CERIN
Canadian Emissions Reduction Innovation Network

CANADA EMISSIONS REDUCTION INNOVATION NETWORK (CERIN) PUBLIC REPORT

1. PROJECT INFORMATION:

Project Title:	NRCan Tank HQP Current State of Knowledge Tank Methane Mitigation
Emissions Reduction Scope/Description:	Tank venting methane mitigation
Applicant (Organization):	Saskatchewan Research Council
Project Completion Date:	April 2023

2. EXECUTIVE SUMMARY:

This study explores methane mitigation from tanks, which are a significant methane source in Canada. The study identifies root causes of tank emissions, which helps to inform mitigation options. It is likely that root causes which result in fluctuating, intermittent emissions contribute to a large portion of the tank methane inventory. This study updates previous reports on methane mitigation options, with a focus on those applicable to tanks. Options are categorized as prevention, sale of gas, conversion to new products, production of efficient power, and disposal. Prevention is the foremost mitigation strategy for existing and new developments. The report includes an economic analysis of several mitigation options, as well as a case study of aerial surveys as a methane management tool for oil and gas tanks. Due to the great diversity in oil and gas site types, and a very large number of sites, there is not a particular culprit nor a "silver bullet" solution. Moreover, it is difficult to estimate the costs of mitigation options because the financial analysis is specific to the site. A solution which is profitable for one site, may be costly for another.

3. KEY WORDS

Methane mitigation, tank venting, upstream oil and gas, produced gas, tanks

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4. APPLICANT INFORMATION:

Applicant (Organization):	**Saskatchewan Research Council**
Address:	Bay 2D, 820 51st Street East, Saskatoon, SK, Canada, S7K 0X8
Applicant Representative Name:	Kyla Clarke
Title:	Senior Research Engineer
Applicant Contact Information:	(306) 385-4277 kyla.clarke@src.sk.ca

5. LEAD CONTRIBUTING PARTNER INFORMATION:

Organization:	N/A
Address:	
Representative Name:	
Title:	

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6. PROJECT PARTNERS

Funding for this project is made possible through PTAC's CanERIC program, funded by Alberta Innovates and NRCan, and by the Saskatchewan Ministry of Energy and Resources, and Innovation Saskatchewan. In-kind contributions are provided by the Saskatchewan Research Council (SRC).

SRC gratefully acknowledges the help and contributions of Wayne Hillier of Modern West Advisory, Calgary, AB.

A. INTRODUCTION

An axiom of the ISO process is “what gets measured gets managed”. Methane management includes both monitoring and mitigation. There is a feedback relationship, such that more mitigation makes it easier to monitor methane, and more monitoring data makes it easier to mitigate methane. Upstream oil and gas industry methane management is complex because there are many, very diverse activities, equipment, and industry regions emitting methane. The types and characteristics of methane sources differ dramatically between regions and sites. There are thousands of upstream oil and gas sites, many with several methane emission sources. It is a complex task to gather information on the number of sources, and their characteristics via monitoring. Due to the variety and number of sources, there are many possible mitigation strategies.

Oil and gas tanks are one of several sources of methane emissions. In *gas* production in Western Canada, pneumatic venting and equipment leaks contribute to a large share of emissions. There are other significant sources of methane from gas production, including tanks. Pneumatic venting and fugitive equipment leaks are not as high for *oil* production in Western Canada and recent monitoring surveys indicate that tanks are one of the largest sources of methane from oil production.

B. METHODOLOGY

The objectives of this project are to:

1. Investigate different options for mitigating tank venting.
2. Analyze the economics of different mitigation options for tank emissions.

3. Asses the implications of mitigating tank methane emissions on a broad scale.
4. Complete a case study of aerial surveys in tank methane management, along with recommendations for best practices and future studies.

The project begins with assessing the current state of knowledge regarding tank emissions in the upstream oil and gas industry, including root causes of emissions. SRC reviews past PTAC (Petroleum Technology Alliance Canada) and CanERIC research reports, and government data sources. Secondly, this study presents different options for mitigating tank methane emissions. Methane mitigation options which are being deployed in other oil and gas production areas, including Canadian offshore sites and the United States, are investigated. Mitigation options are categorized as those which prevent emissions, increase the recovery of gas for sales, produce power, convert gas to other products, and dispose of gas.

This study includes an analysis of the economics and the abated methane volumes from various mitigation options. Methane abatement costs (\$/tonne CO_2e[1]) of a short list of different mitigation options are estimated. SRC assesses the feasibility of installing different methane options on a broad scale, including the volume of methane emissions which can be abated and the overall costs to the industry. Data is provided from another CanERIC project which includes tank methane monitoring by a Canadian oil and gas producer, with aerial surveys. The data is analyzed qualitatively to comment on trends in total and relative amounts of methane versus site characteristics. SRC explores best-practices for aerial methane monitoring of tanks as well as suggestions for future studies.

C. PROJECT RESULTS AND KEY LEARNINGS

Root Causes of Tank Emissions

Tank methane mitigation efforts should begin by focusing on the tanks contributing the most to a given inventory. Methane detection, measurement, and inventory data can prioritize tanks in individual fleets. Once tank emission detection and measurement data is collected, producers can analyze the data in more detail and conduct further investigations as needed to establish the root cause. Root cause analysis can directly inform methane mitigation. In addition, it can inform monitoring strategy (i.e. use continuous detection for root causes which occur only intermittently, and use emission factors for

[1] CO_2e is carbon dioxide equivalent, assuming that 1 tonne of methane is equivalent to 25 tonnes of carbon dioxide.

measuring tanks which have very low, steady emissions). Some of the causes are likely to have a large contribution to the annual methane volumes from oil and gas, and these are highlighted in bold; these emissions are often fluctuating and intermittent, and larger when there are fewer mitigation strategies. More accurate tank methane inventory data is required to validate these assumptions. Furthermore, it is challenging to monitor emissions from these root causes without detection programs and with indirect measurement methodologies which focus on average or typical emissions (emission factors, estimates, equations, gas to oil ratio tests, modelling).

Table 1— Root Causes of Tank Emissions from Upstream Oil and Gas

Tank/Facilities	Root Cause	Example of Root Cause
Uncontrolled production tanks at single or multi well oil batteries (o)[2]	Atmospheric disposal of some or all the gas produced with oil	• **Some gas gathering/fuel use/combustion of produced gas with the remainder flashing from the tank.** • Tank with blanket gas (natural gas) added when the liquids in tank are unloaded. • Small amount of working/breathing/standing losses as tank fills or heats up.
Uncontrolled condensate tanks at gas wells and batteries (c)	Atmospheric disposal of some or all the gas in condensate liquids	• **Some separation of gas from the condensate with the remainder flashing from the tank.** • Tank with blanket gas (natural gas) added when the liquids in tank are unloaded. • Small amount of working/breathing/standing losses as tank fills or heats up.
Uncontrolled water/wastewater tanks (w)	Atmospheric disposal of some or all gas from produced water/wastewater	• **Some separation of gas from water with remainder flashing from the tanks.** • Tank with blanket gas (natural gas) added when the liquids in tank are unloaded. • Small amount of working/breathing/standing losses as tank fills or heats up.
Uncontrolled storage tanks (o /c)	Storage of volatile hydrocarbons	• Gas flashing from tanks. • Tank with blanket gas (natural gas) added when the liquids in tank are unloaded. • Small amount of working/breathing/standing losses as tank fills or heats up.
Uncontrolled tanks (o/c/w)	Inadequate design/operation, failure or intentional shutdown of upstream gas separation or downstream gas[3] equipment	• **Under-sized separator, with insufficient residence time.** • **Failure of level control on separator (hung-up float assembly, change in liquid density, false output signal, and valve seat or disk damaged).** • **Failure of fuel gas/gas gathering compressor or combustor.** • **Planned or unplanned outage of downstream gas gathering plant.** • **Maintenance of fuel gas system, gas gathering compressor, disposal (combustor, underground).**

[2] o = oil, c = condensate, w = water
[3] Downstream gas equipment include gas gathering, on-site fuel systems, disposal (flare, enclosed combustor, underground).

Controlled tanks (o/c/w)	Inadequate design/operation, or failure or intentional shutdown of upstream gas separation, downstream gas equipment or tank control equipment	• **Under-sized separator or vapour recovery unit (VR[4]U).** • **Failure of VRU, fuel gas/gas gathering compressor or combustor.** • **Planned or unplanned outage of downstream gas gathering plant.** • **Maintenance of VRU, fuel gas system, gas gathering compressor, disposal (combustor, underground).** • Fouling of vapour collection piping. • Failure or incorrect set pressure of equivalent-pressure management device.
Controlled tank (o/c/w)	Equipment leaks from piping to and from tank, or thief hatch/valves on tank	• Thief hatch in disrepair. • VRU piping in disrepair.

Tank Mitigation Options

Tank methane mitigation can be achieved with technologies, resource development approaches, operating practices, and management programs, and can be classified into five general strategies **(Fig. 1).**

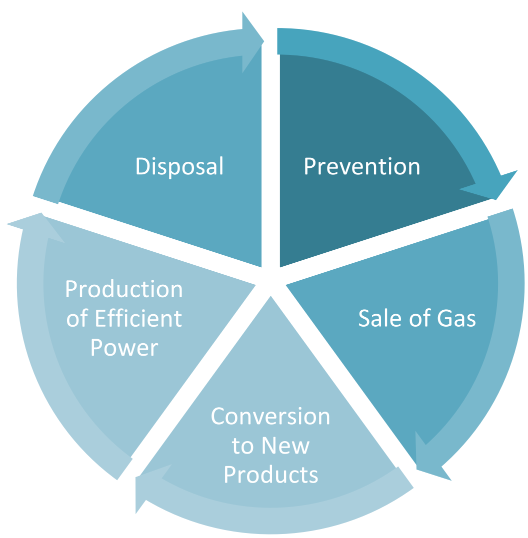

Fig. 1 — Overview of Methane Mitigation Strategies

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Table 2 lists options for each mitigation strategy.

[4] Tanks are considered "controlled" when they have a vapour recovery unit (VRU) to capture vent gas.

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Table 2 — Tank Methane Mitigation Strategies and Options

Strategy	Options	Technologies, Practices, Management Programs
1. Prevention	Multi-well pads and multi-well oil batteries	• Multi-well resource development approach. • Directional and horizontal drilling, multiphase Pumps. • Compression and reinjection of casing gas.
	Detection programs	• Periodic surveys.
		• Continuous monitoring (fixed methane flux instruments, flow meters, detectors).
	Design and construction practices	• Instrumentation, back-up combustion, multiple destinations of produced gas, tanks designed for combustors/VRUs and monitoring. • Redundant equipment, seal-less pumps, leakless valves. • Design for corrosion, welded joints, specifications for gaskets/bolt torque.
	Inspection and preventative maintenance programs	• Inspection of VRU, combustor, compressor. • Preventative maintenance: filters, dryers, grease, oil; clean burners/flame arrestors, ignitors.
	Operating Practices and Management Policy	• Portable combustors or VRUs for maintenance. • Agreements with midstream/downstream, and Standard Operating Procedures and policy to collaborate to minimize methane emissions.
	Digital, AI, Machine Learning	• Digital controllers. • Real-time autonomous optimizers.
	Eliminate Unnecessary Tanks	• Consolidate tanks at centralized site as production decreases.
	Meter Gas Production with Condensate	• Wet-metering.
	Pressurized Storage of Condensate	• Pressurized condensate tanks (with blanket gas) at gas wells/batteries and pressurized transport vehicles.
2. Sale of Gas	Existing Gas Gathering Pipeline	• VRU
	New Gas Gathering Pipeline	• Compressor, VRU
	Virtual Gas Gathering Pipeline	• VRU, compressed/ liquified natural gas • Future possibility of converting methane to solid hydrates). • Underground gas storage.
3. Conversion to New Products	Gas to Liquids (GTL)	• Synthetic crude oil, diesel, gasoline.
	Gas to Chemicals (GTL)	• Convert to methanol, formaldehyde, dimethyl ether, methanol. • Modular, small and very small-scale ammonia plants.
4. Conversion to Efficient Power	Gas to Power: Electricity and Heat Generation	• VRUs, compressors, Stirling engines, combined heat and power. • Internal combustion engine, micro-turbine.
	Gas to Power: Fuel Cells	• Solid oxide fuel cell.
	Gas to Power: Mechanical Power and Heat Generation	• VRUs, compressors, gas-fired engines/heaters. • Lines connecting multiple sites to balance fuel supply and demand.
5. Disposal	Underground Disposal with and without enhanced oil recovery	• VRUs, compressors, underground disposal, enhanced oil recovery.
	Bio-Mitigation	• Biofilters.
	Oxidation	• Catalytic oxidizers.
	Combustion	• Enclosed combustors, incinerators, electronic ignition flares.
	Energy Efficient Oxidation and Combustors	• Catalytic combustors with glycol heat tracing. • Waste heat captured from incinerators for heat tracing or converted to electricity (organic Rankine cycle).

Economic Analysis

The following figure estimates ranges of marginal methane abatement costs reported in recent years for various mitigation options. Marginal abatement costs depend on several assumptions during their calculation, such as gas flowrate, vent gas composition, natural gas prices, availability of infrastructure, local labour rates, etc. Differing assumptions can lead to different costs; it's important to note the input values are directional only and should not be used to make investment decisions.

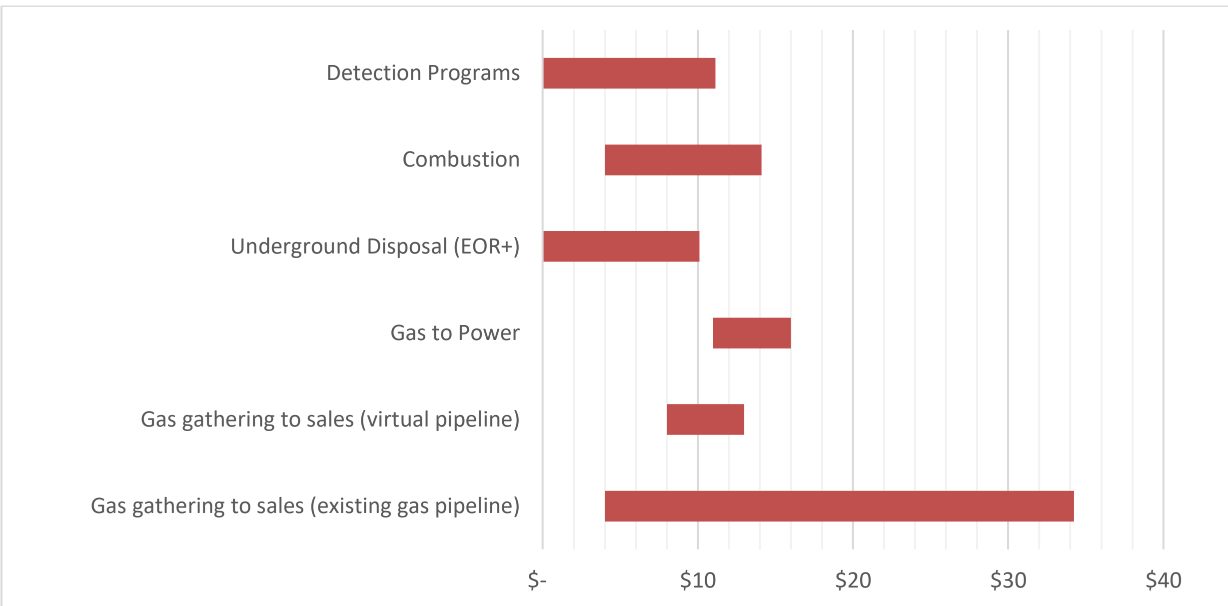

Fig. 2 — Marginal Abatement Cost Ranges of Selected Methane Mitigation Options ($/tonne CO_2e)

Tank Mitigation Implications

As alluded to earlier, there are tens of thousands of atmospheric tanks in onshore non-oilsands oil and gas production in Western Canada. BC, AB, SK, and MB report monthly oil and gas production data through a system called Petrinex, of which only AB and SK monthly production volumes can be accessed by the public. Although Petrinex does not specify the number or types of equipment at individual sites, information on facility types, dispositions, and on-site inventory volumes can be used to estimate the number of multi-well batteries, single well batteries with separators, and single well batteries without separators.

Knowing the number and type of facilities does not tell us conclusively how many tanks are present at each site. Some oil wells will have a combustor or flare for produced gas and a single tank for liquids storage, while others will have multiple tanks for a single site. Individual wells may be flowlined to a central processing facility with separators, heater treaters, and oil and water storage tanks. Other sites may have liquids pipelined directly to midstream operators for sale, depending on the amount and quality of the hydrocarbons produced. In the interest of bounding the problem, several assumptions are made here regarding the number of tanks at each type of facility:

- Gas single well batteries with liquid production are assumed to have a single liquid tank connected to a gas gathering system, plus a pop tank (2 tanks total).
- Oil single well batteries with gas disposition are assumed to have 4 tanks; one pop tank, one water storage tank, one crude oil storage tank and one crude oil over-flow tank, based on the analysis by Clearstone (2019a).
- Oil single well batteries without gas disposition are assumed to have a single liquid tank.
- Multi-well gas and oil batteries are assumed to have a number of tanks calculated using the ratios developed by Clearstone (2019a) based on a survey of AB oil and gas sites.

Using the assumptions above, the number of tanks at AB and SK sites can be calculated from the facility counts from Petrinex. Petrinex data for BC is not publicly available, but in a 2020 report Clearstone Engineering estimated there were 1,611 hydrocarbon production and processing tanks in BC, with total emission of 2,141 tCO_2e/y. Similar to AB, the majority of BC production is gas. The same ratio of gas gathering as AB is applied to the BC tanks. No estimates are available for Manitoba at the time of this report.

Table 3 — Estimated Number of Tanks in Western Canada

Province	Total # of Tanks	# Tanks with Gas Gathering	# Tanks w/o Gas Gathering
MB	No data	No data	No data
SK	9,519	2,661	6,858
AB	23,295	19,803	3,492
BC	1,611	1,370	241
Total	34,425	22,464	10,350

The Canadian Oil and Gas industry had methane emissions of 32.5 Mt CO_2e in 2020. Pembina (2015) predicted 12% of methane emissions in the oil and gas industry would come from tanks, which leads to an estimated 3.96 Mt CO_2e. Clearstone (2020) found uncontrolled tanks emit 2.7 times as much as controlled tanks; therefore we can estimate that tanks with gas gathering account for 1.07 Mt CO_2e, and tanks without gas gathering for 2.89 Mt CO_2e. Assuming that these mitigation options can address 90% of the tank emissions, **Table 4** estimates the tank methane migration volumes and cost by province.

Table 4— Estimated Tank Methane Mitigation Volumes and Costs

Province	Tanks with Gas Gathering		Tanks w/o Gas Gathering	
	Annual Reduction (Mt CO_2e/y)	Upper Bound of Annual Investment (million $/y)[5]	Annual Reduction (Mt CO_2e/y)	Upper Bound of Annual Investment (million $/y)[6]
MB	No data			
SK	0.11	1.2	1.68	57.3
AB	0.80	8.9	0.86	29.2
BC	0.055	0.6	0.059	2.0
Total	0.96	10.7	2.60	88.4

Note that the values in **Table 4** are illustrative only, as they are based on numerous assumptions. Government regulators and oil and gas producers will have up to date information on their respective tank inventories and should be consulted when an accurate count of tanks is required. Suffice to say, any technological solution that will be deployed to address tank emissions will need to be scaled-up to manage tens of thousands of installations as quickly as possible.

Case Study of Aerial Measurements of Tank Methane Emissions:

A case study of aerial survey data from a Canadian oil and gas producer illustrates:

1. Aerial technologies provide producer-level detection and direct measurement of tank methane.
2. There are multiple benefits to aerial surveys:
   a) Cost-effective, quick to deploy, reduced safety risks.
   b) Aerial detection is a mitigation option as it identifies large, intermittent emissions.
   c) Aerial surveys can improve accuracy of tank methane inventory.
3. There are several limitations to aerial surveys:
   a) They may not distinguish tank emissions from other equipment sources.
   b) This technology is unsuitable for tank fleets which rarely have emissions above the minimum detection limits of aerial technology.

[5] Based on a methane mitigation cost of $11.14/t$CO_2e$
[6] Based on a methane mitigation cost of $34/t$CO_2e$

c) The technology only measures methane at one or more instances in time and does not totalize volume. Thus, it does necessarily distinguish between normal, separator operation, with intermittent venting, *versus* gas carryover from separators to tanks due to problems with gas gathering/separators/level control. Advanced digital control systems may help to solve this problem.

4. It is important to conduct root cause analysis of tank emissions along with aerial surveys, to identify appropriate mitigation options.

5. Aerial technologies are especially suited for oil production tanks which vent all/some of produced gas or any tanks.

D. PROJECT AND TECHNOLOGY KEY PERFORMANCE INDICATORS

Organization:	Current Study	Commercial Deployment Projection
Project cash and in-kind cost ($)	$101,150	variable
Technology Readiness Level (Start / End):	N/A	8 to 9
GHG Emissions Reduction (kt CH4/yr):	N/A	up to 142 kt/yr in Western Canada
Estimated GHG abatement cost ($/kt CH4)	N/A	$0 to $850,000
Jobs created or maintained:	N/A	Potentially 100’s

E. RECOMMENDATIONS AND NEXT STEPS

Methane emission intensity is high in Canadian onshore, non-oilsands production, especially where produced gas is low in liquids, volatile organic compounds, hydrogen sulphide, and odours. Recent surveys indicate that tanks are a significant portion of Canada’s upstream oil and gas methane inventory. Tank methane mitigation will improve the accuracy of methane monitoring (including detection, measurement, and inventories). Monitoring data will in turn enhance mitigation efforts.

Tank methane monitoring data is more informative when categorized by site type (i.e., heavy oil single oil well) and equipment (i.e., uncontrolled tank), rather than categorized as routine or non-routine venting and fugitive sources. Upstream oil and gas tanks have high methane emissions when tanks are the primary or back-up means of separating produced gas from liquids and disposing it to atmosphere. Methane mitigation efforts should target tanks contributing the most to a given inventory.

There are multiple root causes of tank emissions in the oil and gas sector. Root cause analysis of tank emissions, at the producer level, informs mitigation solutions. The root causes which likely contribute the largest share to Canada's tank methane inventory are often fluctuating and intermittent, and difficult to measure with estimates, equations, simulations, and emission factors. The leading root cause categories of tank methane emissions, which would not be solved by simply installing controls (VRU's) on tanks, include:

- Disposal of produced gas from oil production via uncontrolled tanks.
- Gas carryover to uncontrolled or controlled production, water or wastewater tanks (deficiency, failure or shutdown of tank controls, gas gathering, utilization, or disposal equipment in gas and oil production).

There are many mitigation options for tank emissions, which fall under five key strategies:

i. Prevention
ii. Sale of gas
iii. Conversion to new products
iv. Production of Efficient Power
v. Disposal

Prevention is the foremost mitigation strategy, which involves new technologies, management systems, operating procedures, design and construction practices, and detection. Installations which inherently prevent methane emissions such as multi-well sites (including gas sales), and design and construction practices, are appropriate solutions for new oil and gas production. For existing oil production, gas to power, underground disposal, combustion, and gas sales are important options. Prevention options such as detection, operating practices and management policy, and digital solutions mitigate gas carryover to tanks in existing and new production.

There are several commercially-ready technologies which merit further demonstration and deployment:

i. Digital control solutions for minimizing gas carry-over to tanks.
ii. Continuous detection and measurement instruments on tanks.
iii. Underground disposal with and without enhanced oil recovery.
iv. Small-scale liquified and compressed natural gas with virtual pipelines.

v. Gas to efficient power units (electricity and heat generation).

As emerging technologies become available, new commercial options worth testing include:

i. Small-scale gas-to-power solid oxide fuel cells.
ii. Catalytic combustors with higher methane destruction efficiencies.
iii. Small-scale gas-to-liquids units.
iv. Bio mitigation.
v. AI and machine learning options applicable to tank mitigation, especially those capable of completing financial analysis of different mitigation options at individual sites.

Financial analysis of tank mitigation options is difficult because of the vast variation in oil and gas site design, characteristics, and location. A solution may result in profit for one site and cost for another. Economics also depend on whether the mitigation options are implemented when the sites are constructed, or as part of a retrofit. Capital costs and marginal abatement costs of tank methane mitigation options have a large range. Marginal abatement costs may be zero for several options such as power generation and underground disposal with EOR. Marginal abatement costs range from 0 to $34/t CO_2e for several options which may address the majority of tank emissions in Western Canada (without accounting for carbon pricing). Given the current federal backstop carbon price is $50/t$CO_2e$ and a future price of $175/t CO_2e by 2030, these options are potentially profitable. A challenge to reducing tank emissions is that there are tens of thousands of tanks across Western Canada.

There would be a benefit of future aerial studies of tank emissions from different oil and gas producing regions which include root cause analysis and comparison to conventional vent gas reporting.