Emissions Management RD&D & Technology Testing Capacity in Canada

Abridged version of Final Report (March 2019)

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TABLE OF CONTENTS

Table of Contents 2
1 Executive Summary 3
2 Introduction 6
3 Methodology 7
4 Results 8
4.1 Facility Features 8
4.1.1 Physical Facility 8
4.1.2 Focus Areas 9
4.1.3 Third-Party Testing 11
4.1.4 Emission Management Priorities 13
4.1.5 Source Categories 14
4.1.6 Technology Readiness Levels (TRL) 16
4.2 Assets 16
4.2.1 Specialized Equipment 16
4.2.2 Access 17
4.2.3 Real Gas Sources 18
4.3 Expertise 19
4.3.1 Organization Contribution and Databases 19
4.4 Data 21
4.4.1 Data Types (Access and Collection) 21
4.4.2 Data Sharing Arrangements 22
4.4.3 Software 23
5 Discussion 24
5.1 Testing Facilities 24
5.1.1 Outdoor Physical; Indoor Test/Laboratory; Mobile Unit 24
5.1.2 Controlled Testing; Field Testing 25
5.1.3 Invasive Technology; Non-Invasive Technology 26
5.2 Data Systems 26

5.2.1 Proprietary Data 26
5.2.2 Proprietary Data Non-Proprietary 27
5.3 Stakeholder Priorities 27
5.3.1 Stakeholder Views on the Characteristics of a Successful Network 29
5.4 Stakeholder Gap Analysis 32
6 Conclusion 35
APPENDIX A - Stakeholder Questionnaire 37
APPENDIX B - Technology Readiness Level 63

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 reflects input from key stakeholders involved in Canada's emissions management activities and collates information that paints a robust picture of the ecosystem. As part of this study, an extensive questionnaire was designed to collect information from key stakeholders involved in Canada's emissions management activities. Data was collected from 26 organizations across four distinct stakeholder groups 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**.

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 in both 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.

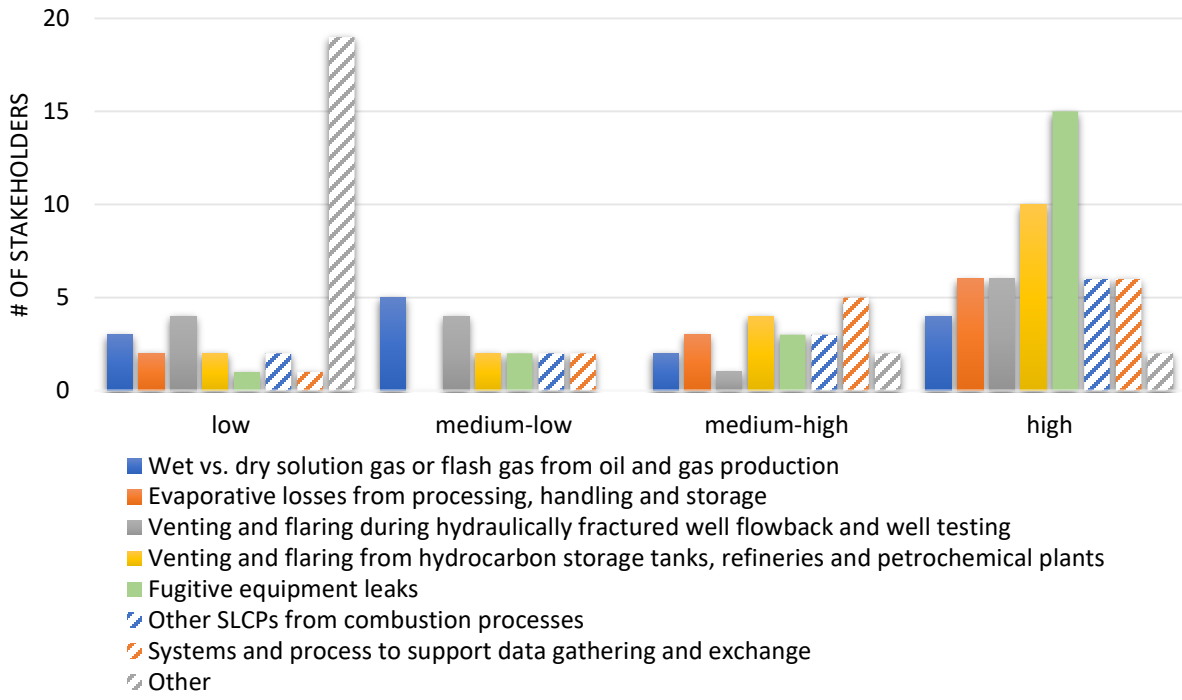

Figure 1-1: Stakeholder Emissions Management Priorities

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.

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.

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;
- Existing databases and data platforms for emissions data and reporting, including associated data sharing arrangements, and data access; and
- Key gaps based on existing facilities, infrastructure, assets and expertise, and opportunities for capacity building to improve the emissions testing landscape in Canada.

3 METHODOLOGY

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.

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.

Questionnaire Design – A web-based questionnaire was designed that allowed for easy access to stakeholders and multiple individual responses within each organization. **A complete list of the questions used in the questionnaire is presented in Appendix A – Stakeholder Questionnaire.**

Stakeholder Categorization – Stakeholders where categorized into four groups for the purposes of aggregating the questionnaire data: Industry/Associations; Post-Secondary Institutions; Clean Tech Developers; and RD&D Facilities.

Data Aggregation – 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 4 and 5 of this report.

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

4 RESULTS

Following a comprehensive stakeholder identification and questionnaire development process, questionnaire links were distributed to 27 individuals from 26 different organizations. A total of 27 responses were received, while only 23 of the 27 responses were collected in time to be included in the quantitative analysis of this report, representing an 85% response rate.

4.1 FACILITY FEATURES

The following section contains key data points and graphical representations of the aggregate responses relating to stakeholder facilities along with the relevant survey questions used to complete the analysis (blue font).

4.1.1 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 having 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 having 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, some stakeholders have outdoor labs or indoor labs, whereas others conduct research in third-party labs or facilities.

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.

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.

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.

4.1.2 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 0-1 below demonstrates the overall activity of each stakeholder group by gas type.

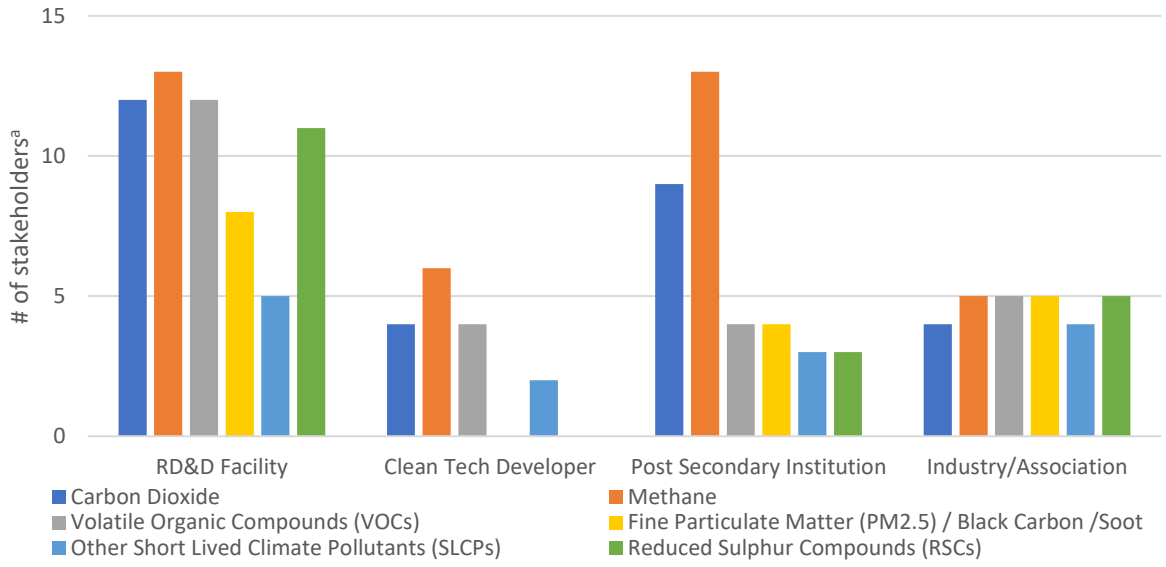

Figure 0-1: Emissions Focus by Organization Type

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.

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: the Clean Tech Developer Group only included three total stakeholders). The Industry/Association group indicated uniform RD&D 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.

Questionnaire respondents were asked identify their RD&D focus relative to quantification, characterization, and transportation of different emissions types. **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.

The information collected indicated that Quantification and Characterization of methane and carbon dioxide are the most prevalent focus areas of RD&D activities across stakeholder groups.

4.1.3 Third-Party Testing

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

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 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.

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. In some instances, 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.

A common obstacle to an effective RD&D and emissions testing ecosystem is **data sharing**. This is a challenge industry associations are currently working through with universities and other organizations (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.

Fugitive emissions are the focus area for industry. However, 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 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.

4.1.4 Emission Management Priorities

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

The following figure illustrates the aggregated emissions priorities of all stakeholders.

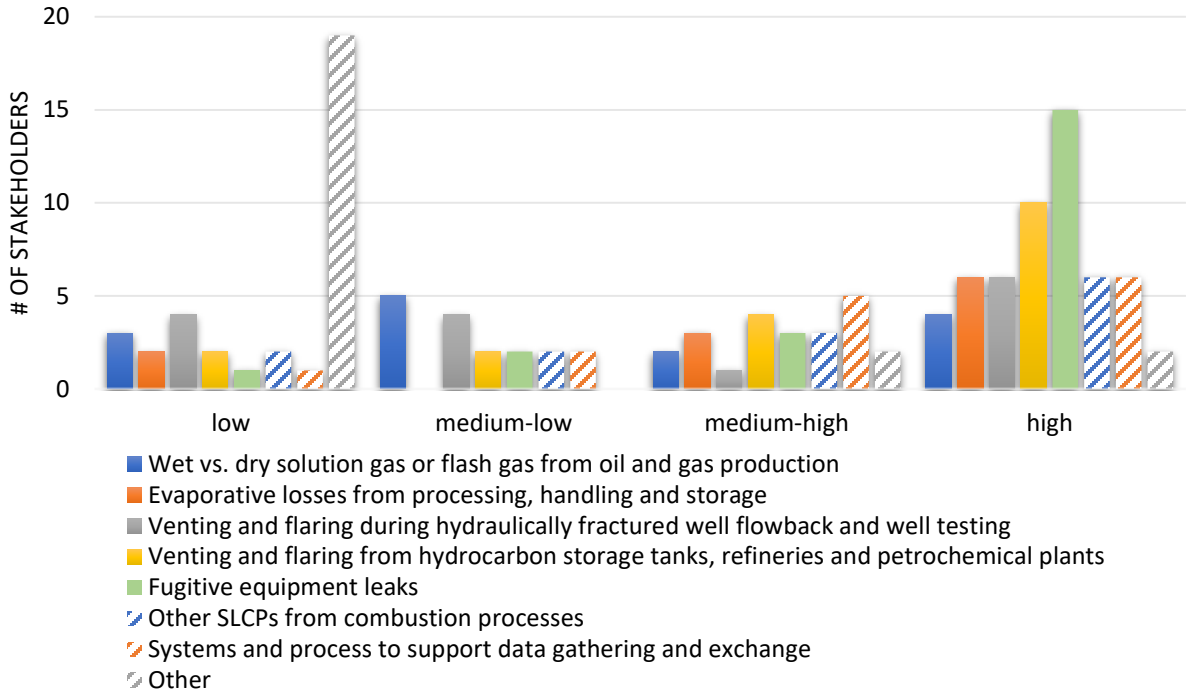

Figure 0-2: Aggregated Emissions Management Priorities for All Stakeholders

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 the next most frequently considered a priority emissions management focus areas, 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.

4.1.5 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 4.1.4 above.

Figure 0-3 below identifies the emissions sources 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 categories (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.

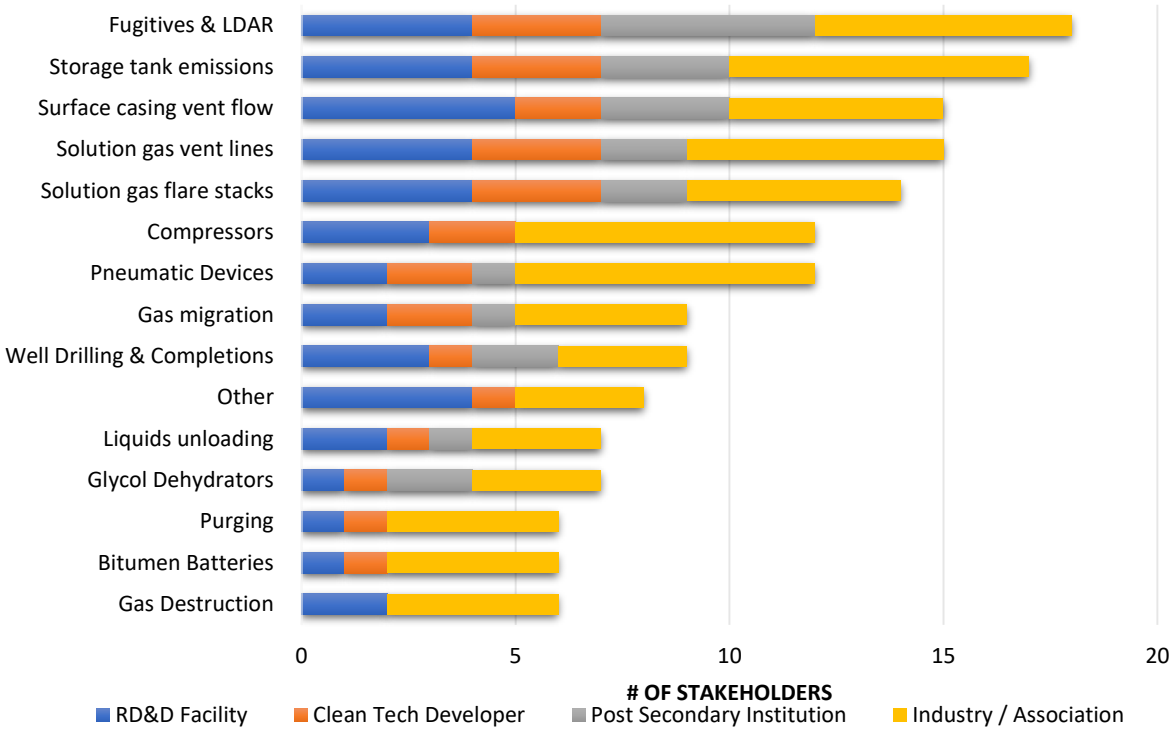

Figure 0-3: Emissions Source Categories Addressed by Stakeholders

Notes:

a. "Other" emissions source categories stakeholders are currently addressing include: pipeline leaks, steam utilization; refinery and petrochemical flaring; background natural emissions, noble gas tracers and migration indicators, natural gas in groundwater and water wells; landfill emissions, agricultural emissions, methane emissions from coal mines; tailings ponds and mine face surfaces at oil sands facilities; meter leaks, plant maintenance; distribution gas leaks; engines; and tailing ponds & oil sands mine face.

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.

4.1.6 Technology Readiness Levels (TRL)

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

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. Refer to Appendix B for the TRL scale used for the questionnaire.

4.2 ASSETS

4.2.1 Specialized Equipment

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

Figure 0-4 displays the specialized equipment/technologies in use by respondents. These specialized equipment/technologies have been organized from highest to lowest frequency.

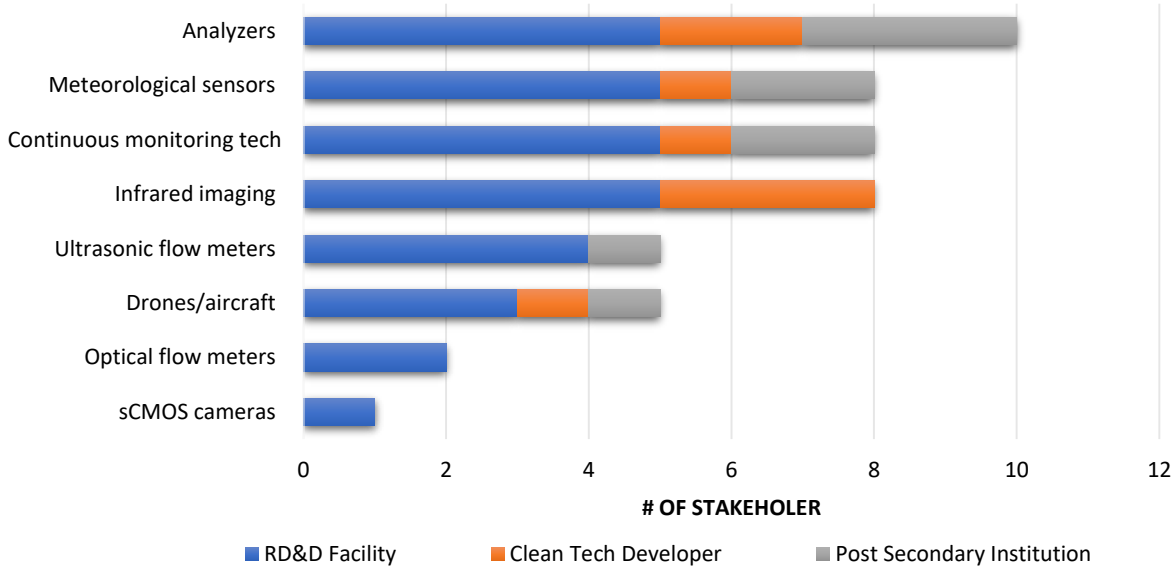

Figure 0-4: Specialized Equipment/Technologies Used by Different Stakeholders

The results in Figure 0-4 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 a number 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.

4.2.2 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 0-1: Facility Access by Stakeholder

	RD&D Facility			Clean Tech Developer			Post Secondary Institution			Industry / Association		
	HA-O[1]	HA-3[2]	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:

a. The quantities represented in the above table reflect the number of respondents who selected that option

[1] Has Access- Owned by Organization

[2] Has Access- Owned by Third Party

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. One post-secondary institution identified lack of forward-thinking industry partners willing to provide site access as the main gap prohibiting exploration of new and innovative ideas. Similar messaging was received from other stakeholders who indicated that bridging the gap to technology deployment requires accessing the field for testing emissions reduction technologies. This reiterates the importance of ensuring producers (field facility owners) are actively participating in the emissions management network/system in Canada.

Capacity Building Considerations

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

- 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 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 is a multitude of options to consider in order to elicit participation from industry, 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.

4.2.3 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 oil and gas 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. It is important that the emissions RD&D testing system have access to both real and controlled emissions sources, as technologies at different TRLs 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. 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.).

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.

4.3 EXPERTISE

4.3.1 Organization Contribution and Databases

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.

Figure 0-5 provides the level of stakeholder involvement in techno-economic analysis for emissions mitigation solutions. Techno-economic analysis can be described as "an evaluation of mitigation technologies considering both environmental and economic performance (cost, energy consumption, emissions performance)".

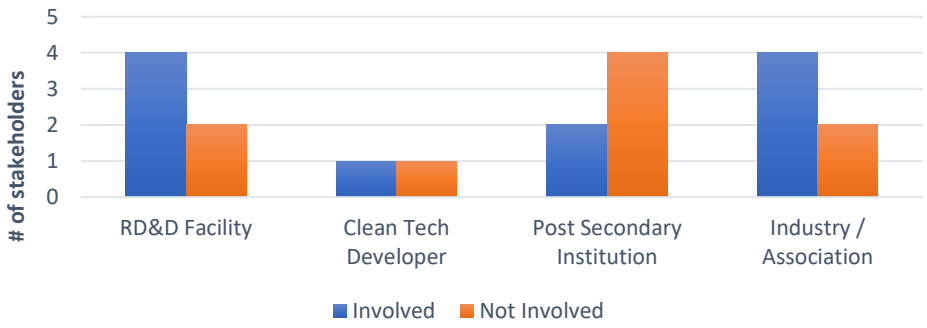

Figure 0-5: Level of stakeholder involvement

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. They did not provide an explanation as to why.

GAP: It is unknown whether or not similar **methodologies** and data sets 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. An approach that uses common data sets is critical to consistent evaluation of technology solutions.

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.

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.

4.4 DATA

4.4.1 Data Types (Access and Collection)

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

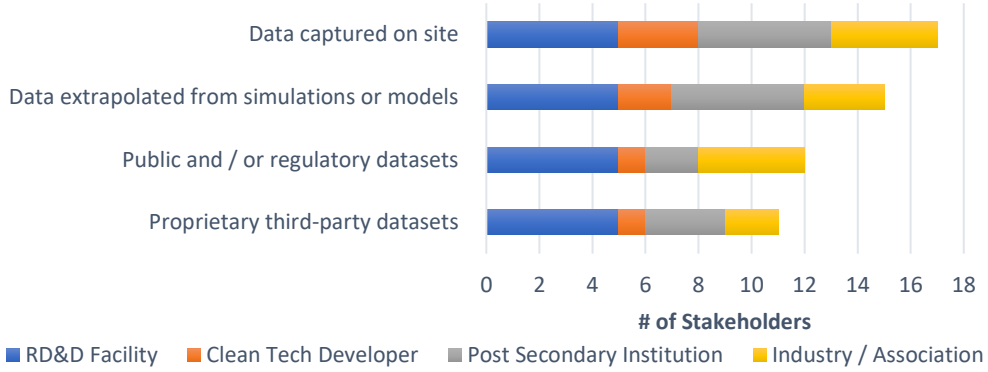

Figure 0-6: Type of data collection across different stakeholders

Simulations and models are widely used in the system today and are likely to remain critical components in the future as a required part of technology development.

GAP: Most of the 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.

4.4.2 Data Sharing Arrangements

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

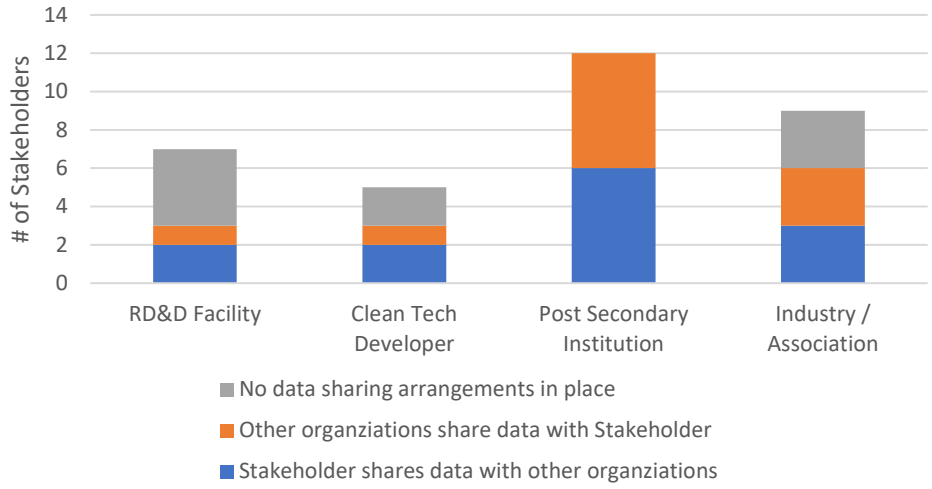

Figure 0-7: Data sharing arrangements by stakeholder type

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. 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.

4.4.3 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 be due in large part 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. A few of the stakeholders surveyed have developed and been using tank emissions simulation software, but, given **tank emissions** has been identified 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.

5 DISCUSSION

5.1 TESTING FACILITIES

5.1.1 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.

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 that could be implemented 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. 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. 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).

5.1.2 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.

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.

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?

5.1.3 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.

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. 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. Calibration 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.

5.2 DATA SYSTEMS

There are two distinct types of data that each possess different risks, opportunities and decision points for capacity building: **Proprietary; Non-Proprietary**.

5.2.1 Proprietary Data

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, 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.

5.2.2 Proprietary Data Non-Proprietary

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's 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.

5.3 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?

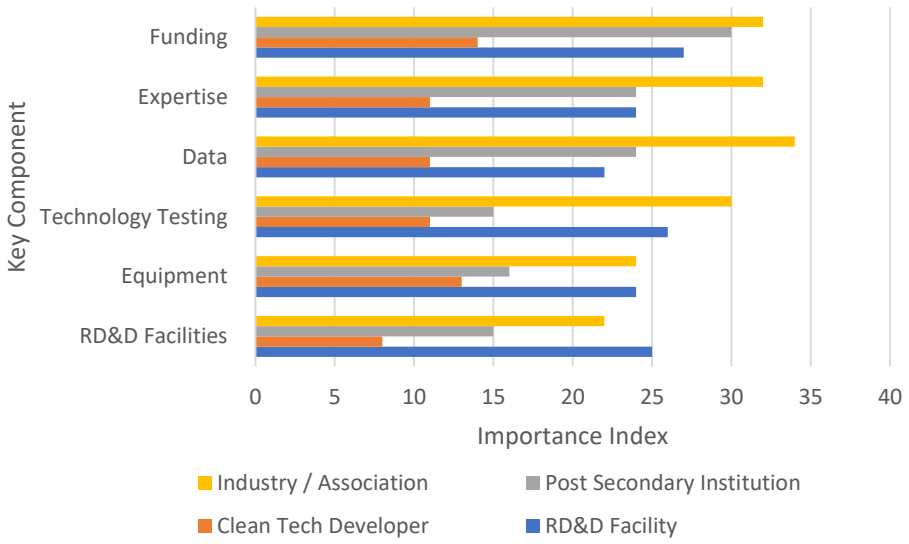

Figure 0-8: Ranking of the Key Components of Canada's Emissions Testing RD&D Network

Notes:

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

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.

5.3.1 Stakeholder Views on the Characteristics of a Successful Network

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?

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 respondents.

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 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:

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 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.

Capacity Building for an RD&D Centre/Network:

- 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;

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

- Deploy a tool to determine what "cost-effective" compliance looks like;
- 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), and strategic collaborative access to Canadian based upstream, midstream and downstream oil and gas facilities.

5.4 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?

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**. 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 leak detection and repair (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.

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.

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. The gap analysis and recommendations contained in this report 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 be enhancements to existing infrastructure or the current ecosystem, or formalization of a network of actively involved stakeholders. 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 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.

This report identifies 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. 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 participating organizations in this study. 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 QUESTIONNAIRE

Questionnaire

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(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.

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(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?

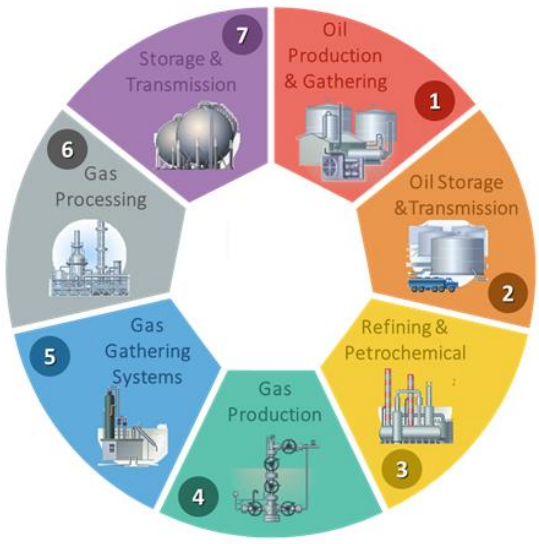
- Yes
- No

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:

(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:

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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)	[ ]	( )	( )	( )	___

	Access	Owned by			Name of third-parties (if applicable)
		Organization	Third-Party	Not applicable	
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.

_____ 1

_____ 2

_____ 3

_____ 4

_____ 5

_____ 6

_____ 7

_____ 8

9

10

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 XXXXXXX 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.

1

1

2

3

4

5

1

☐ 2

☐ 3

☐ 4

(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?

(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:

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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:

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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:

(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?

APPENDIX B - 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.