METHANE DETECTORS CHALLENGE

Continuous Methane Leak Detection
for the Oil and Gas Industry

REQUEST FOR PROPOSAL

Proposal Deadline: 5:00 pm EST, June 17, 2014

A collaborative initiative by:

- Apache Corporation
- BG Group
- Environmental Defense Fund
- Hess Corporation
- Noble Energy
- Southwestern Energy

All information about the Methane RFP including application forms, RFP updates, and responses to all submitted questions can be found on the web site:

www.edf.org/methanedetectors

INSTRUCTIONS

If you are interested in applying for an opportunity to be part of the lab and field tests that will lead to pilot purchases and testing at oil and gas facilities, please follow these instructions:

1. Send a Notice of Intent via email by 5/2/14 to methanedetectors@edf.org if you intend to submit a proposal. Include your name, your organization and an email address that can be used to notify you of any updates.
Note: Failure to submit a Notice of Intent will not negatively affect an application that is submitted by the deadline of June 17, 2014.

2. Submit the proposal by the 6/17/14 deadline, to methanedetectors@edf.org. All applicants must use the Methane RFP Application for Testing form located at: www.edf.org/methanedetectors. Proposals can be no greater than 30 pages long including attachments, and no bigger than 10 MB in size. Proposals must not have any confidential business information.

3. All communications should be made through methanedetectors@edf.org. To ensure a fair process, we request that applicants not directly contact anyone at EDF, Apache Corporation, BG Group, Hess Corporation, Noble Energy, Southwestern Energy or Southwest Research Institute about the challenge. To ensure all questions are fully addressed we ask that inquiries be submitted prior to May 27, 2014. All questions and responses will be posted on the web site: www.edf.org/methanedetectors

4. It is anticipated that applicants selected for participation in the first round of testing will be notified by email not later than July 9, 2014.

5. EDF encourages all applicants and potential applicants to join the LinkedIn group Methane Detectors Challenge by requesting membership in the group as soon as possible. This site can be a forum for networking and exploring possible collaborations

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Executive Summary

Environmental Defense Fund (EDF) is initiating a new effort to catalyze development and commercialization of low cost, methane detection technologies to help minimize methane emissions in the oil and gas industry. Joining EDF in this quest are five natural gas and oil producers – Apache Corporation, BG Group, Hess Corporation, Noble Energy, and Southwestern Energy. These organizations, collectively referenced here as "The Partners", are launching the Methane Detectors Challenge, targeting innovators from universities, start-up companies, instrumentation firms, and diversified technology companies among others. The Challenge is an opportunity for innovators to benefit from no-cost, independent testing of their technologies, and potentially have their technologies purchased and piloted by industry leaders as part of an expanding new market in the United States and internationally.

EDF's mission is to protect the living systems on which all life depends. As part of that mission, EDF is looking to catalyze reductions in the climate change impacts of the oil and gas industry. The Partners are being advised by an independent board comprised of experts from the scientific, technology, and NGO communities. The goal of this program is to identify cost effective systems to detect unintended methane emissions (also known as "leaks") at discrete locations. Initially emphasis will be placed on two types of locations: (1) oil and gas well pads including associated equipment, and (2) compressors at locations along the natural gas supply chain. It is the Partners' belief that shifting the methane emission detection paradigm from periodic to continuous will allow leaks to be found – and fixed – more readily, thereby greatly reducing the amount of gas lost to the atmosphere benefiting communities, the climate and industry.

The Challenge is *not* aimed at accurately quantifying methane flux rates. The Challenge *is* aimed at catalyzing commercial, low cost technology that can consistently detect leaks of methane over time and varying environmental conditions. The detection system is sometimes envisioned as akin to "a carbon monoxide alarm for methane". The ideal system will serve as a "smart" alarm, sending an alert to the operator when an increase in ambient methane is detected, one that reflects emissions beyond what would normally expected to be seen and thus a high probability of a leak. The ability to detect methane is a requirement. A methane selective sensor is preferred, but technologies that also respond to other hydrocarbons will be considered.

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This Request for Proposal (RFP) asks technologists to submit descriptions of their technology for review. The most successful applicant(s) that meet threshold requirements as determined by independent testing will ultimately have an opportunity to market their technologies through pilot purchases and deployment at oil and gas facilities owned by many of the participating companies, in the United States and abroad. There are four main phases of the Challenge: (1) RFP responses and initial selection (2) First round testing (3) Second round testing of systems that successfully met the specifications in the first round (4) Industry pilot purchases and deployments.

For the first two phases of the project, applicants can choose either of the following two options.

1. Submit a "Sensor Only" proposal for an instrument which makes a point measurement of methane concentration in parts per million (ppm) or a sensor that measures methane along an open path in ppm-meters

OR

2. Submit a "Sensor and Leak Detection System" proposal, which from direct measurements of methane concentrations determines if there is a high probability of a methane leak at the facility being monitored. Accurately estimating the flux of methane coming from the leak observed is not expected. However, there is a preference for indication of the relative magnitude of the leak, i.e., "No Leak, Leak, Large Leak".

The proposals will be assessed based on the strength of the evidence presented addressing if the proposed technology could meet the overall goals. The Partners, in collaboration with our advisors, will select the most promising applications for technical assessment by Southwest Research Institute (SwRI) in San Antonio, Texas. This assessment will be conducted during the period July-September 2014. Based on the test results those applicants with the best results will be asked to participate in field tests in March-June 2015 at a location to be determined. Finally, the technologies that performed best during the lab/field testing (assuming they meet the requirements) will be asked to participate in an industry pilot purchase and trial deployment phase targeted to commence in September 2015. The Partners will base their selection of which sensor technologies will become part of the pilot purchase program based on the quantitative results of the testing as well as the realistic estimate of the commercial-scale system price. The Partners are not obligated to select any applicants for any round of testing.

Please note that funding provided by EDF will completely cover the cost of the independent testing of technology, and as indicated below EDF will reimburse reasonable travel expenses as well. Further, during the industry pilot phase, we expect that purchases of pilot technology will be made. Technology development grants or awards are not included for the first phase of this project.

1.0 Introduction

1.1 Background

1.1.1 General Background

The use of horizontal drilling and hydraulic fracturing has caused a dramatic rise in oil and natural gas production in the United States and some international locations in recent years. Because natural gas burns more cleanly than coal, large scale switching from coal to gas for power generation has the potential to significantly reduce greenhouse gas emissions.

However, methane is the primary component of natural gas and is also an extremely potent greenhouse gas. Methane emission estimates from the oil and gas industry vary widely; however, lower bound estimates suggest that at least 1-2% of the product is lost to the atmosphere throughout the value chain, which includes exploration, production, transportation, processing and distribution. This is highly problematic for the climate, since according to the most recent report from the Intergovernmental Panel on Climate Change (IPCC), methane has a global warming potential 86 times higher than carbon dioxide as a greenhouse gas over the 20 years following its release into the atmosphere. Minimizing methane emissions is a necessary step on the pathway to slowing the rate of climate change over the next few decades.

Today's approaches for detecting leaks, for example those caused by equipment malfunction or human error (such as leaving a hatch open), are highly variable across industry. Some leading companies conduct Leak Detection and Repair (LDAR) on a voluntary basis. This may include sending trained personnel to a well pad on a monthly, quarterly, or annual basis. During such inspection visits, many companies use infrared cameras, which provide visual identification of leaks. However, the cost of these cameras is about $100,000 and they cannot be cost effectively deployed on a continuous basis to monitor all potential sources of emissions.

Building on today's breakthroughs in big data and inexpensive sensing technology – and anticipating the "win-win" of minimizing the environmental impact and increasing resource efficiency that result from reduced methane emissions – the Partners believe that substantial market opportunities exist for low cost, continuous methane leak detection. Today, there are believed to be roughly 700,000 oil and gas wells in operation in the United States. If we assume for illustrative purposes that one quarter of those wells were candidates for effective use of a well-pad-based, $1,000 methane/hydrocarbon leakage sensing system, the potential market size is over $150 million.

The potential market size expands when: (1) compressors are included (2) new conventional and unconventional oil and gas wells are drilled, including coal bed methane and tight sands development, and (3) the international market is added.

1.1.2 Scientific research on methane emissions from oil & gas industry

EDF has initiated a series of scientific studies with academic and industry partners to better understand how much and from where methane is released into the atmosphere from along the oil and natural gas supply chains. More than 90 universities, research facilities and natural gas companies are working together on these studies. Data is being collected in five core areas: production, gathering and processing facilities, transmission and storage, local distribution including medium and heavy duty trucks and CNG and LNG fueling stations. The initiative includes 16 independent projects, almost all of which are nearing completion or have been completed. Results will be submitted for publication during 2014.

In September 2013, results from the first of the 16 projects were published in *the Proceedings of the National Academy of Sciences*. Led by Dr. David Allen of The University of Texas at Austin (UT), the study made direct measurements of methane emissions associated with unconventional natural gas production. A team of researchers from UT Austin's Cockrell School of Engineering and environmental testing firms URS and Aerodyne Research completed measurements at 190 natural gas well pads from across the United States.

Emission measurements were taken during well completion flowbacks, at pneumatic controllers and pumps, and of equipment leaks. Study results show that total emissions are in line with EPA estimates from the production of natural gas, yet those emissions are distributed quite differently among activities and equipment than was estimated by EPA for 2011.

Critically important for this Challenge is the observation made by the University of Texas team that emissions from equipment leaks were substantially *higher* than EPA estimated, in the range of 38-69% higher. That indicates there is a significant societal opportunity to address climate change by reducing those leaks and a significant business opportunity to develop technology that can more efficiently detect those leaks so they can be more easily repaired.

1.2 Request for Proposal Contents

The remainder of Section 1 of this RFP includes a note on potential innovator collaboration; the requirement that sensors detect methane; a table of sensor specifications; and the criteria that will be used to evaluate the various RFP applications. Section 2 describes key opportunities and challenges involved in developing a low cost sensor for oil and gas applications that can be used to assist operators in methane/hydrocarbon leak detection. In Section 3, a more detailed discussion is provided on the various tests that are planned to evaluate the submitted technologies.

Appendix A describes technical considerations related to methane detection limits. Appendix B describes the variations in the planetary boundary layer and how that may affect readings of methane/hydrocarbons. Appendix C describes how variations in wind speed and direction can make it difficult to identify the size of a leak. Appendix D describes further background information regarding intentional methane/hydrocarbon emissions from oil and gas operations.

1.3 Innovator Collaboration

The Partners encourage applicants to consider forming teams with diverse expertise and capabilities in order to craft the strongest possible proposal. Each organization will be responsible for protecting its own confidential business information. The Methane Detectors Challenge LinkedIn group is one platform for facilitating networking and open exploration of collaboration opportunities, and interested organizations are highly encouraged to ask to join the group. The Partners may facilitate discussion between/among applicants to enable collaboration.

1.4 Key Specifications for Methane/Hydrocarbon Sensor Technologies.

Detailing a field-ready, integrated sensor-leak detection system is not required for the initial set of materials to be submitted for the first round of testing which is primarily focused on the sensor, but will be required in any follow-up testing. The Partners recognize that there are many promising technologies at different stages of development and completeness, which is why the process has been designed to be inclusive and progressive.

There are no specific hardware requirements for the Sensor and Leak Detection System submissions; however, it is expected that field ready systems will need to incorporate meteorological or other data for successful leak detection. Other measurement devices, algorithms, modeling/inverse modeling programs, etc. are expected to improve the ability of the system to minimize false positives (for example from intended methane emissions, and/or from offsite emissions from either oil and gas operations or other sources) and to provide rough indications of leak magnitude.

Cost is a critically important factor. The Partners will exercise a preference for technologies that could reasonably be expected to be sold for roughly $1,000 or less per well pad (or compressor) when produced at scale in the next 2-5 years. It is understood that costs may be significantly higher in the testing and pilot phases, but articulating a clear path to low cost/large scale production is a necessity. Consideration will be given to multiple point measurement systems where higher system costs are likely but achieve the target cost at an individual well pad or compressor location.

A more detailed description of the specifications is provided in the following table.

Table 1: Specifications desired in each phase of the challenge			
Specification	**First Round Lab Test**	**Second Round Lab/Field Test**	**Industry Pilot Purchase/Deployment**
Detection limits	5 ppm*	5 ppm*	2 ppm*
Detection range	5 ppm - 250 ppm*	5 ppm - 250 ppm*	2 ppm - 2000 ppm*
Leak detection capability	Not specified	5 scfm	2.5 scfm
Calibration frequency	1-2 times or less per test phase	1-2 times or less per test phase	Once per year or less
Remote calibration	Optional	Optional	Preferred
Ability to measure methane	Required	Required	Required
Ability to measure other hydrocarbons	Optional	Optional	Optional
Methane specific detection	Optional	Optional	Preferred
Ability to isolate on-site methane gas from off-site sources	Optional	Required	Required
Power requirements	110v, 20 amp or single size solar panele and rechargeable battery	Single, standard size solar panel and rechargeable battery	Single, standard size solar panel and rechargeable battery
Power consumption	As low as possible	As low as possible	As low as possible
Cost of hardware	Not specified	Not specified	$5000/$1000 per unit**
Inherently safe/Electrical Classification	Not specified	General Purpose	Class 1/Division 1 capability
Ability to roughly distinguish leak size	Optional	Preferred	Required
Machine learning (Adapt to new data)	Optional	Optional	Preferred
Ability to give approximate location of leak	Not specified	Optional	Optional
Enclosed/ protected from weather	Optional	Required	Required
Temperature range	-20 F to 120 F	-20 F to 120 F	-20 F to 135 F
Humidity	0 - 90% relative humidity	0 - 100% relative humidity	0 - 100% relative humidity
Unaffected by poisons	Required	Required	Required
Telemetry	Optional	Optional	Required SCADA compliant and independent
Expected lifetime	Not specified	Not specified	10 years
*Specified detection limits include ambient concentrations of methane which are just under 2 ppm. For applications using open-path methods, assume a 5 meter homogeneous plume for methane detection limit calculation purposes.			
**$5000 per well pad is the target for the pilot phase. During implementation, assuming lower costs due to mass production, the target is $1000 per well pad or less. Consideration will be given to multiple point measurement systems where higher system costs are likely but achieve the target cost at an individual well pad or compressor location.			

1.5 Key Decision Criteria for Selecting the Technologies for Additional Testing

Southwest Research Institute will assess the performance of the technologies that are tested. The Partners – with help from the independent experts on the Advisory Board – will identify the best candidates for additional testing in the Second Round Lab/Field Test and Industry Pilot Purchase/Deployment. The evaluations will be based on the following three factors:

Performance: The technologies which performed the best in testing, adhering to the specifications above.

Cost: The technologies expected to be most cost effective when incorporated into systems approaches produced at commercial scale. Considerations will be given to purchase price of equipment and software, installation price including power requirements, and cost to maintain and calibrate. In other words, the total cost of ownership will be considered.

Readiness: The technologies that could readily be scaled for production and immediate implementation. Consideration will be given to the operating history of the hardware and software in outdoor environments, supporting data provided to demonstrate performance in real world applications, ability to integrate with industry operations, ease/difficulty in meeting electrical classification requirements, innovator track record, and collaborative approach when applicable.

The project schedule currently proposed is as follows:

Challenge announced; RFP issued	*April 3, 2014*
Notice of Intent due (voluntary)	*May 2, 2014*
Applications due from innovators	*June 17, 2014*
Selected participants notified	*July 9, 2014*
Complete testing plan	*July 15, 2014*
Meeting between participants and SwRI to review laboratory testing procedures and exchange materials	*Beginning July 22, 2014*
Complete round 1 of testing	*September 2014*
Select participants for second round testing	*October 4, 2014*
Allow technical development time for sensor only applicants to integrate with devices to form complete systems and allow existing systems time to develop further	*October 2014 – March 2015*
Test systems	*March 2015 – June 2015*
Select 1-3 systems for industry pilots	*July 2015*
Plan industry pilots	*August 2015*
Industry purchases systems and begins pilots	*September 2015*

2.0 Opportunities and Challenges

2.1 Opportunities

The Methane Detector Challenge presents a significant opportunity to innovator applicants. Solving the challenge will yield important environmental benefits, contribute to improved efficiency in a highly competitive industry, and give the innovator a "first mover advantage" in what may become a fast growing market. In the more immediate phase, participating in the testing project will give innovators valuable data and feedback on the performance and readiness of their technologies, and will give selected innovators exposure to potential customers. Below are several additional aspects of the opportunity to consider.

2.1.1 The oil and gas boom in the United States

Oil and gas operations have seen unprecedented growth in recent years. There are roughly 700,000 oil and gas wells in operation in the U.S., and almost 1,800 rigs drilling new wells. The growth in oil and gas production requires additional infrastructure including gathering pipelines, processing plants, and transmission facilities. The necessity for this infrastructure is growing, and the existing infrastructure will be in place for many decades to come. The need to detect and locate leaks may only become more important in the future as equipment ages. A successful, low cost leak detection technology today will see market opportunities for many years.

2.1.2 International scope

Although oil and gas operations have not developed as quickly in the international market as they have in the United States, many nations are seeking to duplicate the U.S.'s efforts. Further, leak detection already is a global market and is expected to expand in the future.

2.1.3 Applications for leak detection

This Challenge was spurred by the desire to reduce methane emissions and leaks in unconventional oil and gas fields and compressors, but may benefit other application areas including conventional drilling as well as coal bed methane and tight sands development. These and other applications will expand the possible markets for leak detection technologies.

2.1.4 Hazardous air pollutants and ozone precursors

Although the primary focus of this effort is to reduce methane emissions, there are other air quality co-benefits that may be achieved. In the upstream segment of the oil and gas value chain, methane is sometimes co-emitted with volatile organic compounds and hazardous air pollutants, which can cause risk to public health and contribute to more regionalized environmental problems such as smog. Therefore, it is anticipated that an important additional benefit of reducing methane leaks is improving air quality and supporting public health.

2.2 Challenges

The goals of this project may be challenging to achieve in the complex, dynamic environments that are often experienced in oil and gas applications. The Partners are seeking to identify applicants who are eager to take on these challenges with simple, low cost technologies. These challenges include the following:

2.2.1 Leak size and concentration measurements

The preferred system will give some indication as to the size of the leak, for example, through a three-tiered system that indicates "No Leak", "Leak" or "Large Leak". However, concentration measurements taken by sensors alone can be deceptive because when wind speeds are high, a large leak may produce very low or no emissions that are measureable above background levels. On the other hand, when the atmosphere is stagnant with little or no wind, a small leak can congregate in an area and produce concentrations that are high (in the hundreds of ppm). The sensor's detection limits must be expressed in terms relative to the background or ambient methane levels. For a more detailed discussion of methane detection limits, see Appendix A.

For reasons expressed above, a sensor that measures concentration in ambient air cannot, without more information, determine if the measured level of methane represents a significant leak. Although it is not anticipated that the methane detection system would provide the exact location of the leak, it is expected that once a system alerts operators that a leak exists, the company will have confidence that a significant leak exists and will dispatch someone to the location with a portable leak detection device (e.g., an infrared camera) that can identify the precise location of the leak source.

2.2.2 Changing atmospheric conditions

The lowest part of the atmosphere, where all weather occurs, is called the planetary boundary layer (PBL) and is constantly changing. Each day as the sun rises it heats up the PBL, causing it to increase in size. A sensor measuring a pollutant will actually see lower concentrations in the afternoon when the air is warm and has expanded. Conversely, in the early morning hours, concentrations will rise as temperatures cool and the air contracts. Sensor systems must be designed so that they do not send out false alarms due to changes in the PBL, and instead alarm only when there is an actual leak at the production site or compressor station. A plot showing the changes in PBL and a discussion about the impact on concentration readings is provided in Appendix B.

2.2.3 Wind profiles

Wind blows at very different speeds depending on height. Further, turbulence can create wind patterns that force air and the pollutants that it carries in unexpected directions. The variations in wind speed and direction at various heights can create a concentration at a sensor that is difficult to correlate to the size of the leak. Having a device that performs an accurate concentration measurement is important; however, the real value for this application is in knowing the approximate size of the leak and providing an alarm to operators when attention is required. In addition to a methane/hydrocarbon sensor, this will most likely require meteorological data, such as wind speed and direction measurements taken at the site. The impact of shifting winds and varying wind speeds is illustrated in Appendix C.

2.2.4 Intentional emissions

There are circumstances where industry intentionally releases natural gas. Because systems at well pads frequently operate without any ties to grid power, the pressure that is available from the natural gas is used to help perform many functions such as the opening and closing of valves.

Pressurized natural gas is used in pneumatically operated devices specifically for this purpose. These devices depressurize by releasing natural gas to the atmosphere. These emissions are not trivial and they can give signals that can interfere with efforts to detect leaks. A more detailed description of intentional emissions is provided in Appendix D of this document.

2.2.5 Background emissions

Many oil and gas well pads will be near sources of methane such as landfills, cattle, and other oil and gas sites. The sensing system must be able to identify leaks that occur above the background emissions in the area to prevent false positives that might cause operators to look for leaks that are outside of their control. There are several different approaches that may be used. Some examples that have been employed include:

a. using a sensor that can distinguish between isotopes of carbon in methane, thus distinguishing between the methane that comes from landfills and cattle and that which comes from older geological sources, such as natural gas. However, this approach is not useful for distinguishing between on-site leaks and emissions from nearby oil and gas sites.

b. using a sensor that can identify temporal changes in emissions, thus determining if the changes are occurring at a slow rate indicative of a background that might be seen from an upwind site with a landfill, cattle or a nearby oil and gas site, or rapid changes indicative of a plume from an on-site leak. This approach would be most useful if integrated with on-site meteorological measurements.

2.2.6 Power availability

Many oil and gas sites are in remote locations and power from the grid is not available. In some cases the only solutions are to operate sensors that are self-powered with a solar panel and rechargeable battery. All systems should be designed to consume as little power as possible.

2.2.7 False Positives/False Negatives

A false positive is defined as an incorrect methane/hydrocarbon reading that is above the designated alarm point and causes an operator to take action when no action is warranted. A false negative is defined as an incorrect (low) methane/hydrocarbon reading when methane/hydrocarbon is present and causes an operator to not act when a leak occurs.

The possibility exists that due to problems with sensor hardware, changes in wind speed/direction or other atmospheric conditions that the sensor may incorrectly signal the oil and gas operator about a leak that does not exist, or conversely, may not detect a leak that does exist. These problems can also occur due to a mechanical failure of the device, a contaminant the sensor reads as methane or other hydrocarbons, and dust or other artifacts that coat the sensor and prevent it from providing an accurate reading. Excessive false positives and false negatives could cause the operators to distrust any readings from the instrument, and must be minimized. This includes incorrectly attributing enhanced background concentrations to an on-site leak or unplanned emission.

2.2.8 Rugged and diverse conditions

Oil and gas sites are located all over the country, sometimes in areas of extreme heat and extreme cold. The terrain may be open and flat, mountainous and/or covered with trees. Some areas are very humid, others dusty and dry. The best sensor applications will be those that can operate successfully in most or all locations and conditions.

The Partners are seeking applicants who are eager to take on these challenges and deliver sensors and sensor systems that will overcome these obstacles and successfully identify and reduce methane emissions.

3.0 Applicant Requirements and Testing Protocols

The Partners will review all applications for this RFP and arrange for testing the best applicants in the lab and in the field. For the selected applicants there are some requirements regarding test planning, start up and interpretation of results that are described in the testing schedule provided below.

3.1 Round 1 - Laboratory Test (July–September 2014)

3.1.1 Explanation of laboratory testing protocols

EDF has contracted with Southwest Research Institute to cover the testing fees. Applicants will be reimbursed by EDF for actual, reasonable expenses for travel and the cost of delivering their instruments to the test sites, up to a maximum of $10,000 per innovator for the first round of testing. Successful applicants are required to attend preparation meetings (by phone and in person) and provide assistance during testing as described in this RFP. The successful applicants should expect to spend a day at the Southwest Research Institute site in San Antonio and provide the labor necessary to ensure their systems are operating correctly.

Testing protocols are currently under development, but are likely to assess items considered essential in order to move on to the next round of testing, such as: controlled releases of methane and hydrocarbons in a laboratory setting and controlled exposure to simulated environmental conditions, potentially including wind and temperature extremes.

3.2 Round 2 – Lab/Field Test (March – June 2015)

3.2.1 Explanation of lab/field testing protocols

In order to qualify for this round of testing applicants are expected to have demonstrated a technology readiness level that provides a high degree of confidence that they could be installed in the field and consistently provide reliable results. Specifically these instruments must be rugged enough to perform well in adverse environments and be able to detect enhanced methane/hydrocarbon concentrations and identify the approximate leak size. They also must meet the additional qualifications determined by the Partners. As indicated in the Methane Detector Challenge Schedule (Section 1.5), some technical development time will be allowed for sensor only applicants to integrate with devices to form complete systems, and allow existing systems time to develop further.

3.3 Requirements of Applicants

A range of applicants are expected to be chosen for Round 1 of laboratory testing and a smaller group is expected to be chosen for Round 2 of lab/field testing. These applicants will be expected to:

- Meet with Southwest Research Institute to discuss lab/field test by phone and in person.
- Deliver the proposed hardware and software to the test site.
- Be present and provide assistance for setting up the equipment in preparation for the measurement testing.
- Provide a written analysis of the Southwest Research Institute lab/field test results on their sensor system to EDF, describing how their instrument performed in the Southwest Research Institute tests

3.4 Evaluation of Methane Detectors

Immediately following Round 1 and Round 2 of testing, a written report on results of laboratory tests and the applicant's response will be provided to EDF. The Partners will select applicants for industry pilot purchases and testing.

Appendix A

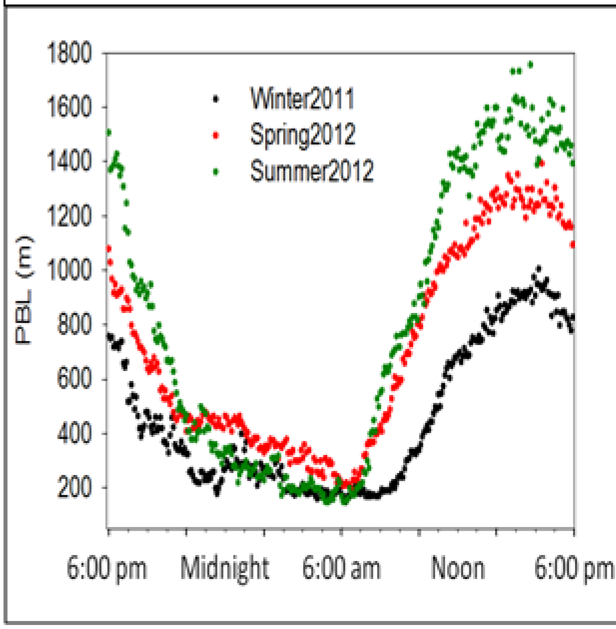
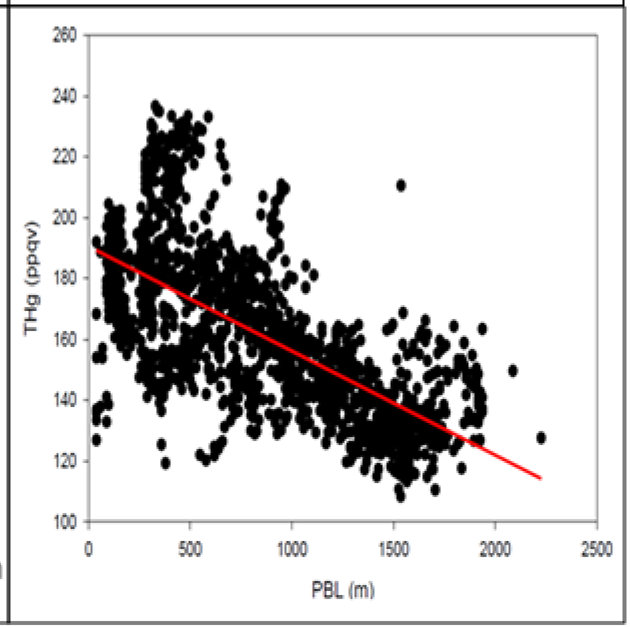
Methane Detection Limits

A sensor's "methane detection limit" is defined as the methane concentration needed to create high confidence concentration measurements (accurate readings with low false positive/negative responses). In general, a high confidence measurement is one that is interference free and has measurement signal levels that exceed the sensor's baseline noise by 6-10 times. Since sensor designs can vary, a complete description of sensor performance will differ between different instruments. Explanations of the derivation of the detection limits are encouraged in the application. Ideally, the applicant should provide example test data supporting sensor performance (if available). Discussions should include sensor accuracy and precision performance factors if known. The applicant should also explain potential interferences to the primary concentration measurement and any compensation approaches (if used). Sensor interferences could include but are not limited to responses to other gases not associated with oil and gas leak detection activities or effects of meteorological variables. In field applications, the sensor may be exposed to a mixture of methane and other hydrocarbons but the detection limits are based on methane response alone. A response of the sensor to other hydrocarbons present in oil and gas emissions, such as ethane and propane, does not constitute a false positive. Note that the sensor will be exposed to methane concentrations that vary in time due to the emission source(s) and winds, and yield a variable output, so the sensor's time response may be a consideration.

Appendix B

The Planetary Boundary Layer

The plots below show how the planetary boundary layer (PBL) changes throughout the day and different PBL heights can influence gas concentrations.

PBLs in Houston	PBL Height Can Influence Gas Concentration
	

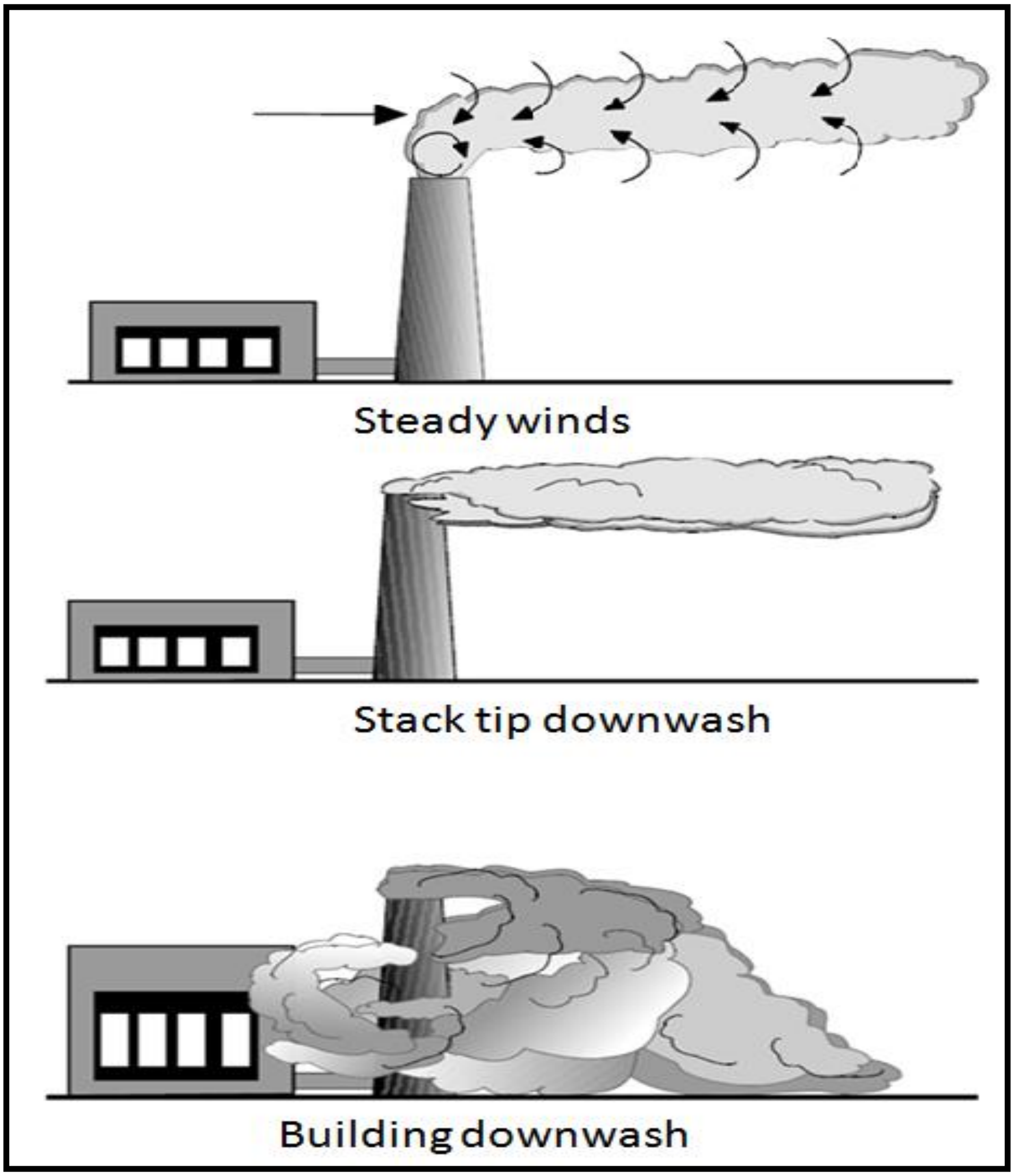
These plots were presented by Robert Talbot from the University of Houston at the Methane Emissions workshop hosted by EDF in June 2013. The first plot shows how the PBL is highest in the late afternoon and lowest in the early morning hours. The second plot shows the relationship between concentration and PBL height. As PBL increases (typically in the afternoon) concentrations decrease. Concentrations rise to their highest levels when the PBL is compressed and concentrated between midnight and 6:00 am.

Appendix C

Wind Profiles and the Impact on Emissions

Several examples of how wind can impact emissions are illustrated in the diagram below.

Stack Emissions under Various Wind Conditions



These diagrams were presented by Robert Talbot from the University of Houston at a Methane Emissions workshop hosted by EDF in June 2013. The top figure illustrates a strong wind in a single direction blows the plume in one direction; however, there is entrainment of ambient air which varies depending on the wind speed. The second figure shows that under certain conditions the stack emissions can blow back on the source. Finally, in the third figure eddies trapped by nearby buildings can trap pollutants in small areas, creating higher concentrations.

These three cases illustrate the difficulty in determining both the size and location of a leak. A concentration reading alone will not be suitable for alerting an operator about an emission problem. The concentration readings must be interpreted in the context of the wind direction, wind speeds and other atmospheric conditions to prevent false alarms.

Appendix D

Intentional Methane Releases by Industry

Natural gas well pads include both intentional and unintentional methane emission sources. Intentional sources include pneumatic controllers and pumps powered by pressurized natural gas. Methane also may be released intentionally when gas is vented for maintenance or unloading liquids accumulated in the wellbore. Unintentional releases of methane, or fugitive emissions, are caused by leaks from equipment such as wellheads, separators, tanks, pipes, and valves. The ability to distinguish intentional and fugitive emissions will be a critical function of a successful methane leak detection system. In many cases, such as during maintenance, there are workers present during the intentional releases. In these cases the workers will know that a release is taking place. However, at other times when pneumatics are operated automatically, employees are not always present.

Pneumatic devices have a wide range in the frequency and magnitude of their emissions. Intermittent-bleed pneumatic controllers only emit during an actuation, while continuous-bleed pneumatic controllers also emit between actuations. The frequency of actuation varies from several times an hour to less than once per day depending on the equipment being controlled. *Allen et al. 2013* (UT Production Study) measured emissions from 305 pneumatic controllers and 62 pneumatic chemical injection pumps (CIPs) at 150 production sites. The average emissions of pneumatic controllers and CIPs was 0.175±0.034 and 0.192±0.085 standard cubic feet methane/minute/device (scfm), respectively. Emissions from individual devices ranged from 0 to 2.27 scfm methane. Well pads often contain multiple pneumatic devices. The average site in the UT Production Study had 6 pneumatic controllers and 1 CIP, and 10% of sites had 20 or more pneumatic devices.

Maintenance activities and liquids unloading can cause very high methane emissions. The UT Production Study reported an average emission rate of 700 scfm for 9 manual liquids unloadings with an average duration of 67 minutes. However, these intentional emission events are scheduled and occur when staff is on-site, which should help distinguish them from fugitive emissions. Plunger-lift assisted liquids unloading, which may occur either manually by on-site staff or automatically without staff on-site, could be more challenging to distinguish from fugitive emissions. Automated unloading vents typically occur on a regular schedule or when triggered by monitoring software, which may be useful for distinguishing these intentional vents from fugitive emissions.

Fugitive emission sources also vary widely in their frequency and magnitude. The UT Production Study surveyed 150 production sites for leaks and found and measured 278 leaking components. The average equipment leak emissions normalized by the number of wells per site was 0.064±0.023 scfm methane/well. Emissions from individual components had an average of 0.108 scfm and range from 0 to 4.817 scfm methane. Total site fugitive emissions had an average of 0.6 scfm and range from 0 to 5.46 scfm methane. Small leaks are more common than large leaks, but responsible for less of the total emissions. In the UT Production Study, leaks smaller than 0.01 scfm comprise 36% of leaks and 1% of emissions, while leaks larger than 1 scfm comprise 1.4% of leaks and 30.1% of emissions (Table 1). A study commissioned by the City of Fort Worth found 2,126 leaking components at 375 well pads. The Fort Worth study also found a highly skewed emission rate distribution with the top 10% highest emitting components comprising 68% of the total emissions. They study identified 42 components with very high emission rates ranging from 5 to 25.6 scfm methane, primarily tanks with open thief hatches or pressure relief valves.

Table 1. Frequency of equipment leaks per well and site and percent contribution of total leaks and emissions by emission rate category in the UT Production Study.

	0 - 0.01 scfm	0.01 - 0.05 scfm	0.05 - 0.1 scfm	0.1 - 0.5 scfm	0.5 - 1 scfm	1 - 5 scfm	All Leaks
Leaks per well	0.20	0.16	0.08	0.10	0.02	0.01	0.57
Leaks per site	0.67	0.51	0.27	0.33	0.06	0.03	1.85
% of leaks	36.0	27.3	14.4	17.6	3.2	1.4	100
% of emissions	1.0	6.6	9.9	29.4	22.9	30.1	100

Works Cited

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