1 Introduction

Recent years have seen significant changes in the U.S. energy economy, much of which has been driven by technological innovations such as horizontal drilling and hydraulic fracturing. Whereas the U.S. was previously dependent on imports of crude oil and natural gas from other countries, it is expected to become an exporter of liquefied natural gas (LNG) in the very near future. Furthermore, driven by concerns regarding environmental impacts linked to the burning of fossil fuels, there has been a shift in the U.S. to using cleaner-burning natural gas as a fuel for electricity generation and compressed natural gas for bus, truck, and automobile fleets. This change presents both opportunities and challenges. One of these challenges is how best to control natural gas emissions while embracing this new energy economy.

For example, although transportation by pipeline is, by certain metrics, the safest form of energy delivery in the U.S., natural gas, like any energy source, poses a potential safety risk along the production-to-consumption chain (USDOT 2018). From the perspective of producers, natural gas leaks also represent a loss of product and thus revenue. Furthermore, because methane, the primary component of natural gas, is a potent greenhouse gas, it has led to a number of states developing regulatory mechanisms to detect and control methane gas emissions. For these and other reasons, it is important to develop new and better technologies to detect natural gas, and specifically methane, emissions.

This document has been developed to assist state agencies tasked with developing regulations targeting emissions of methane from a variety of sources associated with oil and gas production, and natural gas transmission, storage, and distribution. The document presents a compilation of information regarding a wide range of methane detection and quantification technologies and presents a preliminary methodology developed for the evaluation of both current and future technologies for applicability to specific uses.

1.1 Purpose of Document

Several states have recently adopted or are considering regulations of methane emissions related to the oil and gas industry. Moreover, USEPA and DOI have released proposed regulations for methane leaks at new sources and on BLM lands. However, there is currently no standard methodology to evaluate equivalency or superiority of new methane detection and quantification technologies compared with those already approved for specific applications. The purpose of this document is to provide an overview of existing and emerging technologies as well as guidance regarding performance characteristics and parameters to consider in technology evaluation. It also endeavors to identify regulatory barriers to the use and adoption of new or innovative technologies that have the potential to reduce methane emissions. This information is intended to enable regulators, facility owners and operators, and other users to evaluate, compare, and select suitable technologies to detect and quantify methane emissions from various segments of the oil and natural gas supply chain for compliance with existing and forthcoming methane emission (leak) regulations, to monitor inventories, and to enhance workforce and public safety.

1.2 Document Scope

This document is focused primarily on the oil and gas industry because it has the most urgent need for methane detection and quantification technologies due to current regulatory requirements. Although the focus of this document is on methane detection and quantification technologies, there are regulations that apply to both methane and volatile organic compound (VOC) emissions, therefore the document also discusses VOCs in that context.

Furthermore, the following parameters set the scope of this document:

- This guidance addresses the regulatory environment pertaining to on-shore methane emission sources. Although off-shore emissions are of equal concern, these facilities are difficult to access (e.g., production platforms) and may be located in marine or sub-marine environments (e.g., platform-to-shore pipelines), and thus may require a different approach to methane emission detection.
- This document encompasses existing and developing detection technologies but does not delve into ongoing research and development (R&D) efforts. The detection technology field is dynamic and rapidly-evolving so this guidance may require significant updating in a relatively short period of time.

- This document is intended to provide a reasonably comprehensive overview of available methane detection and quantification technologies, but not an exhaustive compilation of all technology combinations (e.g., same sensor on different platforms).
- Similarly, this guidance is intended to provide an overview of the current regulatory environment, but does not seek to serve as an exhaustive, all-inclusive reference for methane emissions regulations in all 50 states and on federal lands.
- Lastly, this document is not intended to serve as a definitive "how to" manual, but to provide information that may be of broad interest and benefit to states, industry, and other stakeholders.

Although this guidance document is focused on addressing the needs of the oil and gas industry, it may also provide useful information for other industries that have a need to detect or monitor methane emissions.

1.3 Intended Audience

This document is intended for a wide audience and may be used as follows:

- Regulatory, technical staff and managers from local government authorities, state environmental programs, and from federal environmental, land management and energy programs can use this guidance for the following:
    - To inform their decisions regarding the requirements incorporated into pending or future regulations
    - To revise existing regulations to allow for application of new technologies or existing technologies in new ways or help determine equivalence between new and existing technologies
    - As a general reference
- Technology developers and vendors can use this document to inform their research and development efforts
- Oil and gas producers, transmission companies, distribution utilities, municipalities, and large facilities with interest in detecting and managing methane releases can use this guidance to assist in selecting existing or emerging methane detection and quantification technologies to address the requirements of existing or pending regulations and as a general reference.

Other audiences may include academics involved in researching, developing, or evaluating methane-detection technologies, as well as tribal, environmental, community, and other interested stakeholders. This guidance will provide them with a common understanding of available and emerging methane detection and quantification technologies, a methodology for assessing the applicability of a given technology for a particular purpose or environment, and of regulatory expectations for technology performance.

1.4 Framing the Guidance Document

This section summarizes the perspectives of the states, the regulated industry, and stakeholders (as defined by ITRC), which participated in the preparation of this document.

1.4.1 State Survey for Regulations

A survey of states was made using the ITRC's State Points of Contact (POC) to collect information on laws, policies, and regulations requiring leak detection and repair (LDAR) or control of methane emissions from the oil and natural gas industries. Thirty-six state POCs responded and of those, 14 reported having relevant regulations in place or under consideration, with six of those requiring both LDAR and control of methane emissions. This survey is discussed in greater detail in the Appendix C – Regulations Additional Material. Most existing regulations rely on Method 21 for leak detection with a few states also allowing the use of optical gas imaging (OGI) cameras.

1.4.2 Industry Perspective and Concerns

Substantial industry, government, and private funding has spurred the development of many methane detection and quantification products and services. From an industry perspective, there are several features that must be considered for technology selection in the methane detection space. First, methane detection and quantification strategies need to be applicable for the industry segment for which they are intended. For example, vehicle-based platforms that could be deployed to monitor dense, urban natural gas distribution systems are unlikely to be the ideal solution for monitoring geographical dispersed oil and gas production sites. Second, cost effectiveness targets must account for the method under which the industry segment actually recovers cost. For example, the production segment tends to assess leak detection and repair costs in relationship to recovered gas, while natural gas distributors tend to be assigned defined budgets for repair activities based on collections from local rate payers. Finally, technologies under consideration for large scale deployment

must be pilot tested in field locations over an extended period while including advanced analytics to sort out actual detections from measurement noise in order to yield actionable insights.

Furthermore, it is important that regulations are flexible enough to incorporate innovative technological solutions even if the performance of the technologies is not identical to those on which the regulation was originally based. For example, several states have adopted regulations that require periodic surveys of oil and gas infrastructure with handheld OGI cameras to locate emission sources. In theory, a technology solution such as a satellite or an inexpensive wellpad sensor, could be used to identify larger sources more quickly than periodic manned surveys, and this could result in better emission reductions despite having higher (poorer) detection thresholds.

1.4.3 Tribal, Environmental, and Community Stakeholder Concerns

The ITRC broadly defines stakeholder as members of environmental organizations, community advocacy groups, tribal entities, or other groups that deal with environmental issues, or a concerned individual who is not a member of any organization or group. Public stakeholders, such as advocacy groups, often speak for the communities that are affected by environmental issues. In this document, a differentiation is made between public stakeholders and interested parties (e.g., oil and gas companies, pipeline operators, and state regulators.)

ITRC has found that environmental regulators and other parties benefit from informed, constructive stakeholder involvement because it can help them make better decisions and reduce the likelihood of costly, time-consuming repeated work. It also allows those in affected communities to participate in decisions regarding the long-term use of land, water, and other resources.

Stakeholders recognize that there are limitations to the areas addressed in this document. The purpose of this document is to provide an overview of existing and developing technologies as well as guidance regarding performance characteristics and parameters to consider in technology evaluation. However, it does not provide an exhaustive, all-inclusive reference for methane emissions in all sectors, in all states, from all sources.

There may still be stakeholder concerns not accounted for in this document. Accordingly, representatives of interested parties who are coordinating discussions of evaluation methodologies or specific technologies with regards to methane detection and quantification should be aware that stakeholders may have additional concerns such as those discussed in Section 7 – Stakeholders.

Stakeholders have expressed specific concerns about emissions including safety due to the explosive and flammable properties of natural gas, and they assert concerns that some natural gas trace constituents or combustion products could be either toxic or carcinogenic (depending on concentrations), or that methane and co-pollutants contribute to regional particulate matter and ozone formation. Methane is also a potent greenhouse gas responsible for 25% of the additional heat trapped by the atmosphere due to human activities (Etminan et al. 2016).

1.5 Document Content

The remainder of this document is arranged into the following sections:

- Section 2 – Characterization: identifies all the known sources of fugitive methane emissions within the oil and gas sector and characterizes the types of emissions and rates that may be expected from each of these sources.
- Section 3 – Regulations: summarizes existing and proposed laws and regulations of local, state, and federal governments that focus on methane leak detection and repair programs for the oil and gas sector; defines the current needs of existing laws and regulations, as well as any legal or other constraints on the use of technology; addresses regulatory barriers to the use of various types of methane detection and quantification technologies such as various types of overly-restrictive language; and briefly addresses regulations in Canada, Europe, and other countries.
- Section 4 – Technology: discusses the relevant available methane detection and quantification technologies and their functional attributes, including whether the data captured is qualitative or quantitative; provides the type of data and whether the measurements are instantaneous or continuous, the relative size of the instrument, the instrument's working distance, and how it may be deployed; and notes the relative costs and other relevant attributes.
- Section 5 – Evaluation: provides a framework for the evaluation of methane detection and quantification technologies, including metrics and procedures for assessing primary and secondary data quality, and a

framework for evaluating technology equivalence for specific applications.
- Section 6 – Lessons Learned: identifies and discusses the observations and lessons learned by the team members during the preparation of this document.
- Section 7 – Stakeholder Concerns: addresses the concerns of stakeholders who may be asked to participate or comment on evaluation methodologies or specific technologies with regards to methane detection.

The following Appendices can be found at the end of the document:

- Appendix A: Case Studies Summaries
- Appendix B: Characterization Additional Materials
- Appendix C: Regulations Additional Materials
- Acronyms
- Glossary
- Acknowledgments
- Team Contacts

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