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Measuring and Managing the Unknown: Methane Emissions from the Oil and Gas Value Chain

by
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- As Canada seeks to reduce greenhouse gas (GHG) emissions, industry and government are experiencing greater pressure to address fugitive methane emissions from the oil and gas sector. Methane packs a powerful punch with up to 36 times the global warming potential of carbon dioxide over a 100-year time frame. If these methane emissions are sufficiently high, then the emissions benefits of displacing higher carbon electricity generation evaporate.
- Politicians have pledged to reduce methane emissions from oil and gas infrastructure 40-45 percent below 2012 levels by 2025. But, scientists have not reached consensus on how much methane escapes from leaky oil and gas infrastructure in Canada and across North America. Regulators will face challenges in verifying the promised reductions unless the emissions baseline is settled. Systems for more accurate measurement are necessary to verify fugitive emissions and confirm reductions.
- Governments in partnership with universities, industry and other stakeholders should work together to improve scientific knowledge about the amount of emissions escaping from oil and gas infrastructure. Regulations for measuring fugitive emissions must ensure suitable accuracy but should remain open to new technology innovation by focusing on outcomes.

As oil and gas production in British Columbia increases and new shale gas prospects emerge across Canada, stakeholders are calling on industry and governments to address fugitive methane emissions from the oil and gas sector. Fugitive methane emissions occur when methane is either intentionally or unintentionally released across the oil and gas value chain, starting from the wellhead, along pipelines, through refineries and storage facilities, and ultimately to the end user.

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The magnitude of these emissions remains unresolved. Recent scientific research suggests that methane emissions may be underestimated in the inventories of both British Columbia and Alberta (Johnson, Tyner et al. 2017, Zavala-Araiza, Herndon et al. 2018, Atherton, Risk et al. 2017). Both industry and regulators face challenges in monitoring emissions from oil and gas infrastructure at the level of devices and components, due to the sheer number of them across the supply chain (National Gas Machinery Laboratory 2006). Meters have yet to produce reliable data – many are in need of replacement, calibration, or maintenance, creating challenges for accurate calculation due to variations in environmental and other factors (e.g., time lags across meters; changing temperatures, volume and pressure of natural gas). Absent the ability to conduct real-time measurement of all devices and components across an extensive oil and gas supply chain, inventories rely on occasional, time-limited measurements combined with often outdated emissions factors. At the same time, stakeholders are concerned about the climate impact of these emissions – methane is a powerful greenhouse gas, with up to 36 times the global warming potential as carbon dioxide over a hundred years (US Environmental Protection Agency 2018).

In 2016, the Canadian government pledged with its North American neighbours to reduce methane emissions from the oil and gas industry 40 to 45 percent from 2012 levels by 2025 (Environment and Climate Change Canada 2018). The Canadian oil and gas industry is committed to upholding this commitment (Canadian Association of Petroleum Producers 2018). Such pledges do not address all concerns: environmental organizations charge that industry and government have insufficient management systems in place to prevent leaks from active and abandoned oil and gas infrastructure in Canada (Gorski 2018, Werring 2018). Without consensus on the baseline emissions, governments and regulators will face challenges in verifying emissions reductions. Similarly, the uncertainty in emissions makes it challenging to understand whether the economics of mitigation are favourable.

Of course, the new Canadian regulations and forward-thinking industry initiatives include improved measurement and mitigation. However, the unresolved baseline points to a need for policymakers to ensure scientific and technological gaps are being addressed. Systems for more accurate measurement are required to both enable and verify emissions reductions and ultimately reduce emissions. Furthermore, regulators often require the adoption of specific technologies, forcing industry to implement low-to-no emissions technologies and innovations that improve both monitoring and measurement. While such requirements are a critical component of reducing emissions, regulators should be cautious in designing rules so they do not inhibit new innovations (assuming an appropriate evaluation of potential unintended consequences of new technologies is undertaken). Specifically for the case of methane, regulations should consider outcome-based standards that could be met by existing technologies or new innovations instead of prescribing use of specific technologies available at the time the regulation is drafted. An integrated, systematic science-policy approach to emissions can address gaps in scientific understanding while supporting iterative improvements of present policies, regulations, and commitments. Such an approach would build upon current initiatives; for example, provincial and national rules now limit venting, require capture of most of the methane known to be escaping the system, and enhance leak detection and repair (LDAR) programs.

Governments are also considering the addition of methane to carbon pricing regulations. Many experts consider putting a price on greenhouse gas emissions as the most effective climate policy for the oil and gas sector. If the price is right, the market should (in theory) internalize the climate costs of these emissions. Emitters will be incentivized to reduce emissions if abatement is cheaper than emitting carbon at the set price. But, the same challenge remains. How can policymakers adequately price the climate externality without knowing how many emissions are being released? Counting carbon dioxide emissions from a smokestack or tailpipe is relatively straightforward when compared to the methane escaping across an extensive, diffuse oil and gas supply chain. Further, the uncertainty in emissions makes it challenging for operators to identify when and where the economics of mitigation are favourable.

We present the case that emissions pricing and existing regulations cannot solve the methane problem, given the limited scientific understanding of the amount of methane escaping from oil and gas infrastructure. To address this limitation, Canadian governments could make systematic, iterative improvements to present policies using the proposed integrated science-policy framework.

To make our case, we begin with a review of the science related to methane measurement in Canada. Then, we describe existing methane regulations and those starting to emerge in Canada. With this in mind, we discuss why neither carbon pricing alone nor existing regulations is sufficient to manage methane. Finally, we propose that Canadian governments systematically improve scientific understanding of emissions while incorporating the deployment of new technologies that can verify emissions in their regulations and partnerships with industry. In tandem, governments should enable comprehensive evaluation of current regulations to ensure they support and are receptive to new science, technology, and innovation. Finally, the proposed approach would seek to harmonize regulation across jurisdictions (to the degree possible) to ensure targets to reduce emissions are verifiable.

To summarize the challenges for policymakers:

- Without accurate measurement of fugitive methane emissions, governments will be unable to ensure that all emissions are covered by a carbon price.
- Industry faces an uncertain regulatory environment for technology adoption due to technical and scientific gaps in measurement. On the one hand, the economics of mitigation technologies may not always be favourable. On the other hand, regulations may be insufficiently flexible to encourage the adoption of new advances in both measurement and mitigation technologies.
- While facing an immediate gap for accurately measuring fugitive methane emissions, policymakers must nonetheless leverage present state-of-the-art regulations to reduce emissions in the near-term; for the longer-term, policymakers could play a more active role in promoting advances in scientific understanding and breakthroughs in measurement/abatement technologies.

Escaping Methane across the Oil and Gas Supply Chain

Similar to Mexico and the United States, Canada estimates methane emissions from oil and gas infrastructure for Intergovernmental Panel on Climate Change (IPCC) greenhouse gas reporting purposes from limited measurements, industry surveys, and emissions factors. Across the continent, scientists are discovering that the reported estimates of methane emissions from the oil and gas sector are systematically underestimated in comparison to measured emissions. Typically, governments have compiled and reported emissions inventories for the oil and gas sector that estimate the cumulative emissions of the industry by scaling estimates for facilities and devices to the entire sector. In recent years, scientists across North American have shown that these inventories underestimate emissions by measuring emissions from the actual devices and facilities and/or measuring methane in the atmosphere and attributing it to oil and gas (Brandt, Heath et al. 2014, Alvarez, Zavala-Araiza et al. 2018).

Research specific to emissions in Canada also confirms that official estimates likely underestimate actual fugitive methane emissions. One study found that methane escaping from Alberta's upstream oil and gas sector is likely 25–50 percent greater than current provincial estimates, without even considering the emissions from mined oil sands (Zavala-Araiza, Herndon et al. 2018). Three-quarters of the methane emissions were estimated to come from 20 percent of the sites examined. To put these numbers in context, 2014 methane emissions from Alberta's oil and gas sector were reported to be 31.4 megatonnes (Mt) of CO_2e, comprising just over 4 percent of Canada's total GHG emissions (716 MtCO_2e) that year (Government of Alberta 2018b, Government of Canada 2018). While there appears to be a discrepancy between results from estimation and measurement, we suggest that estimation methods can be improved using measurement to validate the results.

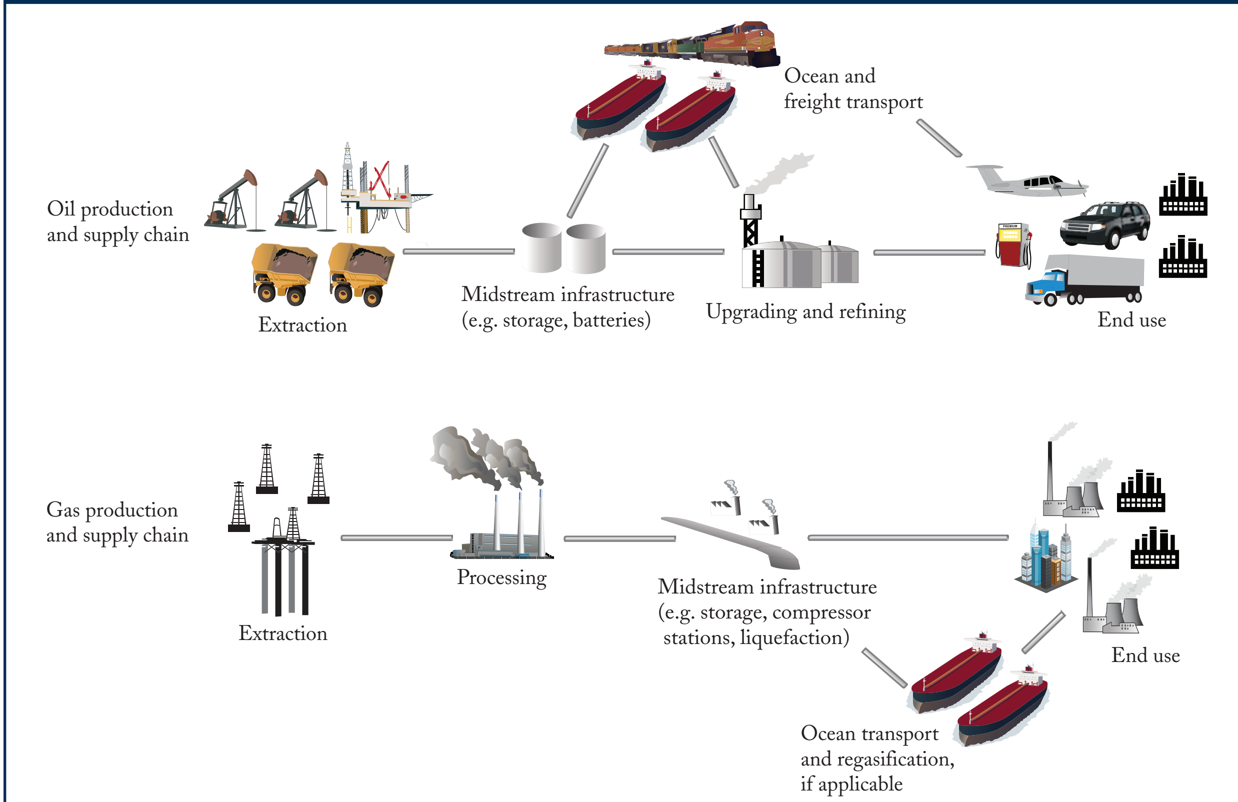
Research in British Columbia suggests similar underestimates of fugitive methane emissions. A study discovered that emissions from the largest producing play alone (the Montney) amounted to 3.1 MtCO_2e, exceeding the provincial estimate of 2.2 MtCO_2e for all sources and plays reported by the government (Atherton, Risk et al. 2017). Natural gas production in British Columbia is expected to increase in the coming years. The National Energy Board expects the majority of this growth to stem from B.C.'s Montney basin, which has already grown from no production before 2006 to 34 percent of Canadian production in 2017 (and is expected to grow another 131 percent by 2040.) The Board further projects growth in Canadian exports to be supported by LNG trade after 2025, a projection reinforced by the recent positive final investment decision for LNG Canada (NEB 2018). Therefore, understanding and mitigating these emissions will become increasingly important for maintaining the province's present trend toward lowering overall greenhouse gas emissions.

Evidence from measurements presently suggests that methane emissions from the Canadian oil and gas sector remain under-reported. That said, it is critical to note that these studies may reflect only snapshots in time; for example, what is captured during one measurement campaign may be as short as daily or even hourly or extend into annual time periods. Policymakers are thus left without defensible evidence describing the trends in methane emissions from the oil and gas value chain over time. We underscore the need to develop more robust baselines with ongoing monitoring: an estimation of emissions from one year (or from time steps shorter than a year) is unlikely representative of future years.

Natural gas, composed primarily of methane, escapes across the oil and gas value chain (Figure 1). Methane emissions from these value chains come in two forms: intentional and unintentional.[1] Intentional emissions, for example, occur during maintenance, emergency situations to ensure safety, and while the oil and gas wells are being completed and connected to gathering pipelines. Unintentional leaks occur when methane escapes from connections, valves, and other areas across the infrastructure system. For example, methane may be released from the drilling and completion process, during extraction, or from midstream infrastructure (e.g., pipelines, processing facilities, transmission lines, liquefaction, transportation, and regasification), up through to the final end use. In addition, natural gas produced from oil wells (also referred to as "associated gas") can be purposefully or unintentionally released from production sites. Leaks may be episodic, occurring infrequently or as single events (e.g., upon the completion of a natural gas well), or they may be continuous, representing slow and steady leaks (e.g., from a leaky valve).

1 Governments should ensure consistent and clear use of terminology for fugitive emissions: the Intergovernmental Panel on Climate Change definition of fugitive emissions encompasses both forms; however, entities (including governments in Canada and the United States) may define fugitive emissions as only unintentional leaks.

Figure 1: Simplified Oil and Natural Gas Supply Chains for Transportation, Industrial Processes, and Power Production.



Source: Figure developed with Adobe Illustrator using symbols courtesy of the Integration and Application Network, University of Maryland Center for Environmental Science (http://ian.umces.edu/symbols/). Leaks may occur at each stage, or through pipelines between stages.

Capturing an Escaping Commodity: Do the Current and Proposed Regulations Work?

Canadian governments are initiating methane regulations to support the national methane reduction target and contribute to reducing GHG emissions. In April 26, 2018, the federal government published regulations requiring both the detection and elimination of methane leaks from the oil and gas sector. The regulations are intended to achieve Canada's pledge to reduce emissions from the oil and as sector by 40-45 percent from 2012 levels in 2025 (Environment and Climate Change Canada 2018). Under these rules, which cover both intentional and unintentional emissions, well operators must capture emissions from upstream equipment and well activities (95 percent of the captured gas must be conserved; up to 5 percent may be combusted and released to the atmosphere as carbon dioxide). Wells covered by B.C. and Alberta rules are exempt from some federal capture requirements. In addition, larger upstream facilities in Canada (those producing or receiving at least 60,000 standard metric meters of natural gas per year) must limit venting and implement leak detection and repair (LDAR) programs to limit unintentional leaks by 2020. Provincial regulations may be relied on as alternative LDAR programs if they meet or exceed the federal regulations. To allow for flexibility, the final federal rules made it easier for operators to use emerging measurement and detection instruments for these requirements. Finally, the federal rules set emissions limits for specific pieces of equipment (controllers, compressors) to be met by 2023.

The federal regulations build upon existing and developing provincial measures. As of October 2010, the British Columbia's Oil & Gas Commission requires operators to report actual flared volumes at wells in addition to flared and vented volumes emitted from compressors and dehydrators (Government of British Columbia 2015). Additional reporting requirements in Alberta are detailed in several directives, which together have the goal of eliminating flaring and venting. Directive 060 requires companies to report routine and non-routine flaring and venting events and submit mitigation plans to the Alberta Energy Regulator (Alberta Energy Regulator 2018b). Directive 060 also requires LDAR programs to meet or exceed the Canadian Association of Petroleum Producers (CAPP) Best Management Practice for Fugitive Emissions Management. Monthly data reports on gas flared, vented, or used on site are required from each well and facility by Directive 017 (Alberta Energy Regulator 2016).

Initially the directives were not comprehensive in their reach. For instance, they did not address compressor stations, which enable the pressure required for oil and gas to flow through pipelines, despite the fact that these facilities have been identified as high emitters (Zavala-Araiza, Lyon et al. 2015). Alberta has since moved to update drafts Directives 060 and 017 to include new requirements for pneumatic devices, leak detection and repair, compressors, and dehydrators (Alberta Energy Regulator 2018a). Additionally, compressors will now be covered in the federal regulation.

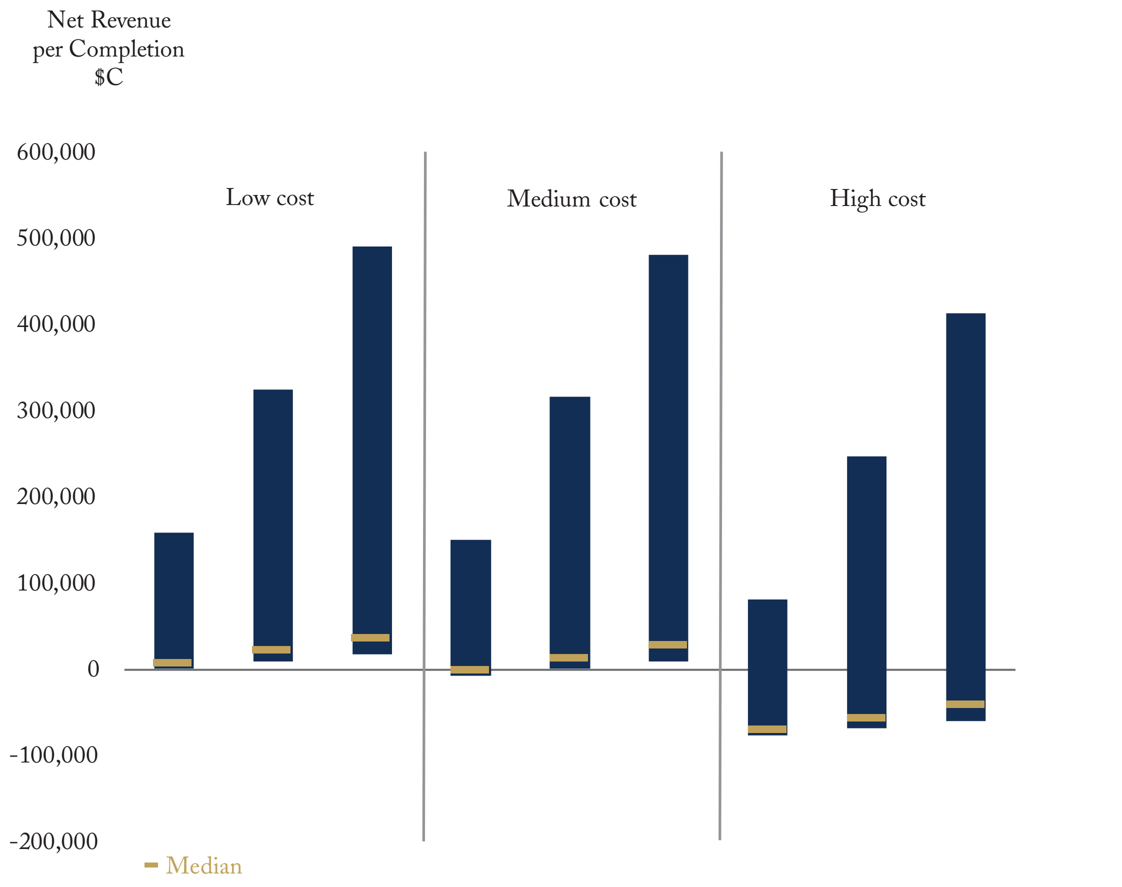
The regulations are becoming more comprehensive, including the collection of important data that governments might use to refine inventories of emissions from different sources across the oil and gas value chain. However, given the persistent uncertainties in the current levels of methane emissions, a substantial question remains for policymakers and the public: how can regulators know when they have achieved the 40-45 percent reduction when there is no present consensus about the baseline? Instead of a market-based approach, federal policymakers opted for more prescriptive regulations given the uncertainty about the magnitude and sources of fugitive methane emissions (Environment and Climate Change Canada 2018).

Yet, the Canadian federal government and its provincial counterparts could do more to fill in the scientific gaps. For example, the new federal record-keeping requirements are focused on determining compliance rather than furthering scientific research.

Data collection has not been well aligned across provinces and territories. In the past, provincial GHG inventories set different thresholds resulting in a patchwork of coverage. Reporting thresholds in British Columnia are more stringent than that of the US Environmental Protection Agency (EPA): facilities must report emissions above 10,000 tCO_2e/yr compared to the EPA's threshold of 25,000 tCO_2e/yr (Coleman, Kasumu et al. 2015, US Environmental Protection Agency 2015). But publicly reported data remain highly aggregate and do not report the detailed facility-level information that would support systematic comparisons to atmospheric measurements.[2] Up until 2018, the province of Alberta has had a much higher reporting threshold than both the Government of British Columbia and the US EPA at 50,000 tCO_2e/yr (Coleman, Kasumu et al. 2015). The differences in thresholds leaves questions regarding how many emissions may be left unreported, further complicating the establishment of a baseline. Alberta has since updated the reporting threshold to

2 Such comparisons would resolve differences in facility- and device-level estimations with atmosphere measurements by sampling atmospheric concentrations and relating the results to emissions from nearby facilities for validation.

Figure 2: Net Revenues per Completion across Major Producing Shale Gas Basins in North America (including Alberta and BC) under Three Price Regimes and Three Cases for Mitigation Cost



Note: Completions refer to the stage after drilling when the proper equipment has been put in place to enable the natural gas to commence flowing.

Source: Umeozor, Jordaan et al. 2018.

10,000 tCO_2e/yr starting in 2018, mirroring British Columbia's requirement. Despite these improvements, it remains unclear how many facility reports rely on existing emissions factors, which have been confirmed as limited. Neither province has had its inventories confirmed by external, independent science (a clear challenge for not only Canada, but North America more broadly (Brandt, Heath et al. 2014)).

A Price on What? Pricing Requires Accurate Measurement

Canadian governments must grapple with the scientific challenge to this policy question: how can carbon pricing drive mitigation when fugitive methane emissions from oil and gas infrastructure are not accurately measured? Pundits often reference carbon pricing as a critical component of reducing greenhouse gas emissions, but methane emissions have yet to be covered in Alberta's and BC's carbon pricing regimes (Gorski 2018). Carbon pricing for on-site combustion in oil and gas operations will commence in 2023 in Alberta under the provincial

Climate Leadership Plan (Government of Alberta 2018a). The potential market failure is clear: the social costs of the climate impacts from this powerful greenhouse gas have not yet been internalized. But how can governments put a price on emissions when they don't know how much is being released?

Additionally, unlike carbon dioxide, methane already has a price – natural gas is a substantial commodity with markets expanding globally. Even without pricing greenhouse gas emissions, the economics of reducing methane can be positive due to the revenues from selling the captured gas. The incentive to reduce emissions may exist even without pricing the externality. In Figure 2, the illustrative example of reducing completion emissions results in generally favourable economics. Specifically, under low and medium mitigation costs, the economics of mitigation can be favourable even without taking into account the social costs of methane.

Experts often present the costs of methane abatement as single value estimates; for example, estimating that leak detection and repair may cost just over $1,000 for one survey of a well site and the subsequent repair (The Delphi Group 2017). While such information is valuable, these results do not capture the facility-level variabilities that many operators experience. Due to the large network of oil and gas infrastructure with many devices and types of facility, potential revenues from methane capture are subject to large uncertainties.

There are cases where the economics of mitigation may be more favorable than others. As one example, the costs of green completions in Canada (when methane is captured at the completion stage)[3] can vary from $3.49-$45.42 Canadian dollars per tonne of carbon dioxide equivalent (CAD/tCO_2e) based on the amount of time the necessary equipment is kept on site and the emissions captured (Umeozor, Jordaan et al. 2018). The average revenue from selling the captured gas is just over C$16 t$CO_2$e, confirming the financial incentive for many but not all cases. This facility-level variability coupled with the existing scientific uncertainty makes methane a complex challenge for carbon and methane economics. Policies would benefit from expanding cost-benefit analyses beyond completion emissions alone (Figure 2) to include evaluations of mitigation options across the full natural gas infrastructure system.

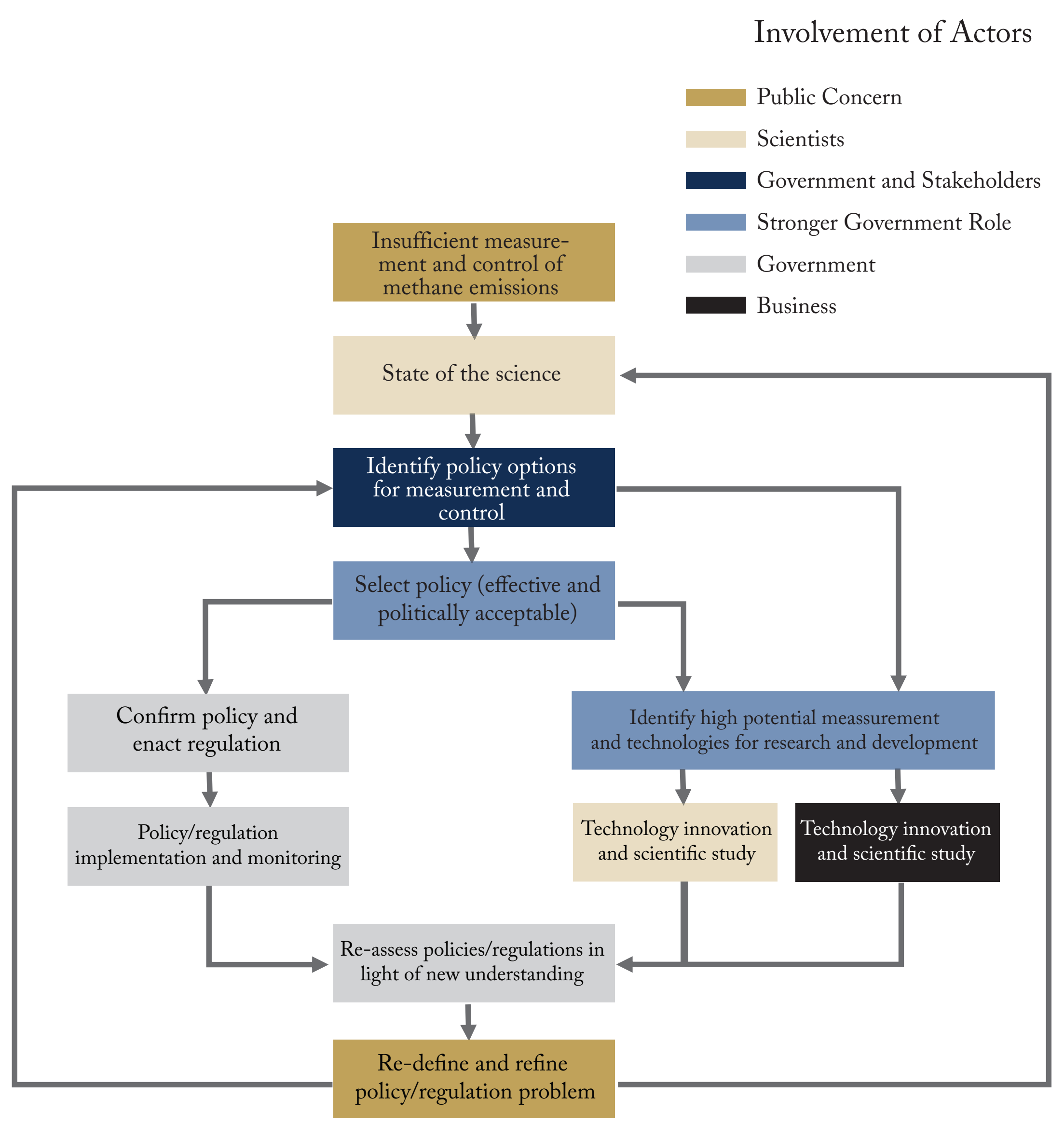
Plugging Leaks from the Oil and Gas Sector

Canadian governments could benefit from implementing an integrated science-policy framework for understanding and reducing fugitive emissions from the oil and gas sector. The proposed science-policy framework structures the interplay between scientific advances, technological developments and regulatory requirements. An integrated science-policy framework would identify policies to improve measurement and, in turn, drive science to refine detection and mitigation technologies for adoption in future policies. Just as importantly, the iterative nature of the framework enables both scientific advancements and technological breakthroughs to be considered by policymakers and regulators. This virtuous cycle would enable Canadian businesses and governments to learn and adapt more quickly, for more effective and efficient results.

In our recent publication in the journal *Climate Policy* (Konschnik, Jordaan 2018), we present such a framework to help policymakers in North America address fugitive methane emissions. We described how former President Obama's US EPA collected data about the cost and efficacy of green completions at well sites for years, and used that information to better estimate methane reductions from requiring this mitigation technology through regulation. Collecting defensible data and conducting robust research can inform better policies and

3 Completions refer to the stage after drilling when the proper equipment has been put in place to enable the natural gas to commence flowing efficiently and safely (http://www.glossary.oilfield.slb.com/Terms/c/completion.aspx).

Figure 3: The North American Emissions Reduction Framework



Source: Re-printed with permission from Taylor Francis (Konschnik, Jordaan 2018).

clearer environmental outcomes. Figure 3 illustrates the actors, activities and iterative information flows involved in this model science-policy framework.

Our model framework also helps to highlight gaps in Canadian policymaking concerning fugitive methane emissions. While recent Canadian regulations broaden coverage by including parts of the value chain that were not previously regulated and incorporate state-of-the-art best practices, current regulations do not integrate academic and industry research to target data gaps. Using the above framework, the relevant regulatory agencies could systematically incorporate deployment of new measuring devices and testing of methane emissions factors in their rules, enforcement agreements, and voluntary partnerships with industry, to improve scientific knowledge of the amount of emissions leaking from oil and gas infrastructure. There is already industry movement in this direction with the newly-announced collaborative project between the Petroleum Technology Alliance Canada, the Canadian Association of Petroleum Producers, and the Explorers and Producers Association of Canada that focus on methane leak detection, quantification, and repair (Petroleum Technology Alliance Canada 2018).

In support of the concept, we make the following recommendations for Canadian governments:

- **What gets measured gets managed**. Most importantly, the 40-45 percent reduction from 2012 levels should be verifiable. To do so, policymakers will have to establish a defensible approach to estimating 2012 methane emissions (acknowledging the gaps that are presently being addressed). Improved measurement across governments can support this goal and improve future estimates. The Government of Canada could work with provincial governments, industry, and other stakeholders to ensure that fugitive emissions are being adequately and consistently measured. Numerous forms of new measurement technologies and strategies can be implemented for state-of-the-art, effective measurement. Measurement will enable emissions sources to be identified and managed. Similarly, new technologies can be deployed for mitigating identified fugitive emission sources; however, such technologies will only be deployed where leaks are known. Alongside direct measurement, governments should also invest in improving the accuracy for estimates non-measured fugitive emissions. Decision-makers can look beyond completion emissions alone to develop methods that better estimate all infrastructure leaks, using measurements to validate results. Such estimation can enable a more comprehensive understanding of the costs and benefits of mitigation under different scenarios of carbon and methane prices.
- **Innovation in tandem by universities, industry and governments**. Innovation can result in creative new ways to measure fugitive emissions, to stop their escape and to produce natural gas. Universities, business and governments should seek to promote innovation by all actors in solving the challenge of fugitive emissions. Partnerships between these actors can also be leveraged with the specific intent to improve access to and availability of data.
- **Regulatory benchmarking and alignment.** With the substantial shale oil and gas boom in the United States, regulations were developed under former President Obama's administration and in specific states to address the environmental questions about fugitive emissions from the oil and gas sector. Canada can leverage approaches to designing regulations adopted in the US and other jurisdictions (and vice versa, keeping in mind the recent reversal of federal government support for climate policy under President Trump's administration (Urpelainen and Van de Graaf 2017)).
- **Integration of policy and regulation with robust science.** Policymakers should not stall progress in regulations due to current gaps in measurement. The current gaps in measurement should not stall moving forward with regulation to reduce fugitive emissions. Our model science-policy framework exhibits how regulations can be refined with ongoing advances in measurement and mitigation technologies.In tandem with present and proposed improvements, Canadian governments may seek to systematically capture fugitive emissions by implementing the proposed framework. The use of carbon pricing to incent reductions of fugitive methane emissions requires technological advances to accurately measure those emissions.

Conclusion

Both oil and gas value chains generate emissions that escape from extensive infrastructure networks. The amount of emissions being released has yet to be resolved, making the confirmation of emissions reductions a challenge to prove.

Canadian governments must ensure reductions are verifiable, developing robust and defensible estimations of 2012 baseline emissions to accountably demonstrate emissions reductions. Putting a price on carbon provides a useful tool to internalize the social costs of carbon dioxide. However, carbon pricing requires accurate measurement of emissions and presently appears ill-suited for reducing the full scope of fugitive methane emissions from the oil and gas sector because they have yet to be confirmed. Both federal and provincial regulations seek to improve both measurement and mitigation. But these regulations should be periodically and systematically revisited to incorporate ongoing scientific advances and technological innovation.

To adequately manage emissions, Canadian governments should consider moving towards an integrated science-policy framework that embraces technological innovation. As such, partnerships with universities and businesses can enable the inclusion of both scientific advancement and technology innovation in regulatory change. Through partnerships with industry, academics, and other stakeholders, policymakers can use this framework to ensure low-carbon natural gas while both addressing scientific uncertainty and cutting emissions across the oil and gas value chains.

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