Natural Gas Leaks of Significant Environmental Impact (SEI)

Report of the 2018 SEI Field Trial

Utilities Enacting the Leak Extent Method

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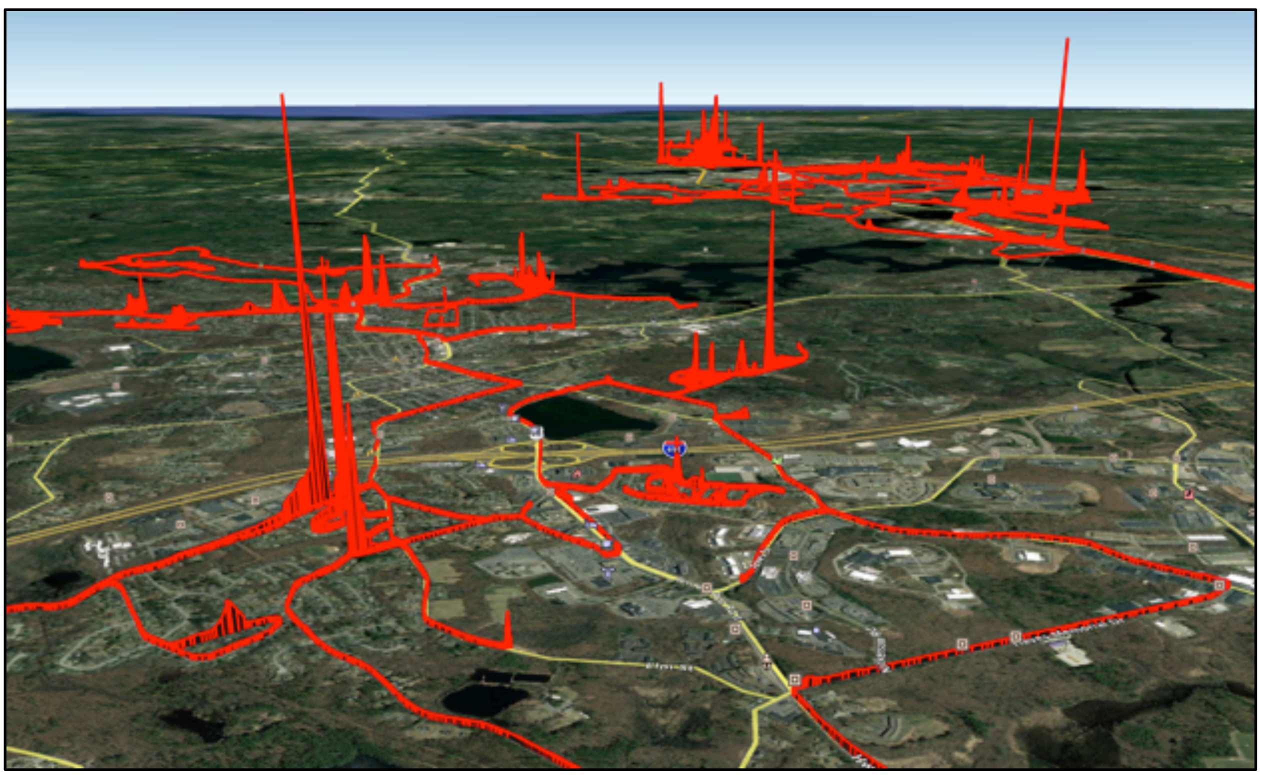

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Executive Summary

Massachusetts has the second oldest natural gas infrastructure in the country. Old pipes leak methane, a greenhouse gas 84 times more potent than carbon dioxide over the first 20 years in the atmosphere.[1]


Old gas pipes

The amount of gas leaked annually from the Commonwealth's aging gas distribution system is equivalent to the emissions of all of the state's stores and businesses combined.[2] The cost of this wasted gas is passed on to the customers, estimated to be over $11 million per year.[3] In addition to polluting the air, methane suffocates street trees as it seeps into their root zones, depriving them of oxygen.

Research by Boston University and Gas Safety Inc.in 2016 showed that just 7% of the greater Boston distribution system leaks emit half of all the gas by volume, creating a clear policy opportunity.[4] Later the same year, the Massachusetts Legislature enacted a law requiring that these leaks of significant environmental impact (SEIs) be repaired, since doing so would cut methane emissions in half for the least cost to the utilities and the least disruption to cities and towns.

However, given that gas companies had always been mandated to focus on the explosive potential of a leak and not emissions, they had no reliable and accurate method to identify these largest leaks that have a significant environmental impact. In 2017, HEET coordinated a large collaborative study working with Columbia Gas MA, Eversource Gas, and National Grid Gas, together with Gas Safety Inc., Mothers Out Front and other stakeholders. This research team field tested multiple methods and found the leak extent method[5] was a quick, effective and low cost solution.[6]

This report documents the progress of this first-in-the-nation program and reports on the use of this new identification protocol - the leak extent method - to identify and repair SEIs in the 2018 dig season in Columbia Gas, Eversource Gas, and National Grid Gas territories. HEET independently verified the results, with Gas Safety Inc., and provided analysis.

Massachusetts is the first to enact legislation to identify environmentally significant leaks, the first to determine an SEI protocol, and the first to test it widely in the field across multiple gas companies. We hope to report in coming years that we are also first in the nation to cut in half our methane emissions from the gas distribution system.

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[1] IPCC Climate Change Report, "Climate Change 2013: The Physical Science Basis," Table 8.7
[2] See page 5
[3] See Appendix 4, Annual Total Cost from the Distribution System for more information. Reference is calculated using findings from McKain et al, Methane emissions from natural gas infrastructure and use in the urban region of Boston, Massachusetts, https//www.pnas.org/content/112/7/1941.
[4] Hendrick et al, "Fugitive methane emissions from leak-prone natural gas distribution infrastructure in urban environments", https://www.bu.edu/ise/files/2016/08/1-s2.0-S0269749116300938-main.pdf
[5] Originally suggested by Bob Ackley of Gas Safety Inc.
[6] Magavi, Z., Ackley, R., Hendrick, M., Salgado, E., Schulman, A., Phillips, N., "A Method of Identifying Large Volume Leaks in Natural Gas Distribution Systems", publication pending.

Main Results of SEI Pilot Year

- Gas companies were able to use the leak extent method to identify SEIs in the field. The measurements of individual leaks were relatively consistent over a work season, even when measured by different personnel from different organizations with varying weather conditions.
- A top-down analysis shows a fast 14-month return on investment for repairing SEIs.
- All three gas companies appear to be under-identifying some SEIs, potentially because the protocol was new. A mobile CRDS (cavity ring-down spectrometer) survey also showed promise in identifying SEIs.
- The FluxBar, a tool for comparing and confirming the emissions of leaks through a proxy measure of flux, needs data in 2019 to determine efficacy and refine the protocol.
- Leak repairs do not appear to always be successful and the success rate should be further evaluated to maximize emissions savings per dollar.
- There is potential for refinement of the leak extent method, helping to identify and repair SEIs faster and for less cost. This will require more information sharing.

In summary, the leak extent method is working to identify the worst leaks so they can be repaired.

SEI Enactment and Barhole Method

On March 8th, the Massachusetts Department of Public Utilities issued the final regulation on identification and repair of SEIs.[1]

In enacting this regulation, the Department of Public Utilities led the nation in prioritizing SEIs and in defining an effective procedure, leak extent, for their identification. Use of the leak extent method will save money for customers, reduce emissions, and potentially cut the equivalent of 4% of the state's greenhouse gas emissions inventory in as little as three years.

Unfortunately, the department also allowed gas companies to use the "barhole method," a method which the 2017 study found did not work at all. No matter which method the gas companies use to identify the SEIs, they will get paid more for repairing them.[1] It is in everyone's best interest for the gas companies to continue to use the efffective leak extent method to save money and emissions.

HEET is a nimble nonprofit that convenes and generates expertise, research, and ideas to drive a swift and just transition off fossil fuels. Our outsized impact is created through leading large networks of diverse stakeholders to enable information and ideas to emerge.

HEET verified[7], analyzed and wrote up the information in this report. To maintain its independence, HEET has never taken money from a gas company. HEET is funded by foundations and individual donors.

HEET testing the FluxBar

Gas Safety Inc. has over 40 years of professional experience with gas and gas leaks and four peer-reviewed scientific publications. The 'leak extent' protocol tested in the Large Volume Leak Study was initially proposed by Gas Safety Inc.

The Gas Leaks Allies is a coalition of more than 20 organizations and researchers focused on reducing methane emissions from the natural gas distribution system in Massachusetts while transitioning to fossil-free energy sources. This unconventional, interdisciplinary collaboration of scientists, gas experts, activists, and concerned citizens is finding solutions for the problems caused by aging, leaking pipes buried in our neighborhoods.

[7] Gas Safety Inc. provided the professional gas work needed, including leak surveys and drive by surveys.

Background

Gas Leaks Accelerate Climate Change

Pipe-quality natural gas is over 90% methane. If leaked to the atmosphere without being burned, it remains methane, a remarkably potent greenhouse gas, much more destructive to the climate than if the gas is burned and transformed to carbon dioxide. Because of the potency of methane, if a total of 3% or more of it is leaked unburned into the atmosphere anywhere from wellhead to point of use, its impact on the climate is worse than burning coal.[8] An estimate from NASA in 2019[9] found that methane emissions are spiking globally in the atmosphere.

Research conducted by Harvard University and Boston University[10] in 2015 measured the amount of ethane (a chemical marker found only in natural gas) in the atmosphere over Greater Boston. From the results, the researchers calculated that approximately 2.7% of the total natural gas being transported into the Greater Boston area was leaked unburned to the atmosphere, instead of being used as an energy source.


Thermal imaging of gas emitting from a sewer

Calculating the Greenhouse Gas Emissions[11]	
Total gas consumption MA statewide 2017 Source: EIA, https://www.eia.gov/dnav/ng/ng_cons_sum_dcu_SMA_a.htm)	449,463,000,000 cubic feet
Rate of gas leaked annually into atmosphere in Greater Boston (Source: McKain et al, https://www.pnas.org/content/early/2015/01/21/1416261112)	2.7%
Total MA statewide annual leaked gas (assuming leak rate applies statewide)	12,135,501,000 cubic feet
Total MA statewide annual leaked gas	343,638,554,717 cubic liters
Total MA statewide annual leaked gas (1 mole per 22.4 liters methane)	15,341,006,907 mole
Total MA statewide annual leaked gas (1 mole methane weighs 16 grams)	245,456,110,512 grams
20 year timeframe of methane's impact on the climate - its global warming potential (Source: IPCC)	84
Total annual leaked gas CO2 equivalent (million metric tonnes CO2 equivalent)	20.26 MMCO2e
Most recently available 2011 MA Greenhouse Gas Inventory (Source: MassDEP https://www.mass.gov/files/documents/2016/11/xv/gwsa-update-16.pdf)	78.6 MMCO2e
Total MA statewide annual leaked gas, as a proportion of the MA GHG inventory	26%
Total MA statewide annual leaked gas from distribution infrastructure (conservatively estimated as 30% of all leaked gas) as a proportion of the MA GHG inventory.	8%
Half of the distribution infrastructure leaked gas attributed to superemitter leaks.	4%

Using the above sources, the estimated impact of the super emitting leaks is equivalent to 4% of the carbon dioxide emissions in the state, or the emissions of half of all our state's stores and businesses (i.e. the commercial sector in 2016).[12].

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[8] Robert W. Howarth, "A bridge to nowhere: methane emissions and the greenhouse gas footprint of natural gas", https://onlinelibrary.wiley.com/doi/full/10.1002/ese3.35

[9] Worden, J.R. et al., "Reduced biomass burning emissions reconcile conflicting estimates of the post-2006 atmospheric methane budget", Nature Communications 8, Article number: 2227 (2017) doi:10.1038/s41467-017-02246-0

[10] McKain et al, 2015, "Methane emissions from natural gas infrastructure and use in the urban region of Boston, Massachusetts", https://www.pnas.org/content/112/7/1941.full

[11] This uses the same calculation approach as described Dr Phillips blog article http://centerforenergyenvironmentalstudies.blogspot.com/2015/01/a-27-methane-leak-rate-represents-10-of.html

[12] 3.9 MMCO2e, "Appendix C: Massachusetts Annual Greenhouse Gas Emissions Inventory: 1990-2016, with Partial 2017 Data", https://www.mass.gov/lists/massdep-emissions-inventories)

7% of Leaks Emit Half of All the Gas

Research conducted by Boston University[13] in 2016 found that in Greater Boston just 7% of the leaks on the pipes under the streets in the distribution system emit fully half of all the gas by volume. Scientific research has duplicated this relationship from wellhead to distribution system, showing that a small fraction of the leaks are responsible for half the emissions.[14] Since the cost of the wasted gas is passed onto the customers, this also represents wasted money.

> *If "super emitting" leaks could be identified and repaired, the state could cut emissions and wasted money for the least cost and the least disruption*

Grading of Gas Leaks

Methane gas is explosive when it builds up to between 5 and 15% of the ambient air in any space. Leak grading has historically focused on this.

Grade 1(hazardous): Any leak in or near a contained space, such as a building or manhole, that could explode. Grade 1 leaks are fixed immediately.

Grade 2 (potentially hazardous): Any leak that could become a Grade 1 – close to a building, etc. Grade 2 leaks are monitored and fixed within 12 months.

Grade 3 (non-hazardous): All other leaks, those that are not close to buildings or in contained spaces. A Grade 3 leak in the middle of the street for instance could be leaking an enormous quantity of gas. Before the SEI law, there was no requirement that high emitting leaks like this be fixed by the gas company and some leaked for decades.

Significant Environmental Impact Law Passed in 2016

In 2016, the Gas Leak Allies, a coalition of over 20 nonprofits and researchers working to reduce emissions, worked to develop and pass new legislation[15] requiring that these gas leaks of "significant environmental impact" (SEI) must be repaired. Grassroots mobilizing by Mothers

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[13] Hendrick et al. 2016, "Fugitive methane emissions from leak-prone natural gas distribution infrastructure in urban environments", https://www.bu.edu/ise/files/2016/08/1-s2.0-S0269749116300938-main.pdf

[14] Brandt et al, 2016, "Methane Leaks from Natural Gas Systems Follow Extreme Distributions", https://pubs.acs.org/doi/abs/10.1021/acs.est.6b04303

[15] "Section 144, The 191st General Court of the Commonwealth of Massachusetts", https://malegislature.gov/Laws/GeneralLaws/PartI/TitleXXII/Chapter164/Section144

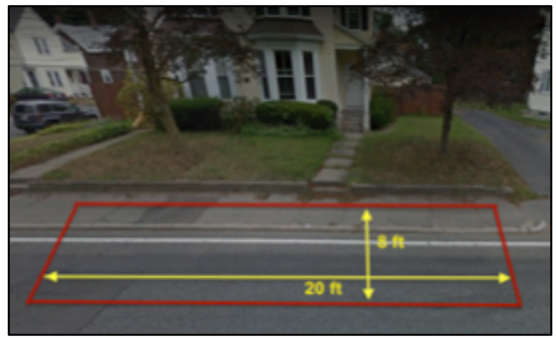
Out Front was a driving force in this effort.

Unfortunately, with the concept of super-emitting leaks so new, *the gas companies had no proven method to identify which of the over 17,500*[16] *unrepaired leaks in the state were emitting the most.*

The 2017 Large Volume Leak Study

In 2017, HEET coordinated the "Large Volume Leak Study", working with Columbia Gas MA, Eversource Gas, and National Grid Gas, as well as with Gas Safety Inc., Mothers Out Front and other stakeholders.[17,18]

The study measured leak emissions using the chamber method, a peer reviewed method for measuring emissions over time, and then tested five proposed proxy methods for identifying the largest volume leaks quickly in the field. Gas workers worked together with grassroots volunteers and scientists to collect the data on leaks across the state.



Key Findings of the 2017 Large Volume Leak Study

The study concluded that the Leak Extent Method was the fastest and most reliable proxy method for identifying high emitting leaks. This method classifies a leak with a gas-saturated surface area larger than 2000 sq. ft. as emitting enough gas to be considered a leak with a Significant Environmental Impact (SEI).

The study found the emissions of a leak are strongly correlated (n=67, R_2=0.86) with the leak extent, or size of the gas-saturated surface area over the leak. The bigger the leak, the greater the emissions.

One of the alternate methods tested was the "barhole method." The barhole method involves making a hole in the ground using a handheld bangbar and inserting a combustible gas indicator in the hole. According to the method, any leak with any sub-surface reading over 50% gas would be considered an SEI leak. However, the study found no correlation (n=, R_2=0.003) between the emissions of a leak and a barhole subsurface reading of over 50%. In addition, National Grid trained gas personnel returned to their studied leaks using the same equipment at the same location and were unable to replicate the barhole readings, showing no correlation between past and present barhole method results.

[16] Report on the Prevalence of Natural Gas Leaks in the Natural Gas System, DPU 17-GLR-01
[17] Magavi, Z. "Identifying and Rank-Ordering Large Volume Leaks in the Underground Natural Gas Distribution System of Massachusetts", 2018. https://dash.harvard.edu/handle/1/37945149
[18] Magavi, Z., Ackley, R., Hendrick, M., Salgado, E., Schulman, A., Phillips, N., "A Method of Identifying Large Volume Leaks in Natural Gas Distribution Systems", publication pending.

Shared Action Plan

Based on the outcomes of the Large Volume Leak Study, in October 2017, HEET, Columbia Gas, Eversource, and National Grid created a five-year “Shared Action Plan” (Appendix 3). The three gas companies and HEET submitted comments jointly to the Massachusetts Department of Public Utilities (DPU) with the request that the leak extent method and the Shared Action Plan be enacted as regulation.

The Shared Action Plan detailed that:

- The leak extent method would be used by the gas companies to identify SEI leaks, until or unless replaced by a superior method.
- These SEIs would be fixed faster than the DPU had initially suggested.[19]
- There would be data transparency, independent verification of the results coordinated by HEET, and annual reassessment of data to iterate and refine methods.

SEI Enactment

The Massachusetts Department of Public Utilities (DPU) issued the SEI regulation March 8, 2019. Before that date, the gas utilities have not been allowed to submit for reimbursement of SEI repair expenses. In spite of this uncertainty of reimbursement, for the 2018 field trial year, the gas companies identified 212 SEIs and performed repairs on 19 of those, honoring the Shared Action Plan.

[19] “Uniform Natural Gas Leaks Classification”, https://fileservice.eea.comacloud.net/FileService.Api/file/FileRoom/9172578

SEIs Are Worth Repairing, Both for the Climate and for the Wallet

For this report, Applied Economics Clinic (AEC) created a top-down analysis on the likely return on investment of SEI repairs. As a top-down estimate, it represents the upper range of potentially wasted money and emissions. A bottom-up measurement of emissions would give a lower boundary to the potential range. An accurate bottom-up direct emissions measurement of SEIs would require a larger scale emissions study with many more leaks surveyed than has been done to date.

AEC used the findings of the 2016 Harvard University / Boston University study[20] to calculate the amount of gas lost into the atmosphere.[21] AEC assumed that just a third of that lost gas came from the distribution system (with the rest coming from inside buildings, LNG tanks, etc.) and multiplied that amount by the marginal cost of gas to get the total cost of the wasted gas.

Super-emitting leaks (7% of the total leak population) are responsible for half of the leaked gas from our distribution system. The remaining 93% of the leaks emit the rest of the gas. With this information AEC calculated the amount of gas lost per super emitter and gas lost per average leak. While the exact quantity of gas is estimated and varies over time, the relationship or ratio should hold true and indicate the relative savings of repairing large leaks first.

The average cost of a leak repair was calculated using the total cost of repairing all the leaks across the state divided by the total number of leaks remaining (both cost and number of leaks as reported by the gas companies).

SEI leaks are identified using a proxy method (leak extent) that is easy and reliable, but not perfect; therefore the leaks identified are a slightly larger percentage of the leak population (~10%). The table below shows the results. Fixing an average SEI leak gives consumers a return on investment, with the given assumptions and approach, in approximately 14 months. This means the payback for an SEI repair is nine times faster than for a non-SEI repair.

	Total gas lost/year (therms)	Number of leaks	Gas lost per leak/year (therms)	Cost of lost gas/year	Return on Investment (years)
Average leaks	37,753,544	17,810	2,120	$633	6.2
Superemitter leaks	18,876,772	1,186	15,915	$4,752	0.8
Grade 3 leaks excluding super emitters	18,876,772	15,758	1,198	$358	11
SEIs	20,009,378	1,781	11,235	$3,355	1.2

[20] McKain et al, 2015, "Methane emissions from natural gas infrastructure and use in the urban region of Boston", Massachusetts, https://www.pnas.org/content/112/7/1941.full
[21] The Energy Information Administration report that year stated a smaller amount of lost gas in Massachusetts (1.9%); https://www.eia.gov/naturalgas/annual/pdf/table_a01.pdf

2018 SEI Field Trial Results

Columbia Gas, Eversource Gas and National Grid trained surveyor personnal to use the leak extent method (Appendix 2) and successfully identified 212 SEIs, then reported that they repaired 19 of them. HEET, an independent nonprofit, worked with Gas Safety Inc. to directly measure the subsurface leak extents of 30 of these leaks and assessed the repairs of 5 of them, providing verification of the utility-provided data.

This field trial program is a first-in-the nation model, showing that gas distribution companies can successfully identify and repair the gas leaks that emit the most methane in order to cut the emissions from leaking natural gas pipes in half.

The 2019 work season is expected to be a full scale rollout of the program across all gas companies in the state.

HEET using a Combustible Gas Indicator

A Choice in Methods

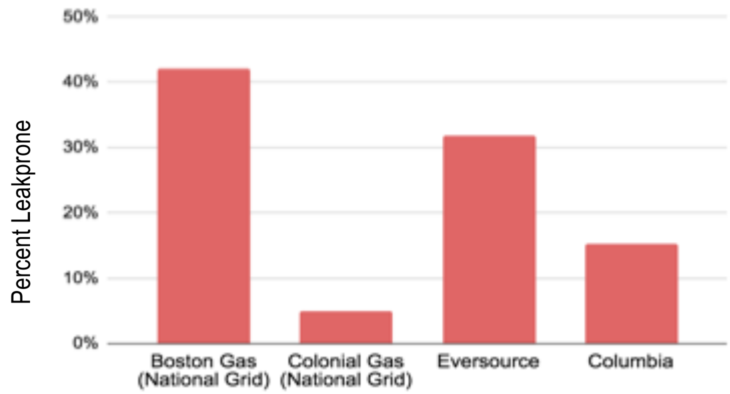
The Environmental Defense Fund (EDF) announced an agreement in 2019 with People's Gas in Pittsburgh, to pilot a different way of identifying the highest emitting leaks. The EDF-Pittsburgh method requires a mobile sensing lab (see the CRDS mobile survey below) to survey the streets. This type of mobile survey results in many additional benefits such as digital records, but a single mobile lab costs over $100,000 a year to lease.

The HEET agreement with Eversource Gas, Columbia Gas, and National Grid Gas in Massachusetts, announced in 2017, uses the leak extent method, requiring only a measuring tape in combination with conventional utility gas detection equipment. Since some gas companies and customers might fight the expense of the surveys (and not value the many additional benefits), this leak extent method offers an attractive and doable alternative.

HEET recommends that all gas companies and states adopt one of these methods to begin to reduce distribution system methane emissions now.

Leakprone Infrastructure By Gas Company

The aging infrastructure in Massachusetts is not evenly distributed across the state or within any one gas distribution company. This must be accounted for as we evaluate the results on the small subset of leaks studied in this field trial.



Source: Report to the Legislature (D.P.U. 18-GLR-01), 2018

National Grid SEIs Could Not Be Verified

National Grid identified 15 SEIs before their labor lockout,which ran from June 2018 to January 2019. Regrettably the lockout meant that SEI identification halted, addresses were not shared, and none of their initial work could be verified.

National Grid has the greatest number of gas customers in the state, and its Boston Gas Territory has the highest rate of leakprone infrastructure in the state.[22] Thus National Grid is the gas company likely to have the most SEIs. Thus National Grid has an opportunity to lead on methane emissions reduction at the distribution level in the 2019 work season.

Estimating Leak Extent Is Not Accurate

Only 50% of estimated leak extent SEIs were verified to be SEIs.

Columbia Gas was committed to cutting gas leak emissions in 2018 and wanted to get SEIs on their repair schedule before the seasons leak surveys were completed. So they tried using leak reports from the previous year to estimate leak extent in order to identify potential SEIs.

Columbia Gas identified 148 potential SEIs in this manner and shared with HEET the addresses and estimated leak extents of the 13 SEIs they intended to fix during the 2018 workseason.

HEET was able to perform above-ground leak extent surveys on six of these before Columbia Gas had completed their repair work on all the leaks.

[22] National Grid territory covers 90 different municipalities in National Grid Massachusetts territory, https://docs.digital.mass.gov/dataset/massgis-data-public-utility-service-providers

The *estimated* leak extent was not very accurate. The HEET-measured leak extents turned out to be on average less than half of the required 2,000 square foot extent of an SEI. Of the six HEET measured, only 3 of them were verified to be SEIs.

2018 Pilot Year, 6 Columbia Gas *estimated* SEIs, 50% verified by HEET to be SEIs

Measuring Leak Extent Protocol Works in the Field

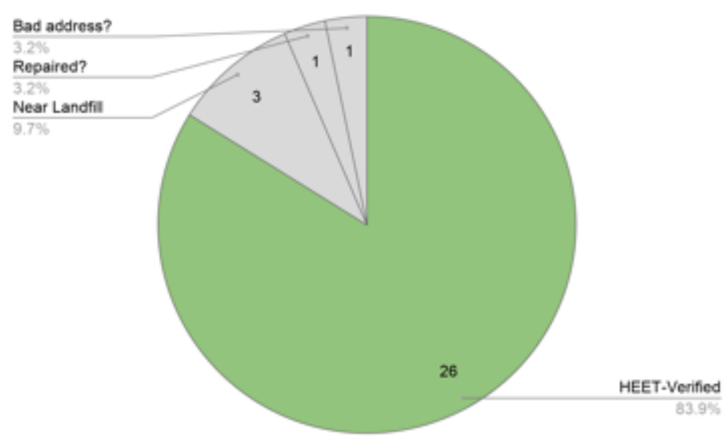
83% SEIs identified by measured leak extent were verified SEIs.

Eversource used the leak extent method to identify 49 SEIs, then shared the addresses and extents with HEET. Working with Gas Safety Inc.,[23] HEET verified the subsurface leak extent of 30 of those leaks in order to check that the new protocol would work in the field across personnel and organizations.

25 of these 30 Eversource-identified SEIs were confirmed to be SEIs by HEET, since the gas-saturated surface area over each of these leaks were over 2,000 sq feet.

The remaining five leaks either had an unclear address, the leak might have been already repaired, or the leak was close enough to a town dump that the source of the methane in the soil was not certain to be natural gas. In none of these cases was there a problem with the protocol.

This result demonstrates the protocol is rigorous and can be used in the field by different personnel and organizations to identify SEIs.



2018 Pilot Year, 31 Eversource-identified SEIs, 84% verified by HEET to be SEI

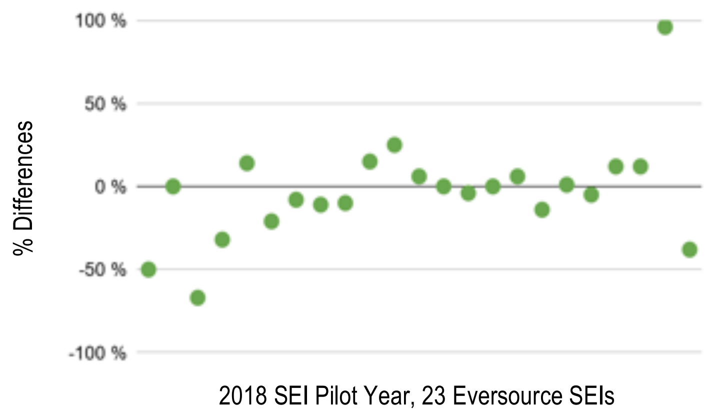
[23] Gas Safety Inc. provides utility-independent fully certified, accredited gas surveys.

Subsurface Leak Extent Method is Consistent Over Time

For each of these 26 verified-SEI leaks, we calculated the difference between the extent measured by OMark (Eversource's leak survey contractor), and HEET's partner, Gas Safety Inc.

On average, the difference was very small - just 3%, in spite of the fact that:

- An average of four months had passed between measurements.
- The extents were measured by different personnel from different organizations.
- The weather and the ground moisture levels were different between measurements.



The leak extent measurement at individual leaks remained relatively consistent, over an average of four months, even when the same leak was measured by different personnel from two different organizations. This method appears to be robust.

Were Any SEIs Missed?

In the 2017 Large Volume leak study, approximately 10% of the leaks fit our definition of an SEI. (The leak extent method is a proxy identification method that is fast and reliable but does end up including a few more than just the super emitting leaks). However, in the 2018 SEI pilot year, all three gas companies were finding SEIs at a lower rate than 10%.

	# of Leaks Surveyed	Utility identified SEIs	SEI Identification Rate
Columbia Gas	1,715	148	**8.6%**
Eversource	1,194	49	**4.1%**
National Grid	500	15	**3%**[24]

[24] We were not able to confirm any of these National Grid SEIs because the addresses were not shared with us.

Some possible reasons for this might be:

- The limited territory surveyed this season didn't include areas as prone to SEIs (i.e. older pipes, or higher pressure, or other characteristics that might make pipes more prone to developing larger leaks).
- Gas company personnel or subcontractors were not yet enacting the new leak extent protocol consistently.
- The only leaks measured by the gas companies were unrepaired Grade 3 leaks from the previous year's survey. It could be that some portion of the SEIs that were not found by the gas company personnel were new leaks.
- The leaks in the Large Volume Leak Study may not have been representative and therefore the leak extent threshold may be set too high to capture 7% of leaks in MA.

Searching for Missed SEIs

During the 2017 Large Volume Leak study, Gas Safety,Inc., surveyed several hundred miles of road with a Picarro cavity ring down spectrometer (CRDS) natural gas analyzer to identify likely SEIs. The survey found many likely SEIs.

In December 2018, Gas Safety Inc. again surveyed 200 miles of roads with the Picarro CRDS in municipalities that Eversource had already surveyed for SEIs. We checked the results against the Eversource-identified SEIs.[25]

A Picarro CRDS Natural Gas Analyzer

The Picarro CRDS installed a the car

As the car is driven, a sensor detects parts per million of methane and records the amounts found together with GPS coordinates. This CRDS is similar to the CRDS that EDF uses in its mobile surveys.

Gas leaks in Lexington, MA

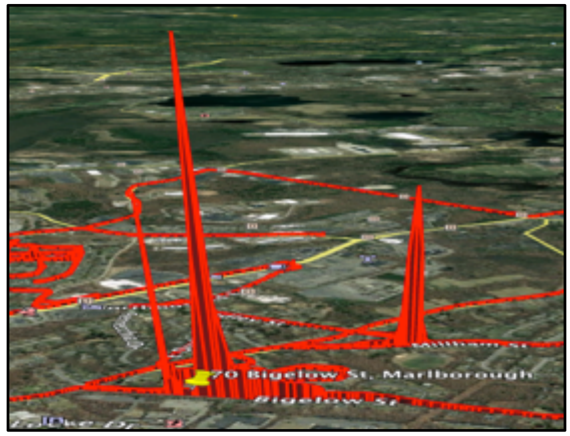
The Picarro data can be visualized in Google Earth maps. The red lines shows where the car drove; the peaks show where methane was found.

[25] We selected Eversource territory because by late 2018 National Grid was occupied with their lockout and Columbia Gas was occupied with the post Merrimack Valley gas system reconstruction effort.

The CRDS Detected Already Identified SEIs

On the survey route, there were 15 leaks that had already been identified by Eversource, and the CRDS detected 14 of these. It's possible that wind interfered with the detection of that 15th leak.

This image shows Belknap Road at Grove Street, Framingham, MA. Orange pin shows an Eversource identified SEI which lines up perfectly with a CRDS-sensed methane peak.



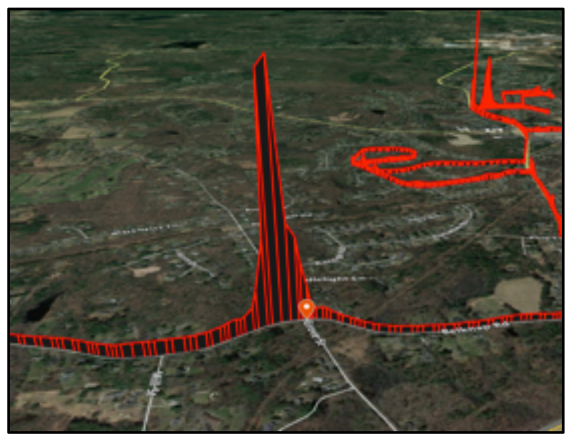
A known leak aligns with CRDS mobile survey data

CRDS Found New Additional SEIs

We studied the CRDS data and identified the top five likely SEIs. Gas Safety Inc. then performed subsurface leak extent surveys of these five potential SEIs.

Three of the five leaks were over 2,000 square feet and thus verified to be SEIs. One leak was too small to be an SEI and one leak appeared to have been recently repaired.

We conclude that the mobile CRDS survey is effective at quickly surveying large sections of road to identify likely SEIs.s



A potential SEI identified by CRDS mobile survey

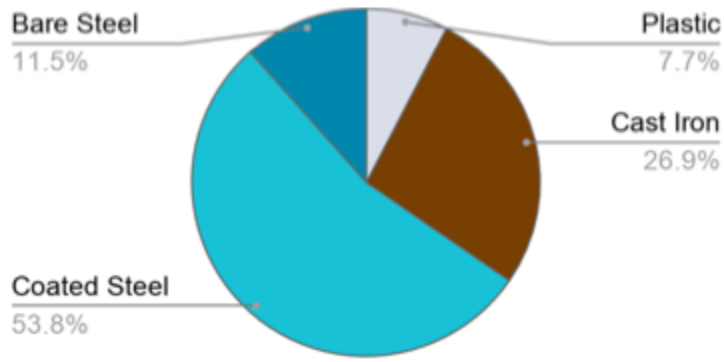
What Conditions Foster SEIs?

Our hope is that as we learn about SEIs in terms of their tendency to appear on different types of pipe materials or different amounts of pipe pressure, we might be able to refine the leak extent method to help the gas companies prioritize the areas most likely to have SEIs.

Of the 26 Eversource-identified and HEET-verified SEIs, we had information about the pipe material on 24 of these. We compared the frequency of the materials of these verified SEIs to the frequency of the totals materials of the Eversource territory.

Frequency of HEET Eversource Verified SEIs by Pipe Material

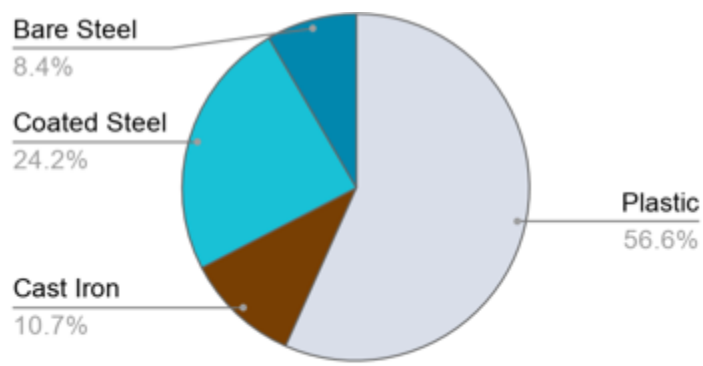
Coated steel and cast iron pipes appear to be more likely to develop SEIs, especially when compared to the material distribution of the Eversource territory below. More data is needed to confirm this tendency.



2018 SEI Pilot Year, 24 SEIs, Eversource territory

Distribution of Pipe Material Across Overall Eversource Territory

While there were hardly any SEI leaks found on plastic pipes during the pilot year, Eversource territory as a whole has over 50% plastic pipes. This difference suggests that plastic pipes are less likely to develop SEIs.

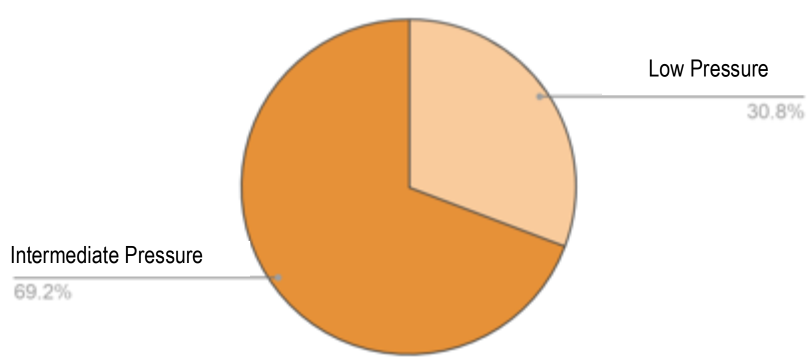


2017 Eversource Gas System Enhancement Plan, Pipe Materials for All of Eversource Territory (Source: D.P.U.17-GSEP-06)

SEIs by Pressure

We examined the distribution of the 26 SEIs by pipe pressure.

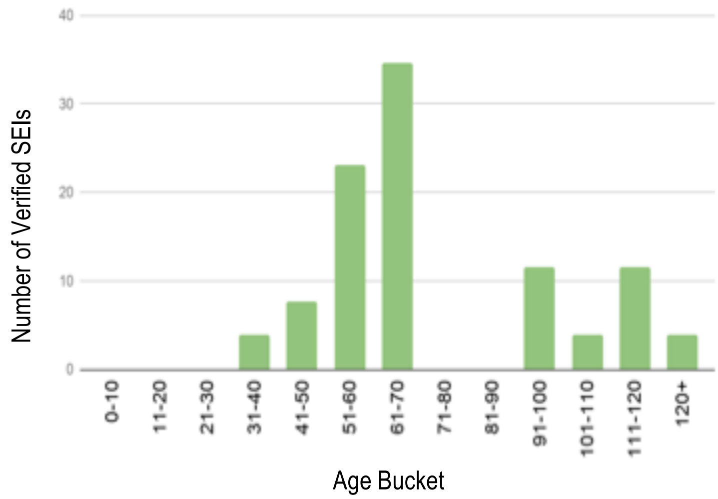
More SEIs occured on intermediate pressure pipes than on low pressure. We did not have information on pipe pressure across the entire Eversource territory to use as a reference and give this result more meaning.



2018 SEI Pilot Year, 26 SEIs, Eversource territory

SEIs by Age of Pipe

We examined the distribution of the 26 SEIs by the age of the pipe installation. We did not have information on ages of pipes across the entire Eversource territory to compare this with. Both median and modal age was 63, and the average was 73. We suggest that the gap in the 71-91 years old range is possibly due to no new pipes being installed because of World War II, and the spike around 60 years old is possibly due to a building boom leading to an increase in the number of pipes being installed at that time.



With more precise pressure data about the Eversource territory as a whole, we could look at this more deeply.

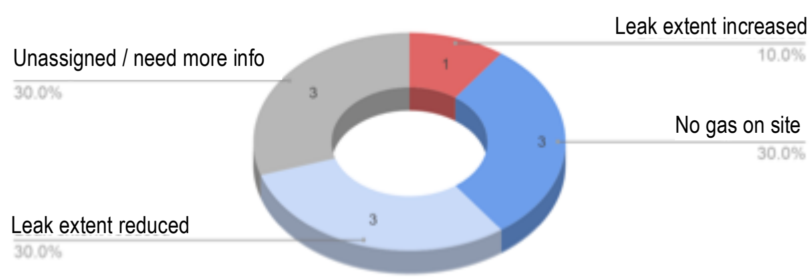
SEIs by Pipe Diameter

We had no pipe diameter data for the 26 SEIs so we could not do this analysis.

More information sharing and faster responses from all the gas companies would help enable HEET to analyze the results more thoroughly. More data will allow for further refinement of the leak extent protocol, ensuring it is a viable and low cost path to emissions reduction for MA.

Success Rate of Leak Repairs

Of the 62 leaks shared with us, 19 leaks were reported repaired by the utilities. To allow all residual gas to leave the soil in the area, HEET returned to 12 of these leaks at least a month after repair[26] to check for the presence of gas. If there was any, we recorded if the leak extent was smaller, the same, or larger. (We did not consider methane readings found in a sewer as part of a leak extent (since the readings could potentially derive in part from decomposition rather than natural gas.)



[26] We weren't able to measure some of the leak repairs because we couldn't confirm repair completion and/or timing. Of the 12 evaluated, two were discarded due to missing information or possible non pipeline sources of methane.

The distribution of leak repair results mirrored results from last year's 2017 Large Volume Leak Study. Both times, only 30% of the repairs seem to be successful enough that there was no gas at the site. The data set is much too small to be conclusive, but it is a concerning trend.

The repair crews are careful and effective and we do not doubt that they repaired a leak at the leak site. However, leaks tends to cluster since the gas pipes for neighborhoods tend to be laid at the same time and from the same material, thus becoming leakprone at the same time. It is likely that some SEIs are made up of more than one hole in one pipe under the ground. Thus some of the potential reasons for gas existing at the site over a month post repair are:

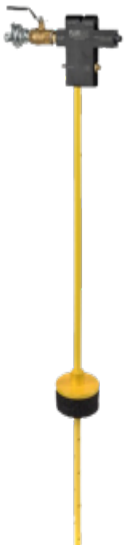
- The repair crew repaired one hole in one pipe, and did not repair all holes in all pipes within the leak extent.
- The loosened dirt from the repair created a pathway for gas from a different but nearby leak to exit the ground.
- The repair jarred the aging pipe and caused further damage.

According to the gas companies' *Report to the Legislature* 2017[27] the cost of repairing all 17,810 leaks left in the state will be over $70 million. This means that learning how to increase the success rate of leak repair will be money well spent for both gas companies and customers.The least expensive time to repair a leak is the first time.

[27] Report to the Legislature on the Prevalence of Natural Gas Leaks in the Natural Gas System, 2018, D.P.U. 17-GLR-01

Promising Technologies

Learning More about SEIs With The FluxBar



The FluxBar was invented during the pilot study through a collaboration of HEET, Eversource, Columbia Gas, Gas Safety Inc, Boston University Nathan Phillips and Millibar. The FluxBar is a utility-familiar tool that was redesigned to allow gas companies to compare the emissions of leaks in order to identify which were the largest just prior to repair. The FluxBar is not intended as a tool to identify SEIs as it requires a truck compressor and therefore can only be used by the leak repair crew just prior to repair. This repair crew use of the FluxBar on a significant number of SEIs could help result in data about SEIs (such as the pipe material, age or pressure that are correlated with SEIs), making identifying SEIs more efficient. It could also provide much needed directly measured flux data.

The FluxBar is inserted through a hole drilled through the road over the leak. It is connected to a truck compressor that blows air through the horizontal top of the tool. The flow of air (thanks to the Venturi effect) vacuums air up the standpipe at a steady three cubic feet per minute. A combustible gas indicator connected to the FluxBar head can then measure the percent of gas in that steady air flow from under the road surface, right over the leak. The gas readings over time are noted to calculate the steady state plateau. The result allows a consistent comparison of directly measured flow rate from one leak to the next.

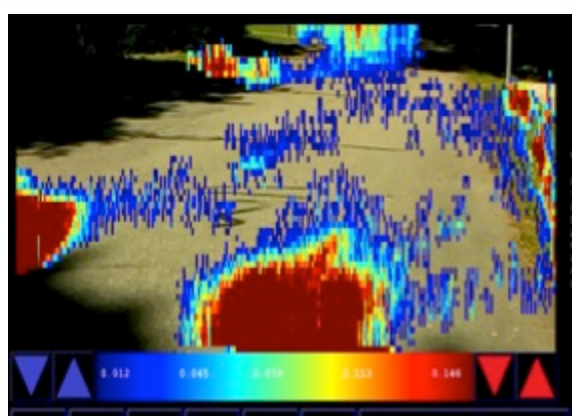
In 2017, the Large Volume Leak study found a correlation between FluxBar results and emissions, as measured using the chamber method (a peer-reviewed method). Since emissions are also correlated with leak extent, there should be a relationship between leak extent and FluxBar results. Later in 2017, Columbia Gas captured a different leak extent through holes that were drilled through the road surface, instead of through “barholes” made using a handheld tool on the side of the road. We analyzed this second data set and found that while the distribution of the FluxBar steady state readings were similar to our initial data set, there was no correlation between the drill hole leak extent and the Fluxbar steady state. Then, in 2018, we got no new FluxBar data and cannot report any advances in understanding. In 2019 we hope to get more data to ensure that the FluxBar has an appropriate protocol and that we understand the relationship between drillhole, barhole, and above-surface leak extent measures and the FluxBar steady state measure. The study may include some or all of the following:

- Explore the relationship further between FluxBar measurements, chamber method measurements and subsurface leak extent measurements
- Test the zone of influence of FluxBar in different soils under different conditions
- Explore drill hole leak extent protocol consistency and explore questions about dynamic changes in initial hour measurements

Seeing Gas With The MSS Spectographic Camera

Through a MassCEC Catalyst Grant, HEET was given a Multisensor Scientific Camera. The camera visualizes methane and ethane through spectroscopy. We intended to use it to quantify emissions during the 2018 work season to see if it could improve leak repair success rate leak repairs and other tasks.

Initial field testing identified improvements needed in the beta version of the camera. In the 2019 work season, we will field test an updated version.



HEET's 2019 Goals

During 2019, HEET will continue to adhere to the Shared Action Plan, providing independent verification, analysis and reassessment.

With the regulation enacted, the Commonwealth has a plan to reduce its emissions by the equivalent of 4% of its greenhouse gas emission inventory within 4 years: so long as the gas companies only use the leak extent identification method, not the ineffective barhole method.

While it is possible to get these gains faster, the agreed to plan is as follows. The utilities have surveyed a third of the known Grade 3's in their territory in the 2018 Field Test, and will complete the remaining two thirds over the next two years. They are obligated to repair all identified SEIs within two years of discovery, so the entire system's current SEIs should be repaired within four years. New SEIs will be addressed in an ongoing manner, maintaining the emissions reduction.

HEET's goals include the following:

- Collect data on 100+ SEIs (pre- and post-repair leak extents).
- Ensure SEIs are not missed by the gas companies by performing a CRDS mobile survey on some areas already surveyed by the gas companies.
- Collect FluxBar data and improve the FluxBar protocol and test outcomes.
- Compare concurrent subsurface & above-ground data gathered during same-day visits.
- Collect more above-ground extent measurements of previously measured and unrepaired leaks, and analyze for consistency over time.
- Field Test MultiSensor Scientific camera.
- Perform research on behavior of residual gas.
- Look for ways to refine leak extent protocol.
- Disseminate the findings nationally so other states and gas companies can cut their emissions in half for the least cost and disruption.

Appendices

Appendix 1 - Definitions and Acronyms

- **Barhole** : a hole made into the ground using a bangbar, into which a CGI is typically inserted to measure gas.
- **Barhole method :** The barhole method involves making a hole in the ground using a handheld bangbar and inserting a combustible gas indicator in the resulting barhole. Barhole reads are performed in different locations around a gas leak. Any leak with a barhole (sub-surface reading over 50% gas was considered an SEI leak.
- **Chamber method** : the scientific gold standard for leak emission measurement, using chambers of varying sizes to capture flux, or flow of methane over time, across the surface area of a leak.
- **Combustible Gas Indicator ("CGI")** : a device used to detect flammable gas concentrations. The CGI is equipped with a 2-3 foot probe rod and hose assembly normally attached to an electronic unit that draws in an air sample using a built-in pump or by squeezing a rubber bulb.
- **Department of Public Utilities (DPU**) : In Massachusetts, the government agency charged with regulating the utility companies, with leadership appointed by the secretary of energy and environmental affairs.
- **EDF** - Environmental Defense Fund
- **Flame Ionization Unit ("FIU")** : a device used to detect flammable gas concentrations. The FIU is comprised of a 2-3 foot probe rod and hose assembly normally attached to an electronic unit that draws in an air sample using a built-in pump which will provide a direct readout of gas in air concentrations.
- **Flux** : the rate of flow of a gas, such as methane, per unit area over time.
- **FluxBar** : a device used just prior to repair to capture and compare leak emissions
- **Grade 3 Gas Leak** : A leak classified as non-hazardous by utility workers at the time of detection and expected to remain non-hazardous..
- **Grade 3 SEI, or SEI** : a leak of Significant Environmental Impact. A grade 3 (non-hazardous) leak that emits enough gas to be in the top 10% of gas leaks in terms of emissions
- **GSEP** - Gas System Enhancement Plan is the 20 to 25 year plan of the gas companies to replace all the leakprone pipes under the ground in Massachusetts.
- **Large Volume Leaks (LVLs**) : large leaks in the distribution system, defined by a threshold leak extent measure of 2000 sq ft or more. Research so far indicates this is approximately 10% of all leaks, though further data may adjust the threshold. Also known as a leak of significant environmental impact (SEI).
- **Leak Extent** : surface area in which a gas company has detected positive CGI or FIU readings surrounded by an area of negative CGI or FIU readings.
- **Leakage Perimeter** : the process of creating a boundary of the leak extent. The leakage perimeter consists of subsurface inspection locations that can be monitored for changes in CGI readings. The leakage perimeter is established when 0% gas is obtained in two consecutive subsurface inspections (e.g., barholes, available openings).
- **Natural Gas** (or just 'gas' in this report) : a fossil fuel that, when processed and distributed as 'pipe quality', is roughly 97% methane.
- **SEI** - Significant Environmental Impact leak prioritized for repair in 2016 law passed in MA.
- **Subsurface Gas Detection** is the sampling of the subsurface atmosphere through barholes and/or available openings (e.g. cracks in the pavement, subsurface structures such as manhole covers, valve boxes, catch basins, etc.) with a combustible gas indicator (i.e. placing the indicator at least 6 inches into the barhole and/or available openings)
- **Super emitting leak** : the top 7% of any population of leaks, emitting half of all the total gas by volume.
- **Surface Gas Detection** is a continuous sampling of the atmosphere at or near ground level for buried gas facilities and adjacent to above-ground gas facilities using an instrument approved for this type of survey on the appropriate sensitivity scale

Appendix 2 - Proposed Standardized Survey Method to Measure Leak Footprint

This protocol was created by all MA gas companies in Spring of 2018 in order to enact the leak extent method, adhering to the Shared Action Plan. (Note: definitions not included)

Suggested Method to Establish Leak Extent using CGI and Barhole

1. Establish the initial leakage perimeter of the suspected leakage area using a surface gas detection survey in accordance with appropriate Company standards or procedures.
2. If a gas indication is found, continue to establish the leakage perimeter by using the subsurface gas detection survey in accordance with appropriate Company standards or procedures.
3. Leak Extent is measured by multiplying the greatest width (perpendicular to the pipe) by the longest length (parallel to the pipe) to get total surface area. The width and length is established based on zero to zero readings.

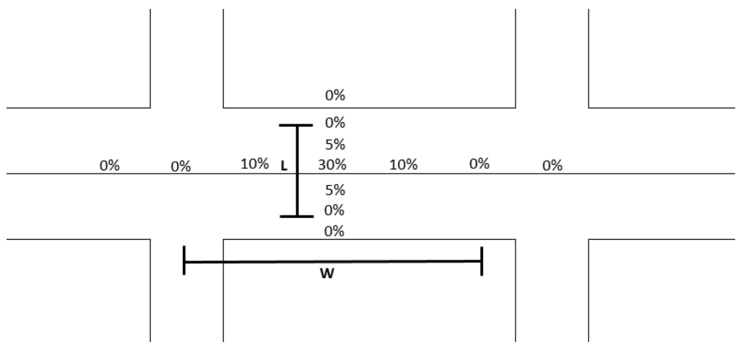


Figure 1 Capturing Leak Extent

Appendix 3 - Shared Action Plan

This is the Shared Action Plan agreed to by Columbia Gas, Eversource Gas, National Grid MA, and HEET, and supported by Mothers Out Front and the Gas Leaks Allies. It was sent in to the Massachusetts Department of Public Utilities with a request that it be enacted statewide.

Identification

- Grade 3 LVL determined using leak extent as sole proxy method, at least for the first year.
- Leak footprint evaluated with a consistent and defined method across utilities (i.e. either with CGIs/FIs, barhole or drill holes). Method to be decided by utilities.
- Leaks over 10 years old not prioritized for repair unless it is LVL.

Repair

- Leaks > 10,000 sq. ft. fixed within 12 months of determination by leak repair or main replacement.
- When 2,000 to 10,000 square foot leaks are discovered and verified, we will endeavor to repair them within two years with the exception of inaccessible or challenging leaks which shall be repaired when access can be gained. If any 2,000 to 10,000 square feet leaks are on pipe that will be replaced through GSEP within five years, we will endeavor to eliminate the leak within three years.
- An LDC (a gas utility) may choose to cap its environmentally significant leak repairs in any one calendar year at 7% of its total Grade 3 leak inventory as indicated in the previous year's final quarterly leak report on file with the Department of Public Utilities.

Verification

- For first year, at minimum, a statistically significant randomized sample of Grade 3 LVL leak repairs are FluxBarred prior to repair. Method of verification to be reassessed annually. See below.

Reporting (Department of Public Utilities)

- On GSEP reports, the number of known LVL leaks on each pipe segment.
- On Annual Service Quality reports the leak address, leak footprint, date leak was reported, LVL classification date and repair date.

Reassessment

- Methods and results reassessed and adjusted annually for at least five years by a panel made up of utilities, HEET research team, and a mutually agreed-upon independent third party to provide recommendations to DPU.

Collaboration

- Initial Year Collaboration to support the transition. Leak addresses, reports and repair dates of all high emitters shared with HEET so we can randomly survey 100 leaks to ensure consistency across utilities. FluxBar data forms shared with HEET for the first year so we can provide any needed assistance. Fluxbar results will allow for apples-to-apples comparison between leaks, progress to be benchmarked and further learning to allow for more efficient allocation of resources.

Appendix 4 - Applied Economics Calculation Additional Information

Calculating the cost of repairs per leak.

Measure		Source
Annual MA total gas consumption (therms)	4,660,931,310	EIA, MA total annual natural gas consumption, 2017 http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_SMA_a.htm
Annual share lost in transmission	2.7%	McKain K, et al http://www.pnas.org/content/112/7/1941.full
Annual total gas lost in transmission (therms)	125,845,145	(Share X consumption)
Annual share lost in distribution system	30.0%	Senior authors on McKain K. et al paper (Harvard Prof. Wofsy & B.U. Prof. Phillips) assume between 30% and 50%; personal communication
Est. Annual gas lost in distribution (therms)	37,753,544	(Transmission loss X share lost)
Gas cost (per therm)	$0.30	Marginal cost of gas/ million btu: EIA Henry Hub Gas Spot Price, 2017 average ; EIA conversion factors: https://www.eia.gov/tools/faqs/faq.php?id=45&t=8
Est. Annual total cost of gas lost in distribution	$11,272,579	(Gas cost X gas lost)
MA total number of reported leaks	17,810	DPU report to legislature December 2017 https://eeaonline.eea.state.ma.us/EEA/FileService/FileService.Api/file/FileRoom/9171108
MA utility reported estimates of leak repair	$70,085,286	DPU report to legislature December 2017: https://eeaonline.eea.state.ma.us/EEA/FileService/FileService.Api/file/FileRoom/9171108
Cost of repair/leak (calculated)	**$3,935**	(Total cost / leaks)

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GAS LEAKS ALLIES: Arise for Social Justice, Boston Climate Action Network, Brookline GreenSpace Alliance, Clean Water Action, Climate Action Now–Western Mass., Conservation Law Foundation, Consumers for Sensible Energy, Emerald Necklace Conservancy, Friends of the Public Garden, Garden Club of the Back Bay, Gas Safety Inc., Green Committee, Prof. Nathan Phillips of Boston University, Neighborhood Association of Back Bay, Green Justice Coalition, HEET, Mass. Health Professionals for Clean Energy, Mothers Out Front, Salem Alliance for the Environment, Sierra Club MA, Springfield Climate Justice Coalition, Toxics Action Network, Union of Concerned Scientists, 2degreesatgreenneighbors.earth, 350MA