the resource constraints within the system, should capacity building focus on improvement of emissions inventories (field data), testing of emerging technologies, or deployment of readily available technologies? This question, along with others identified herein, can be answered through additional work using the valuable information collected in the questionnaire provided to the 26 stakeholder participants in this project. Timelines are tight, however, and working diligently and efficiently to identify where Alberta Innovates and Natural Resources Canada can participate in the emissions management ecosystem presents an exciting challenge in an ever-evolving, technical, national landscape.

APPENDIX A - STAKEHOLDER LIST

A.1 Identifying Stakeholders

To begin the project, a list of 30 key stakeholders with some combination of knowledge, experience, regulatory authority and/or direct involvement in emissions testing were identified based on the contractor's existing knowledge and experience with emissions management in Canada, participants who attended the AI/NRCan workshop (April 2018), and other targeted recommendations. The goal of this practice was to obtain input from a diverse set of Canadian-based stakeholders actively involved at different stages of the emissions RD&D and technology testing value chain. The focus was first on physical facilities, then laboratory and field-testing capacities, then science, research, and analysis capabilities, then network outreach and related experience. This approach would ensure the ability to identify the gaps within, and needs of, the current emissions management ecosystem.

Initial requirements for relevant stakeholder organizations to be included in the research related to the focus area of the organization, technical and research capabilities, and facility assets. The individuals within each organization were further identified based on position and known experience. The qualified stakeholders included organizations ranging across federal/provincial governments, research or funding organizations, physical RD&D facilities, industry and industry associations, post-secondary institutions, environmental non-governmental organizations (ENGOs), and clean technology providers. Additional stakeholders were identified following some primary research and preliminary stakeholder interviews.

Some organizations were not identified as stakeholders relevant to the research completed here. Notably, some prevalent clean technology companies have a wealth of experience in developing and deploying emission reduction technologies but are already established in the market and do not require additional testing capacity. A multitude of local technology incubators were not included because they are focused on providing entrepreneurs with resources required to start their companies but do not provide emissions testing capabilities. Other technology and innovation funders were excluded from this research because their focus is on financial support rather than technical support and data management/analysis. Each of these groups of organizations are important to the overall emissions management RD&D ecosystem and should be considered when a complete picture of the national emissions management system is developed, however, they were not deemed to be a target for the research completed for this project.

Ultimately, four stakeholder buckets were identified to capture the types of stakeholders identified through this process.

Clean Tech Developer – An organization that is directly developing and/or testing an emissions measurement, monitoring, or mitigation technology.

RD&D Facility – Physical infrastructure dedicated to emissions monitoring and technology testing.

Post-Secondary Institution – Any academic institution involved with the testing of emission reduction technologies and/or analysis of the data collected from field and lab tests conducted throughout the country.

Industry or Association – Includes stakeholders that are involved in the production of oil and gas or a related organization that represents a multitude of producers, government funders, regulators, and/or special interests. The following table identifies the 26 stakeholders included in the research for this report.

The final list of stakeholders contacted for this work are included below:

Table A-1: Project Stakeholders

Stakeholders							
Industry or Association		**Post-Secondary Institution**		**Clean Tech Developer**		**RD&D Facility**	
1	Alberta Energy Regulator	1	University of Alberta	1	FLIR	1	Natural Resources Canada Canmet ENERGY
2	BC Oil & Gas Commission	2	University of Calgary	2	Kairos Aerospace	2	C-FER Technologies
3	Canadian Association of Petroleum Producers	3	Carleton University	3	MultiSensor Canada	3	Clearstone Engineering
4	Petroleum Technology Research Centre	4	University of Guelf			4	CMC research
5	Environmental Defence Fund	5	NAIT			5	Drayton Valley Clean Energy Technology Centre
6	Emission Reduction Alberta	6	SAIT			6	Innotech Alberta
7	National Research Council	7	St. Francis Xavier University			7	Saskatchewan Research Council
8	Pembina Institute						
9	Petroleum technology Alliance Canada						

APPENDIX B - STAKEHOLDER QUESTIONNAIRE

B.1 Overview

The core requirements for this report required a detailed questionnaire to be distributed to each identified stakeholder. The following information provides a high-level review of the questionnaire focus areas.

The primary method of collecting data from the stakeholders was through a web-based questionnaire that was shared with each organization via the SurveyGizmo platform. The questionnaire was designed considering the characteristics of each stakeholder organization (e.g. whether they have testing facilities) and was built in a manner that allowed for both pre-determined inputs (drop-downs, check boxes, etc.) and long-form text responses. Questions were designed to gather information from each organization in the following focus areas:

- General Overview
    - To request introductory information about each organization and help categorize the services that the organizations may be able to provide. This helps to obtain a general understanding about the emissions management areas that each stakeholder organization might be involved in or have a knowledge of.
- Facility Characteristics
    - To catalogue the unique features and characteristics of each organization which is required to identify the strengths and capabilities of each organization and create an inventory of specific services that the stakeholders can provide.
- Current Assets & Capabilities
    - To identify the equipment available on site (if any), the quantification capacity of the organization and the data systems associated with stakeholder testing capabilities.
- Operating Model
    - To gain insight related to each organization's business model and partnerships and request recommendations for other organizations of interest. The responses collected for this focus area can help provide insight into a business model for a potential national emissions management network in Canada.
- Partnership/Key Projects
    - To request information about how each organization uses, collects, analyzes, and shares data with other organizations. The responses in this section can help provide an understanding of the existing collaborations and databases that could be leveraged for development of a national emissions management network.
- Emission Management RD&D Testing Capacity in Canada

- To ask each stakeholder to identify gaps within the emissions management ecosystem and components that would help them succeed with their emissions management practices. The stakeholder responses to the questions in this section are critical to identifying the gaps that exist in the emissions management space in Canada, and how they may be addressed most effectively.

While the input from stakeholders was mainly collected through the online questionnaire some phone and in-person interviews were also conducted depending on stakeholder types and breadth of online response. Reponses from these interviews were then combined with the responses from the online questionnaire to complete the summary documents in APPENDIX E ~~Appendix~~ E.

About the questionnaire:

- SurveyGizmo[17] was used to transform the question list into a web-based format that could easily be shared with stakeholders.
- This online survey platform is customizable, provides a variety of options for presenting questions, and is user-friendly.
- Individualized links were created for each stakeholder to allow them to share the link between different personnel in their organization and work on the response at different times as needed.
- To prevent survey fatigue and present the stakeholders with relevant questions to their organization, logic was employed to filter out irrelevant or repetitive content based on a series of qualification questions.
- The web-based questionnaire was the preferred method of gathering information because:
  - It is an objective format for collecting data where the risk of biasing stakeholder responses can be minimized
  - It reduces chances of misinterpreting information collected from stakeholders, and,
  - It streamlines the data collection process for data analysis
- The data obtained from the questionnaires were then exported via MS Excel worksheets for subsequent analysis.

In general, question types and response options were designed so that quantitative answers would be obtained for as many of the questions as possible. Quantitative responses were preferred to qualitative responses to improve consistency and accelerate data analysis. For example, when asking what specialized equipment/technologies a stakeholder facility currently uses, numerous response options were provided so that stakeholders could select options instead of providing their own responses in an open-ended comment box. Structuring the questionnaire to be quantitative made it easier to compare responses between stakeholders to improve ease of ecosystem mapping. However, comment boxes were still provided for most questions in case the provided options were not exhaustive.

[17] https://ca.surveygizmo.com/

B.2 Questionnaire

B.2.1 Intro

Alberta Innovates and Natural Resources Canada are undertaking a mapping study of Canada's oil and gas emissions management landscape, to better understand existing capabilities, assets (facilities, equipment, infrastructure), and expertise across the country, with a focus on RD&D and technology testing capacity.

The following questionnaire will request your organization's priority activities, assets, and capabilities, and will ask for your perspectives on key gaps, needs and required features for establishing a coordinated, collaborative approach to cost-effective oil and gas emissions reductions.

The results of this study are of great importance, as they will help to inform federal-provincial initiatives on building capacity, supporting collaborative RD&D projects, and fostering an integrated network for improved emissions management to help Canada achieve its emissions reduction targets.

Thank you for your time and effort. Please contact Matt Beck at the Delphi Group (mbeck@delphi.ca) or Jackson Hegland at Modern West Advisory (jhegland@modernwestadvisory.com) if you have any questions or concerns while completing this questionnaire.

B.2.2 Organizational Overview

This section requests introductory information about your organization and helps us categorize the services that your organization is able to provide.

1) Organization / Facility Name*

The name of your organization or facility as you would like it to be displayed in the Methane and SLCP RD&D System Mapping Report.

2) Contact Name*

Full name of the person responsible for collecting information and completing the questionnaire on behalf of your organization.

3) Phone number where you can be reached to discuss your response.

4) Email address of the person responsible for collecting information and completing the questionnaire on behalf of your organization.*

5) Please provide the contact information of other people within your organization that have helped you complete this questionnaire.

6) Does your organization have a physical facility where you undertake emissions management RD&D?

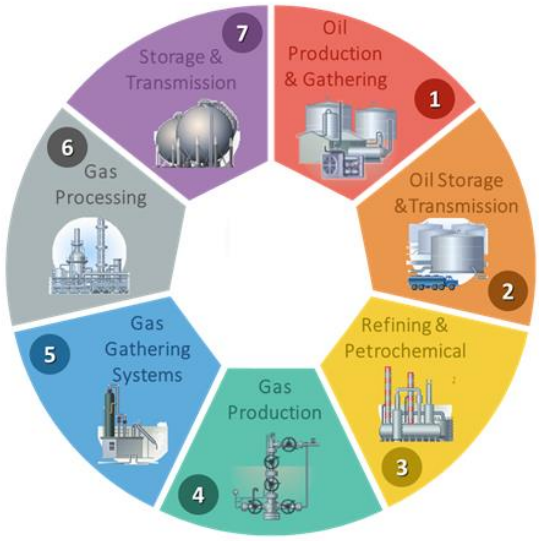
- Yes
- No

7) Please provide a high-level description of your organization as it pertains to emissions RD&D or technology testing/validation/certification (mission and objective).

Please summarize within 2-5 sentences

8) Which of the following oil and gas areas does your organization cover with regards to emissions management/technology testing?

Refer to the Emissions Management Ecosystem Diagram as a guide.



- ☐ 1. Oil Production & Gathering
- ☐ 2. Oil Storage & Transmission
- ☐ 3. Refining & Petrochemical
- ☐ 4. Gas Production
- ☐ 5. Gas Gathering Systems
- ☐ 6. Gas Processing
- ☐ 7. Storage & Transmission

9) What types of emissions does your organization focus on? Are you involved in their quantification, characterization, or transportation?

- Quantification - Determining the volume of emissions being released
- Characterization - Emission speciation and properties
- Transportation - Dispersion of gaseous and particulate emissions

Select all that apply

	Quantification	Characterization	Transportation	Other	Not applicable
Carbon Dioxide	☐	☐	☐	☐	☐
Methane	☐	☐	☐	☐	☐
Volatile Organic Compounds (VOCs)	☐	☐	☐	☐	☐
Fine Particulate Matter (PM2.5) / Black Carbon / Soot	☐	☐	☐	☐	☐
Other Short Lived Climate Pollutants (SLCPs)	☐	☐	☐	☐	☐
Reduced Sulphur Compounds (RSCs)	☐	☐	☐	☐	☐

Please provide examples and / or explanations of other activities related to your responses:

10) What stakeholder category (ies) best describe(s) the mandate of your organization?

- ☐ Not-for-profit research facility
- ☐ Private research organization
- ☐ Post-secondary institution
- ☐ ENGO
- ☐ Incubator / Accelerator
- ☐ Industry association or partner
- ☐ Federal innovation agency / funder
- ☐ Provincial innovation agency / funder
- ☐ Regulator
- ☐ Clean tech provider
- ☐ Other - Write In: _____

Comments:

11) Which emissions research, development and demonstration (RD&D) activities is your organization actively involved in, and at what scale? Please provide examples.

Select all that apply

	Scale					**Example**
	Fundamental / Exploratory	**Bench**	**Pilot**	**Field**	**Not Applicable**	
Emissions quantification and characterization research	[ ]	[ ]	[ ]	[ ]	[ ]	___
Emissions reduction research	[ ]	[ ]	[ ]	[ ]	[ ]	___

Emissions reporting	[ ]	[ ]	[ ]	[ ]	[ ]	___
Emissions quantification and characterization technology development	[ ]	[ ]	[ ]	[ ]	[ ]	___
Emissions reduction technology development	[ ]	[ ]	[ ]	[ ]	[ ]	___
Emissions quantification and characterization technology demonstration	[ ]	[ ]	[ ]	[ ]	[ ]	___
Emissions reduction technology demonstration	[ ]	[ ]	[ ]	[ ]	[ ]	___
Other, please specify in example box	[ ]	[ ]	[ ]	[ ]	[ ]	___

12) Does your organization provide third-party testing/validation/certification of technologies?

Yes

No

Logic: Hidden unless: #12 Question "Does your organization provide third-party testing/validation/certification of technologies?" is one of the following answers ("Yes")

13) What type of technologies can you validate and at what scale?

Scale options: bench, pilot, field, modeling/simulation

Logic: Hidden unless: #12 Question "Does your organization provide third-party testing/validation/certification of technologies?" is one of the following answers ("Yes")

14) Please provide a brief description of associated procedures/equipment used.

15) What emissions management priorities is your organization currently addressing?

Wet vs. dry solution gas or flash gas from oil and gas production	[__] Not Applicable	☐
Evaporative losses from processing, handling and storage	[__] Not Applicable	☐
Venting and flaring during hydraulically fractured well flowback and well testing	[__] Not Applicable	☐
Venting and flaring from hydrocarbon storage tanks, refineries and petrochemical plants	[__] Not Applicable	☐
Fugitive equipment leaks	[__] Not Applicable	☐
Other SLCPs from combustion processes	[__] Not Applicable	☐
Systems and process to support data gathering and exchange	[__] Not Applicable	☐
Other, please specify in comments	[__] Not Applicable	☐

Explain why you prioritized these focus areas:

16) What emission source categories is your organization currently addressing?

Addressing a source category includes any or all activities related to emissions from that source (e.g. data, physical testing, solution development).

☐ Well Drilling & Completions

- ☐ Pneumatic Devices
- ☐ Compressors
- ☐ Solution gas vent lines
- ☐ Solution gas flare stacks
- ☐ Storage tank emissions
- ☐ Fugitives & LDAR
- ☐ Gas Destruction
- ☐ Glycol Dehydrators
- ☐ Bitumen Batteries
- ☐ Liquids unloading
- ☐ Purging
- ☐ Surface casing vent flow
- ☐ Gas migration
- ☐ Engines
- ☐ Other - Write In: _____
- ☐ Other - Write In: _____
- ☐ Other - Write In: _____

Briefly explain how your organization is addressing these emission source categories:

17) What Technology Readiness Level (TRL) stage(s) does your organization focus on?

Select all that apply.

- TRL 1 – Basic principles observed and reported
- TRL 2 – Technology concept and/or application formulated
- TRL 3 – Analytical and experimental critical function and/or characteristic proof of concept
- TRL 4 – Product and/or process validation in laboratory environment
- TRL 5 – Product and/or process validation in relevant environment
- TRL 6 – Product and/or process prototype demonstration in a relevant environment
- TRL 7 – Product and/or process prototype demonstration in an operational environment
- TRL 8 – Actual product and/or process completed and qualified through test and demonstration
- TRL 9 – Actual product and/or process proven successful

18) Briefly describe your organization's key RD&D features and provide examples (specific or unique to your organization).

19) Describe your human resource assets relevant to the emissions management space, including any specialized in-house talent/expertise/highly-qualified personnel (name, title, responsibilities, degrees/qualifications and years of experience).

You may attach up to 2 files with a max size of 2MB each. Organizational charts are encouraged. If you prefer not to attach files, please provide a description in the comments box below.

Please include any additional comments below:

B.2.3 Features and Highlights

This section catalogues the unique features and characteristics of your organization.

20) Is your organization involved in any techno-economic research/analysis for emissions mitigation solutions?

Techno-economic research/analysis can be described as: An evaluation of mitigation technologies considering both environmental and economic performance (cost, energy consumption, emissions performance).

- Yes
- No
- Not applicable

Please provide examples if applicable (e.g. tools developed, databases, publications, etc.):

Does your organization have a physical facility where you undertake emissions management RD&D?

21) What specialized equipment/technologies does your facility currently use?

- ☐ Analyzers
- ☐ Infrared imaging
- ☐ Drones/aircraft
- ☐ Pneumatic systems
- ☐ Continuous monitoring technologies
- ☐ Optical flow meters
- ☐ Ultrasonic flow meters
- ☐ Meteorological sensors
- ☐ Scientific complementary metal-oxide-semiconductor (sCMOS) cameras
- ☐ Other - Write In:
- ☐ Other - Write In:
- ☐ Other - Write In:

Comments:

---

22) What types of operating facilities does your organization have access to (examples provided below)? Do you own the asset(s) or is it owned by a third-party? Please identify relevant third party (ies).

	Access	Owned by			Name of third-parties (if applicable)
		Organization	Third-Party	Not applicable	
CHOPS	[ ]	( )	( )	( )	___
Gas batteries	[ ]	( )	( )	( )	___
Multi-well oil batteries	[ ]	( )	( )	( )	___
Gas plant(s)	[ ]	( )	( )	( )	___
Single well(s)	[ ]	( )	( )	( )	___
Uncontrolled tank farms	[ ]	( )	( )	( )	___

Space for additional assets types. Please provide whether the asset is owned by your organization or a third party and what third party, if applicable:

---

23) What emissions quantification methodologies does your organization employ?

- ☐ Isolation flux chamber measurements
- ☐ Tracer-to-pollutant ratio technique
- ☐ Remote sensing with inverse dispersion modelling
- ☐ Direct flow measurement and speciation
- ☐ Species mass balances
- ☐ Simulations
- ☐ Other - Write In: _____

☐ Other - Write In:

☐ Other - Write In:

A space for additional emissions quantification methodologies used at your facility:

24) Does your emission quantification work involve real gas sources or controlled-release of gas?

Quantification of real gas sources can be described as field based measurements on actual equipment at oil and gas facilities.

Quantification from controlled sources can be described as work done on simulated sources at the lab, bench, or pilot scale.

	Yes	No	Not applicable
Real gas sources	○	○	○
Controlled release of gas	○	○	○

25) Are you able to adjust the content of the gas used in the system?

○ Yes

○ No

If yes, please explain how adjustments are made:

---

26) Amenities and site specific details - What amenities and services are accessible to your facility?

☐ Easy access to feed stock (e.g. sweet vs. sour gas)

- ☐ Fresh water access
- ☐ Access to city roads
- ☐ Close proximity to R&D centre/testing facilities
- ☐ Close proximity to academic institutions
- ☐ Close proximity to city centres
- ☐ Other - Write In:
- ☐ Other - Write In:
- ☐ Other - Write In:

If applicable, describe how feed stock or resources are brought to site (e.g. gas trucked in from off-site loading station).

What site-specific features associated with your facility's current location do you consider a key asset?

27) What are the permitting requirements associated with your facility? Are there any limitations to your site from a permitting standpoint (e.g. room and flexibility for expansion, located close to schools and neighboring communities)?

28) Describe your organization's contribution to emission management RD&D, testing and/or technology evaluation.

- ☐ Technology development
- ☐ Key Publications
- ☐ Patents
- ☐ Databases
- ☐ Models
- ☐ Presentations at major conferences
- ☐ Solution testing and evaluation
- ☐ Other - Write In:

29) Please provide copies of relevant publicly available reports/publications or references, as applicable

Note: Maximum allowable file size is 10 MB. A maximum of ten separate files can be uploaded. Please email files to bedwards@delphi.ca if you are unable to load files here.

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30) Please comment on the status of the patents.

31) Please provide a fact sheet of your organization, if available.

Note: Maximum allowable file size is 10 MB. A maximum of two separate files can be uploaded. Please email files to bedwards@delphi.ca if you are unable to load files here.

1

1

32) Please provide photos of your equipment and infrastructure, if available.

Note: Maximum allowable file size is 2 MB. A maximum of ten separate files can be uploaded. Please email files to bedwards@delphi.ca if you are unable to load files here.

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2

3

4

5

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2

3

4

B.2.4 Operations, Projects and Partnerships

This section explores your organization's business model and partnerships and requests recommendations for other organizations to speak to.

33) Describe your organization's business model.

Fee for service

Government R&D Funding

Private Funding

Combination

Other - Write In:

Provide a short description of your facility's business model:

The next series of questions will ask you to identify and describe the key partnerships (up to 10) that you consider to be significant in your work on emissions management RD&D. You will need to answer the same set of the following questions for each partner.

34) Please identify the number of key emissions management RD&D partnerships for your organization.

Note: If your organization has key partnerships, sub-questions will ask the nature of the partnerships in terms of contributions/benefits.

0

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10

Please explain if your organization has more than 10 significant partnerships. :

35) What is the name of Partner]'s organization?

36) Briefly describe this partnership.

37) How does your organization contribute to this partnership?

38) How does your organization benefit from this partnership?

\

39) Who are currently the most important players across Canada's emissions management RD&D/tech testing ecosystem (i.e. specific companies, labs, researchers, etc.)

40) Are there specific projects, partnerships, demonstrations, or RD&D initiatives underway in Canada (not currently occurring at your facility) that are worth investigating or profiling as part of this analysis (from a best practice standpoint)?

41) Who else would you suggest we speak with as part of this analysis and why?

B.2.5 Data and Systems

This section requests information about how your organization uses collects, analyzes, and shares data.

This next set of questions asks for information on how you share data across the RD&D ecosystem. The intention is to gain more insight into how effective the network is managing data and knowledge transfer.

42) What type of data does your organization collect/have?

Briefly describe datasets mined and associated activities in the comment box.

- ☐ Data captured on site
- ☐ Public and / or regulatory datasets
- ☐ Data extrapolated from simulations or models
- ☐ Proprietary third-party datasets
- ☐ Other - Write In:

Comments:

---

43) Do you employ any specific quality control/quality assurance measures (e.g. EPA, ISO) to the data you collect on site?

- ○ Yes
- ○ No

44) Please briefly describe your quality control/quality assurance measures.

45) Do you have any data-sharing arrangements with other organizations?

☐ Yes, we share our data with other organizations

☐ Yes, other organizations share their data with us

☐ No, we do not have any have any data sharing arrangements in place

46) Please identify relevant organizations. Are the data sets open/sharable?

If you have more than 3 data sharing arrangements, please describe additional arrangements in the comments.

	Organization	**Data availability**		**Data and arrangement description**
		Open	**Proprietary**	
1	___	( )	( )	___
2	___	( )	( )	___
3	___	( )	( )	___

Comments:

47) What are the limitations of the data you collect or use?

48) What software, data processing, modelling, and analytical tools does your organization use? Are any of these in-house tools, and if so, are they shareable?

	Tool developed in-house	Tool is used in-house	Tool is shareable
Tank simulation software	☐	☐	☐
Dispersion modelling software	☐	☐	☐
Software for emissions calculations	☐	☐	☐
Data processing and reporting software	☐	☐	☐

Comments:

B.2.6 Emissions Management: Priorities, Capacities and Gaps

This section asks you to identify gaps within the emissions management ecosystem and components that would help your organization succeed.

49) What are your organization's short-term development plans (over the next 1-3 years)? Will you be expanding current capabilities and/or physical assets or expanding into new areas of study? If so, please describe.

50) What does a successful emissions management RD&D tech testing Centre/Network look like to you, that meets your organizations needs/objectives? Describe key features that would address your needs and fill the gaps that you consider to exist in the current emissions management/technology testing ecosystem?

51) Rank key components of Canada's emissions management RD&D network by their relative importance to the success of your organization.

	Low Importance	Low-Medium Importance	Medium Importance	Medium-High Importance	High Importance
RD&D Facilities	○	○	○	○	○
Technology Testing Facilities	○	○	○	○	○
Equipment	○	○	○	○	○
Funding	○	○	○	○	○
Data	○	○	○	○	○

Expertise	○	○	○	○	○

Comments:

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52) What key emissions management RD&D areas should we be paying more attention to?

- ☐ Emissions quantification and characterization research
- ☐ Emissions reduction research
- ☐ Emissions reporting
- ☐ Emissions quantification and characterization technology development
- ☐ Emissions reduction technology development
- ☐ Emissions quantification and characterization technology demonstration
- ☐ Emissions reduction technology demonstration
- ☐ Other - Write In: _____
- ☐ Other - Write In: _____
- ☐ Other - Write In: _____

Why should we pay more attention to these key emissions management RD&D areas?:

---

53) What are the missing tools/capabilities required to achieve your organization's emissions management objectives?

54) Key Gaps

What are the key gaps in RD&D/tech development to achieving cost-effective compliance with emissions management policies and regulations?

What additional work is required to address this issue and what does that entail?

B.2.7 Thank You!

Thank you for completing our questionnaire! If you happen to have reached this page without having a chance to complete your response, please reach out to us and we will help ensure that you are using the correct link.

Alberta Innovates and Natural Resources Canada appreciate the time you have taken to assist us in this study. The results of this study are of great importance, as they will help to inform federal-provincial initiatives on building capacity, supporting collaborative RD&D projects, and fostering an integrated network for improved emissions management to help Canada achieve its emissions reduction targets.

As results are reviewed, we may reach out to you to discuss your organization's emissions management activities further. If you have any more questions, don't hesitate to contact Matt Beck at the Delphi Group or Jackson Hegland at Modern West Advisory.

APPENDIX C - ADDITIONAL RESULTS VISUALS

C.1 Stakeholder Categories

Q10: What stakeholder category(ies) best describe(s) the mandate of your organization?

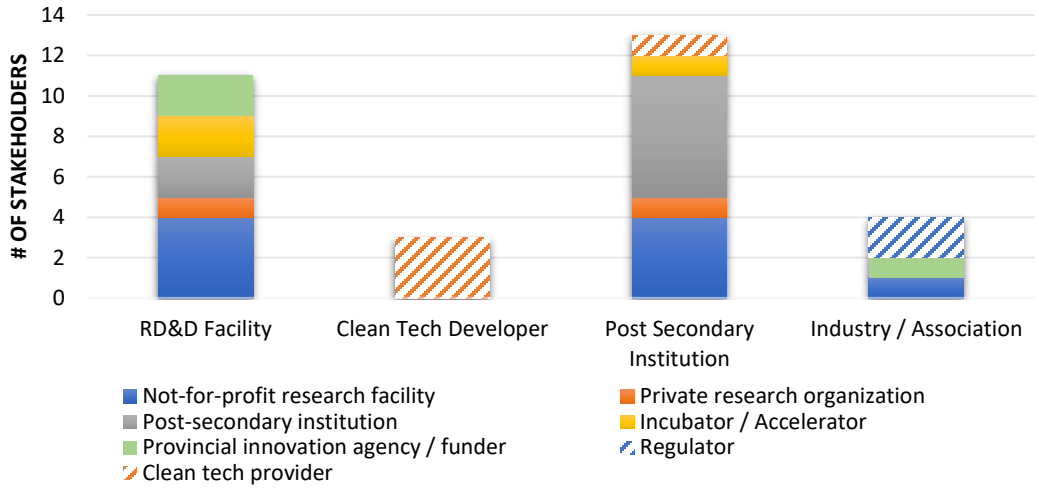


Figure C-1: Stakeholder Categories

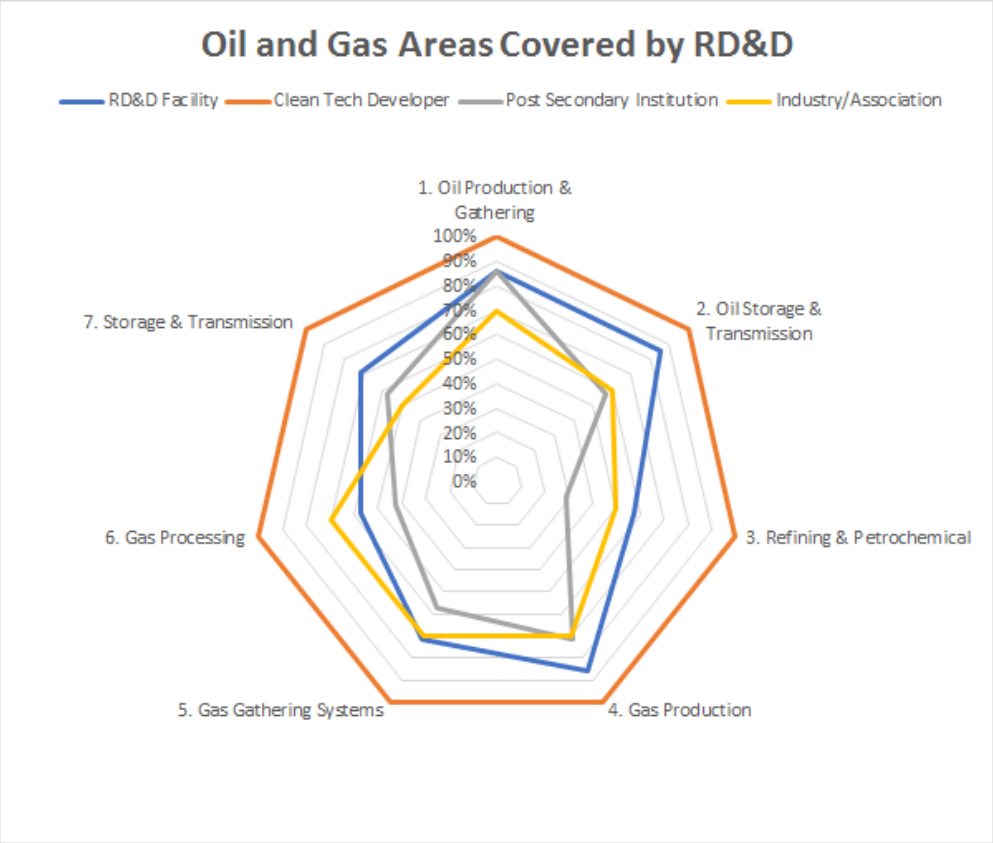
Notes:

a. Other self-identified stakeholder categories include: Provincial research facility (SRC); and NGO (Pembina).

C.2 Oil and Gas Areas – Distribution

Q8: Which of the following oil and gas areas does your organization cover with regards to emissions management/technology testing?

Figure C-2: Oil and Gas Areas Covered by RD&D



C.3 RD&D Involvement & Scale

Q 11: Which emissions research, development and demonstration (RD&D) activities is your organization actively involved in, and at what scale? Please provide examples.

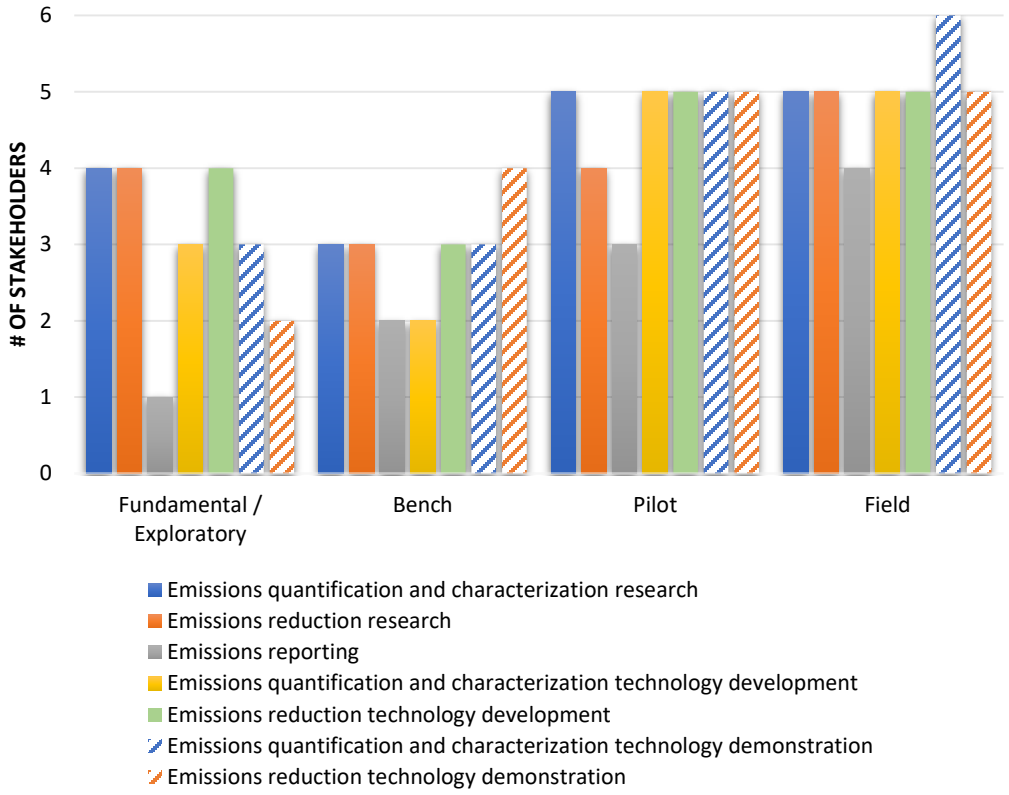


Figure C-3: Scale of RD&D Activities for Research Facilities

Notes:

a. Other RD&D activities that RD&D Facilities are actively involved in include: Subsurface and groundwater (CMCRI); and regulatory analysis (Carleton)

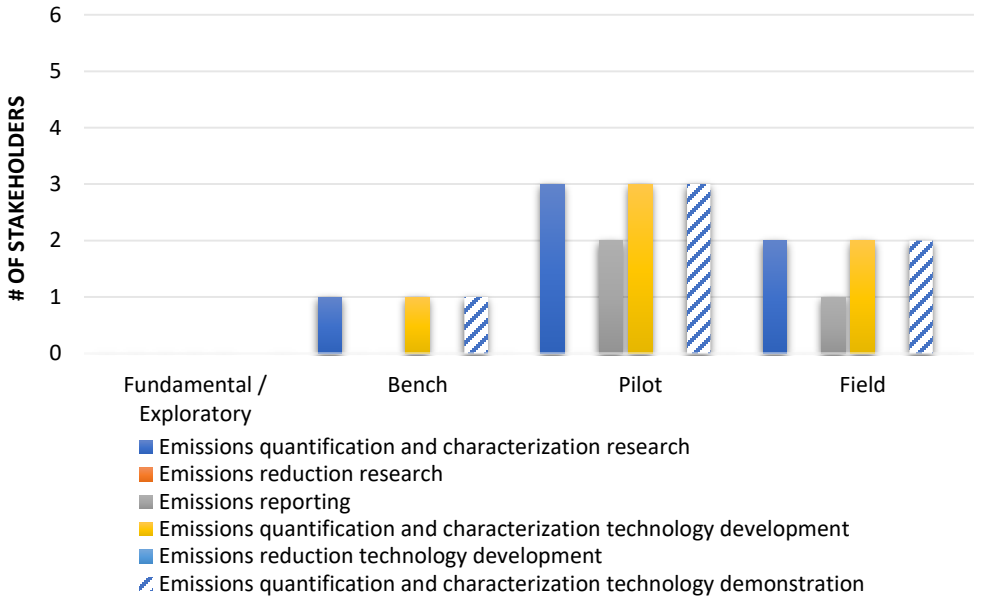


Figure C-4: Scale of RD&D Activities for Clean Tech Developer

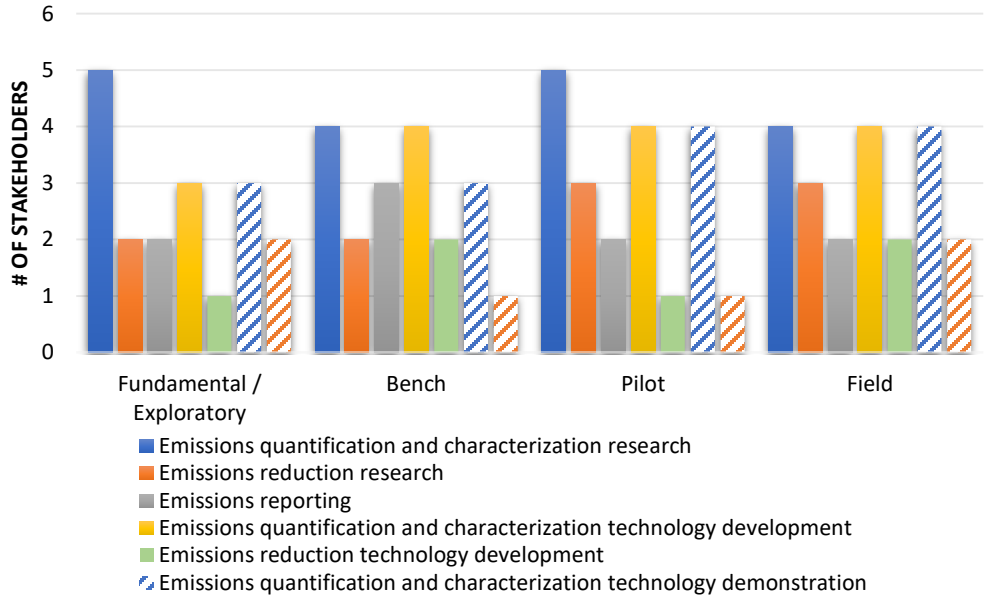


Figure C-5: Scale of RD&D Activities for Post Secondary Academia

Notes: "Other" RD&D activities that Post Secondary Institutions are actively involved in include regulatory analysis (Carleton).

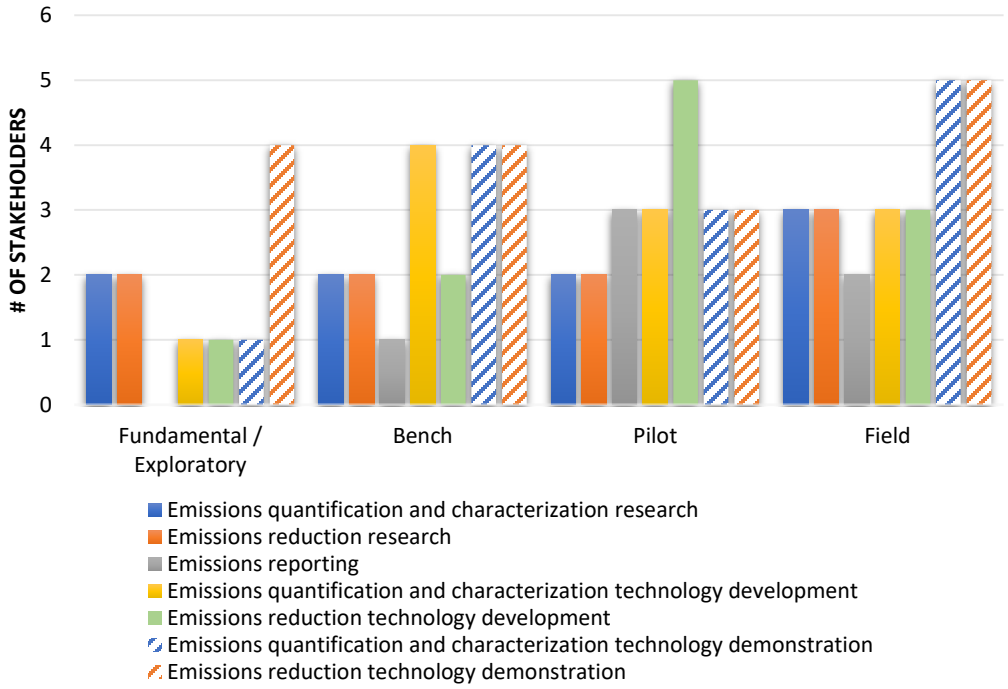


Figure C-6: Scale of RD&D Activities for Industry/Association

C.4 Business Model

Q 32: Describe your organization's business model.

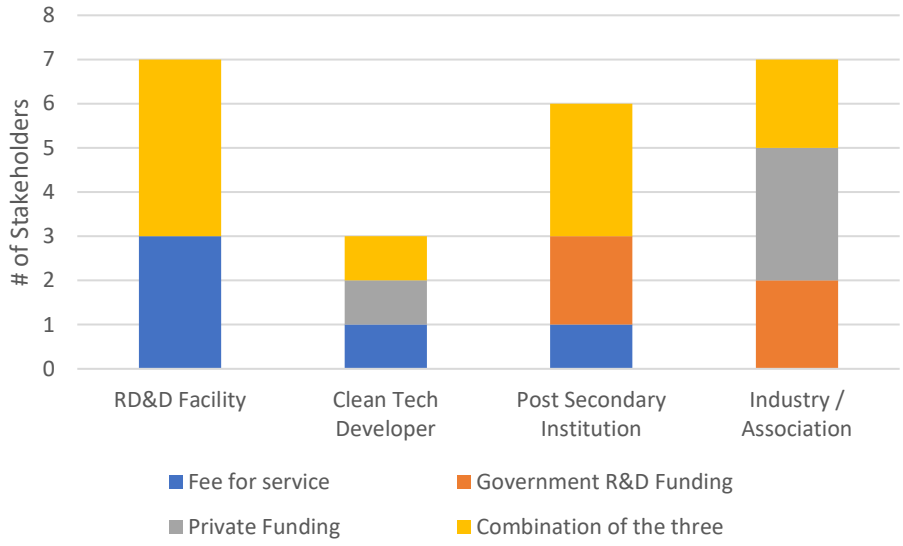


Figure C-7: Self-Identified Business Model

Note:

a. "Other" business model's identified by stakeholders include: federal R&D funding with cash and in-kind support from external collaborators such as federal governments where none of the leveraged resources go directly to their group as they are net contributors (Canmet); private funding supplemented with government R&D funding (MultiSensor); membership fee (CAPP); industry funded (BCOGC); industry funded, administered via Government of Alberta (AER);

C.5 Specialized Equipment

Q 21: What specialized equipment/technologies does your facility currently use?

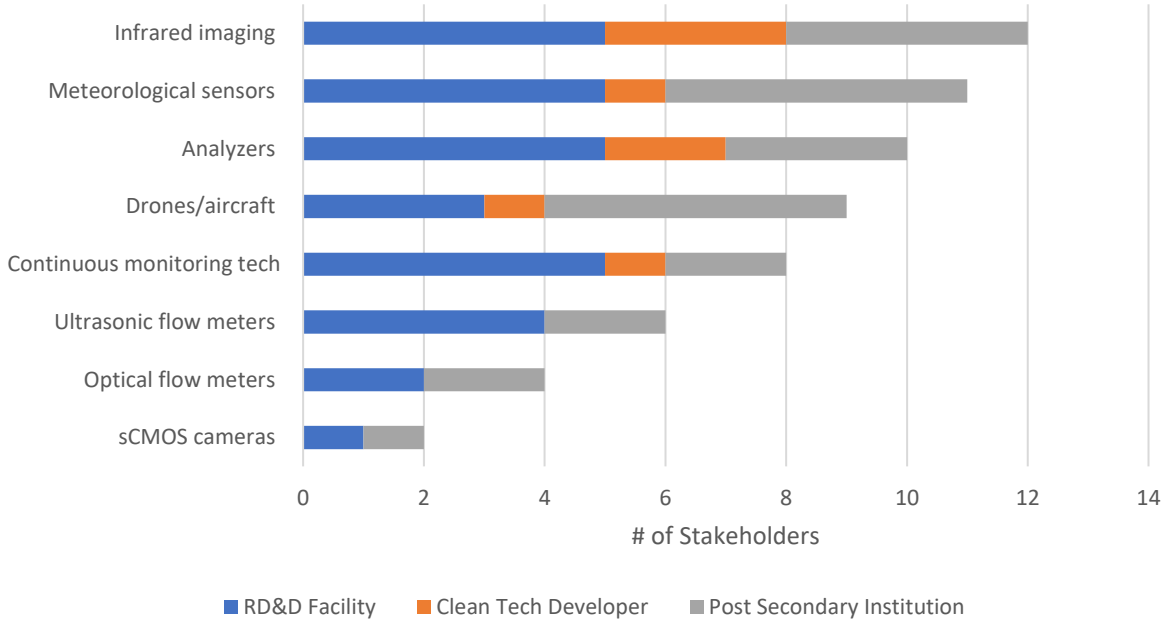


Figure C-8: Specialized Equipment/Technologies Used by Different Stakeholders

Notes:

a. "Other" specialized equipment used and identified by stakeholders includes: Pipeline leak simulation facilities for in soil and on water liquid releases, special Environments Laboratory providing full-scale simulation of equipment in explosive, corrosive or toxic gas environments, high-temperature flow loops for testing equipment for thermal oil sands operations and waste heat recovery/conversion technologies (C-FER); purpose built TDLAS based continuous measurement and speciation, purpose built laser based technologies for soot characterization and quantification of the atmospheric radiative climate forcing of black carbon PM2.5 soot particles from flaring (Canmet); cavity ring-down spectrometry Picarro, dual frequency comb laser interferometry, gas chromatography mass spectrometry (CMCRI); data loggers, wireless transmitters, SCADA systems, temperature, pressure, distance, GPS coordinates, weight, and liquid level measurement systems and calibration systems (Clearstone); custom optics, custom detectors (MultiSensor); portable release system, vehicle-based R&D platform (UCalgary); computational server for atmospheric modelling (UGuelph); black carbon measurement technologies, tunable diode laser spectroscopy systems, field deployable spectrometers (Carleton); emission flux chambers for gas migration, floating, etc, and vehicle-based emissions technology (StFX).

C.6 Amenities and Permitting Requirements

Q 26: Amenities and site-specific details -

- *What amenities and services are accessible to your facility?*
- *If applicable, describe how feed stock or resources are brought to site (e.g. gas trucked in from off-site loading station).*
- *What site-specific features associated with your facility's current location do you consider a key asset?*

Q 27: What are the permitting requirements associated with your facility? Are there any limitations to your site from a permitting standpoint (e.g. room and flexibility for expansion, located close to schools and neighboring communities)?

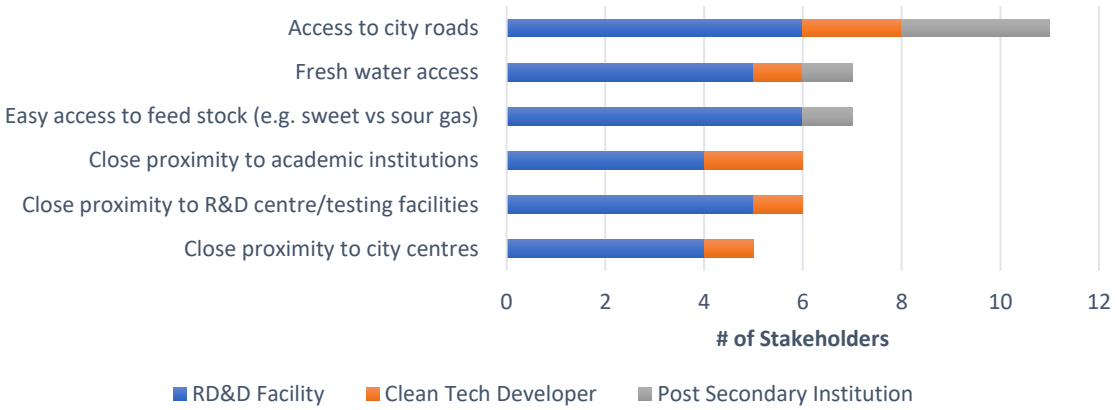


Figure C-9: Amenities & Services

Notes:

a. "Other" amenities and services accessible to stakeholder facilities include: explosion proof testing facilities (C-FER); 200 ha research space, 40,000 sqf state-of-the-art multipurpose facility for technology development and validation equipped with all utilities (natural gas, steam, clean electricity, cooling and chilled water), real life flue gas from natural gas boiler, up to 2 tpd (CMCRI); close proximity to academic institution, < 1km (DV CETC); machine shop, 3D printing, electronics lab (Clearstone);

C.7 Emission Quantification Methodologies

Q 23 What emissions quantification methodologies does your organization employ?

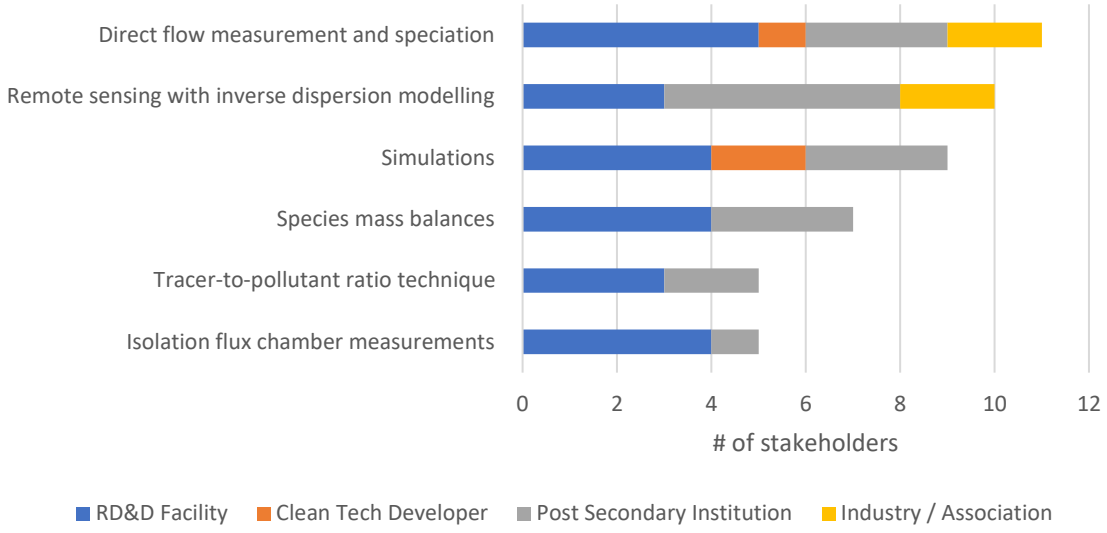


Figure C-10: Emission Quantification Methodologies Used by Different Stakeholders

Notes:

a. "Other" emissions quantification methodologies that stakeholders employ include: semi-quantitative forward looking infra-red imaging, eudiometry, controlled atmospheric releases (CMCRI); plume transect technique (concentration and velocity gradients across a plume cross-section are mapped and integrated to determine emission rates, inline tracer techniques, Hi-Flow sampler (Clearstone); quantification using pixel absorbance response in an optical gas imaging camera developed by Providence (FLIR); proprietary, patented technology based on non-thermal infrared imaging combined with flow hydrodynamics, Coriolis mass flow meters, photonics (MultiSensor); unique measurement protocols tailored specifically to target sources which might not otherwise be measurable, camera-based remote measurements of black carbon, remote spectrometer measurements (Carleton); field OGI cameras and portable detection monitors used for periodic field inspections (BCOGC); the Methane Abatement Project Platform Analytics (MAPP Analytics) by Cap-Op Energy will build methane analytical tools and integrate the existing DEEPP and MAPP Cap-Op platforms, which will offer tools compatible with the Petrinex reporting system, REMVue Low Horsepower (LHP) technology, solar powered electronic control systems (PTAC).

C.8 Quality Control

Q 74: Do you employ any specific quality control/quality assurance measures (e.g. EPA, ISO) to the data you collect on site?

Q 75: Please briefly describe your quality control/quality assurance measures.

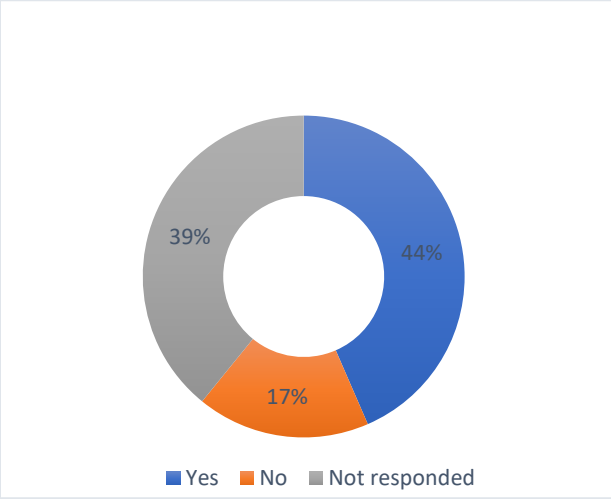


Figure C-11: QA/QC Measures In Place Across Different Stakeholders

APPENDIX D - TECHNOLOGY READINESS LEVEL

TRL 1 – Basic principles observed and reported

Lowest level of technology readiness. Scientific research begins to be translated into applied research and development (R&D). Examples might include paper studies of a technology's basic properties.

TRL 2 – Technology concept and/or application formulated

Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions.

TRL 3 – Analytical and experimental critical function and/or characteristic proof of concept

Active R&D is initiated. This includes analytical studies and laboratory studies to physically validate the analytical predictions of separate elements of the technology.

TRL 4 – Product and/or process validation in laboratory environment

Basic technological products and/or processes are tested to establish that they will work.

TRL 5 – Product and/or process validation in relevant environment

Reliability of product and/or process innovation increases significantly. The basic products and/or processes are integrated so they can be tested in a simulated environment.

TRL 6 – Product and/or process prototype demonstration in a relevant environment

Prototypes are tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a simulated operational environment.

TRL 7 – Product and/or process prototype demonstration in an operational environment

Prototype near or at planned operational system and requires demonstration of an actual prototype in an operational environment (e.g. in a vehicle).

TRL 8 – Actual product and/or process completed and qualified through test and demonstration

Innovation has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development.

TRL 9 – Actual product and/or process proven successful

- Actual application of the product and/or process innovation in its final form or function.

APPENDIX E - STAKEHOLDER SUMMARY SHEETS