THE MYRIAD BENEFITS *of* METHANE MAPPING:

How Innovative Technology and Big Data Analytics are Dramatically Revolutionizing Natural Gas Distribution Repair and Modernization

ENVIRONMENTAL COUNCIL OF THE STATES
FALL MEETING
ALUMNI-LED WORKSHOP
SEATTLE, WASHINGTON

MARY GADE
GADE ENVIRONMENTAL GROUP LLC/EDF

TOPICS

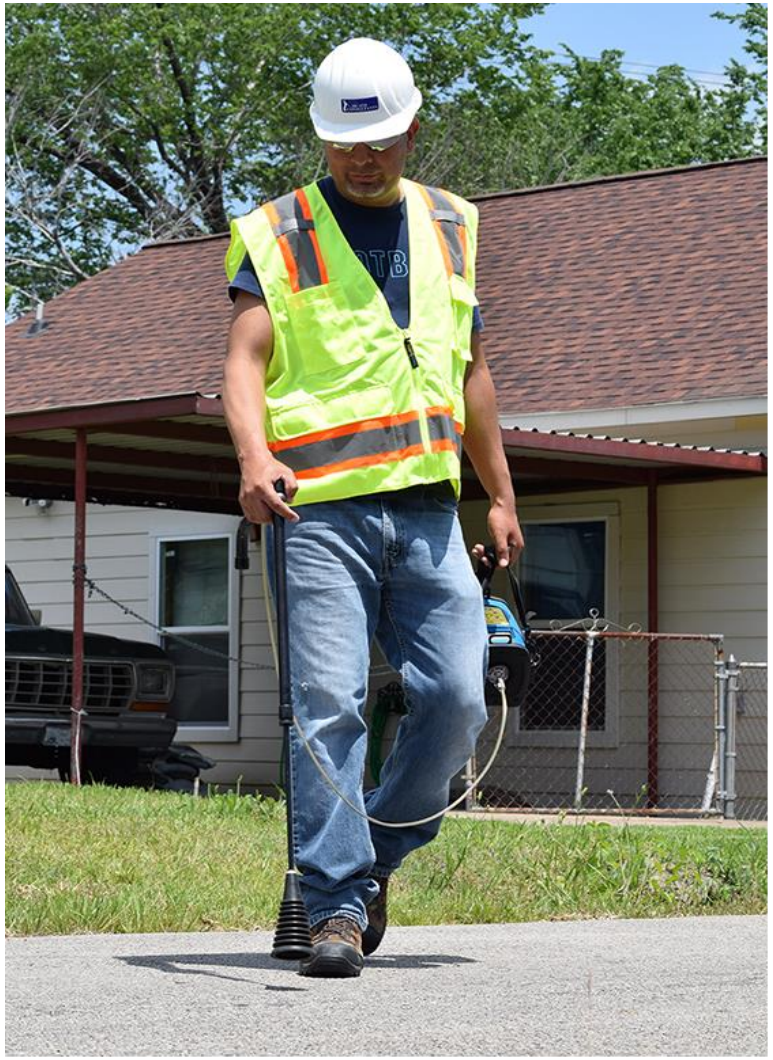
Facts About

- Methane and local natural gas distribution utilities
- Advances in leak detection, quantification and prioritization of repairs
- Experience and outcomes with ALD
- Benefits and policy recommendations

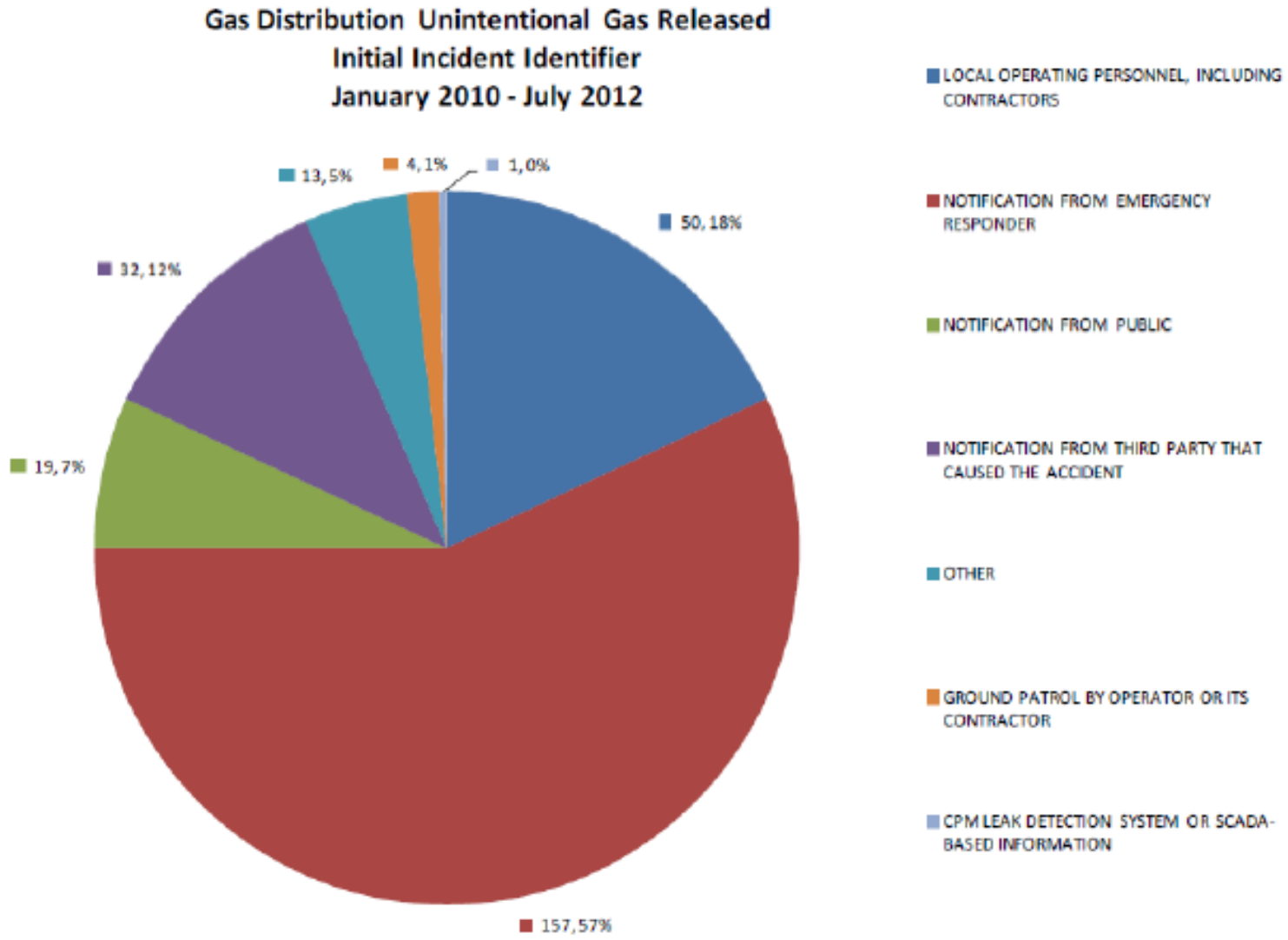
Leak Detection Advances

How Utilities Found Leaks Before

- The “state of the art” is handheld methane detectors, DIMP, surveys or responding to odor calls.
- The vast majority of leaks are found by first responders or customers smelling gas.
- Is there a better way? TBD



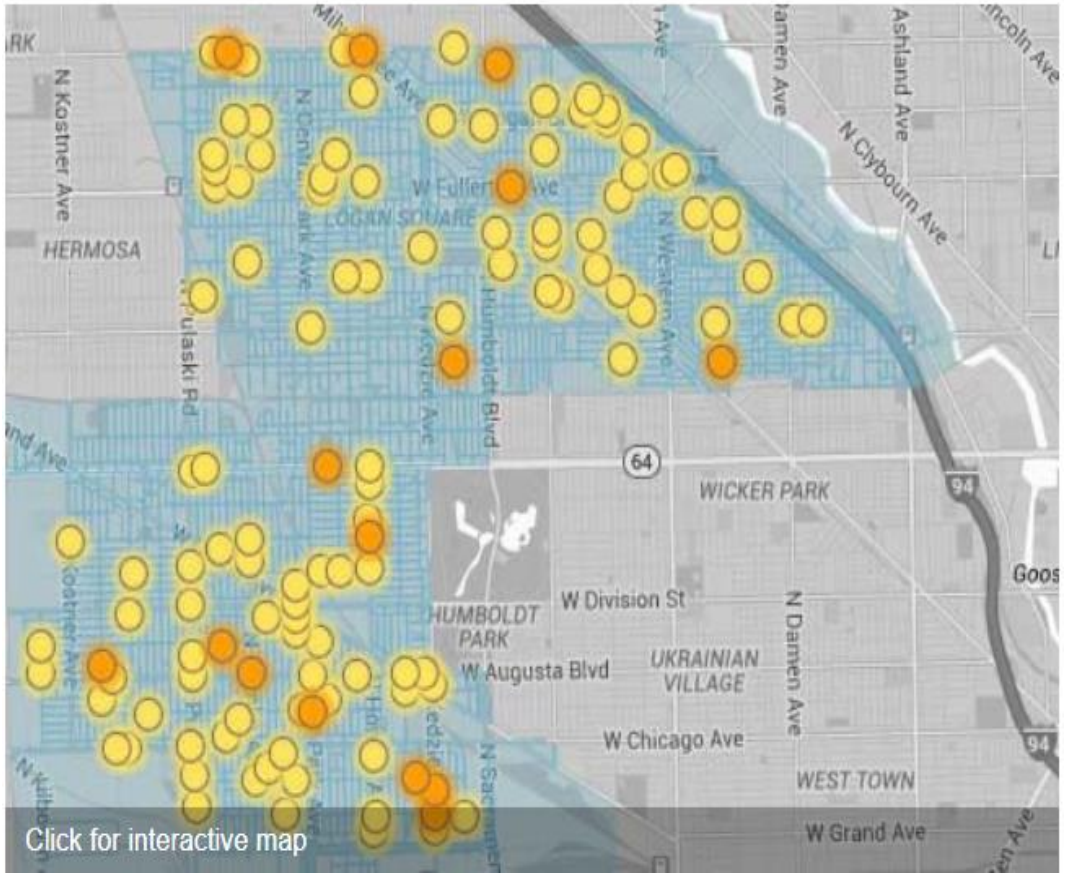
2012: First Responders Find Most Leaks



Leak Detection Advances

EDF/Google Leak Mapping Project

What began as an EDF science and methane public awareness campaign in 2014 is shaping gas utility business practices in 2019.



ALD+ = Sensors and data analytics

- High sensitivity, mobile Mounted methane detectors
- Available to utilities via Picarro, Heath/LGR
- Faster, more sensitive than optical imaging or hand held flame ionization
- Can quantify leak flow volume

Validation of false positives and leak size estimation

Validation of false positives & leak size estimation

Weller *et al.*

EnvSci&Tech 2018

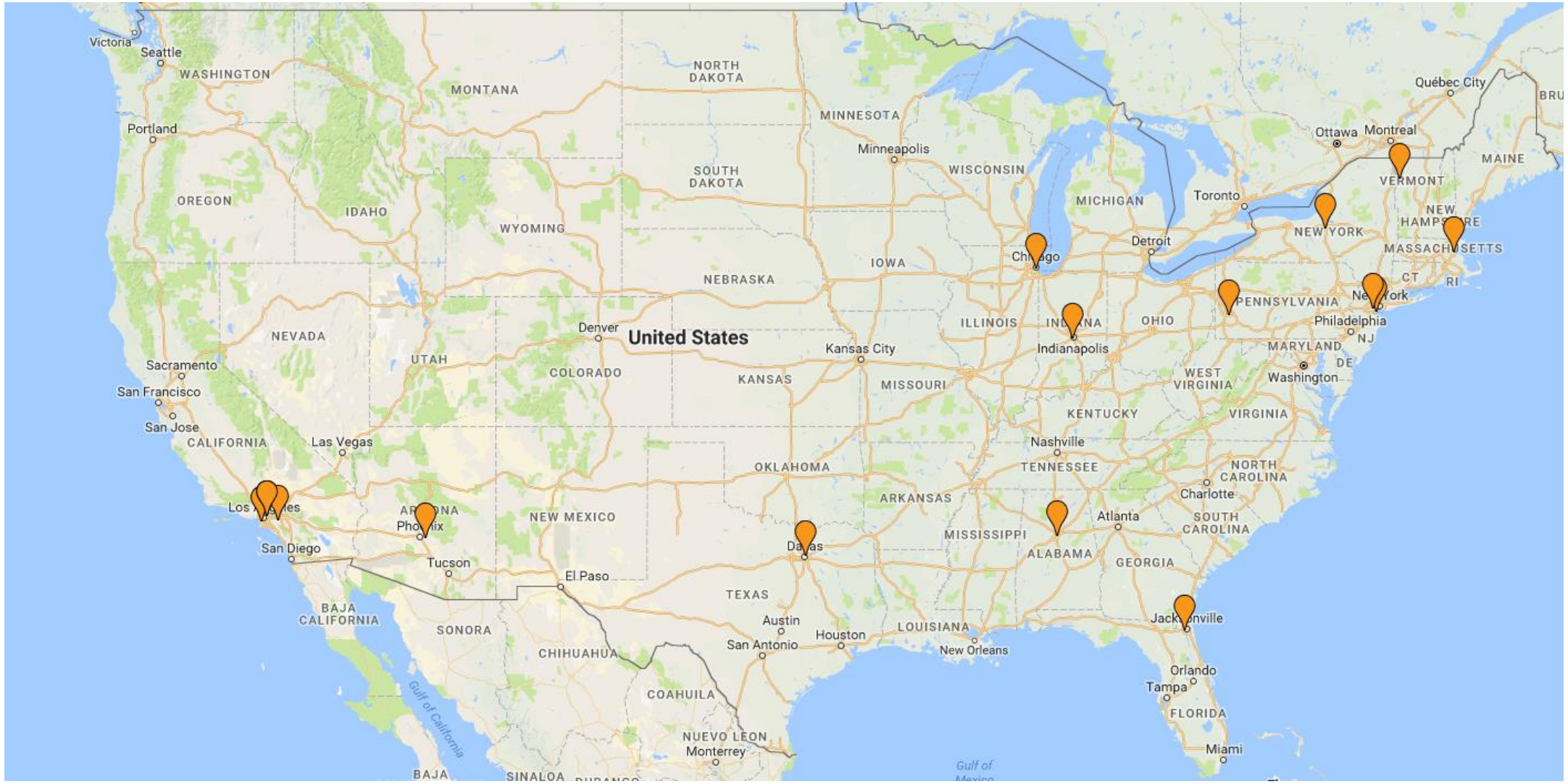
Vehicle-Based Methane Surveys for Finding Natural Gas Leaks and Estimating Their Size: Validation and Uncertainty

ALD finds leaks that other methods miss: PG&E, Centerpoint Energy, CSU analysis finds 3 to 5 times more leaks than standard utility survey methods

Today's Best Practice: Emissions Quantification & Leak Density Estimation Analytics

- Mobile mounted high sensitivity leak detectors find and quantify leaks
- Using methane data, analytics estimate leak density and measure emissions of pipe segments rather than identifying individual leaks
- Pipe segments with highest leak density are identified for repair or capital replacement
- Emissions, costs and safety risk are reduced

EDF Mapped Cities



ALD – Leak Abatement Optimization

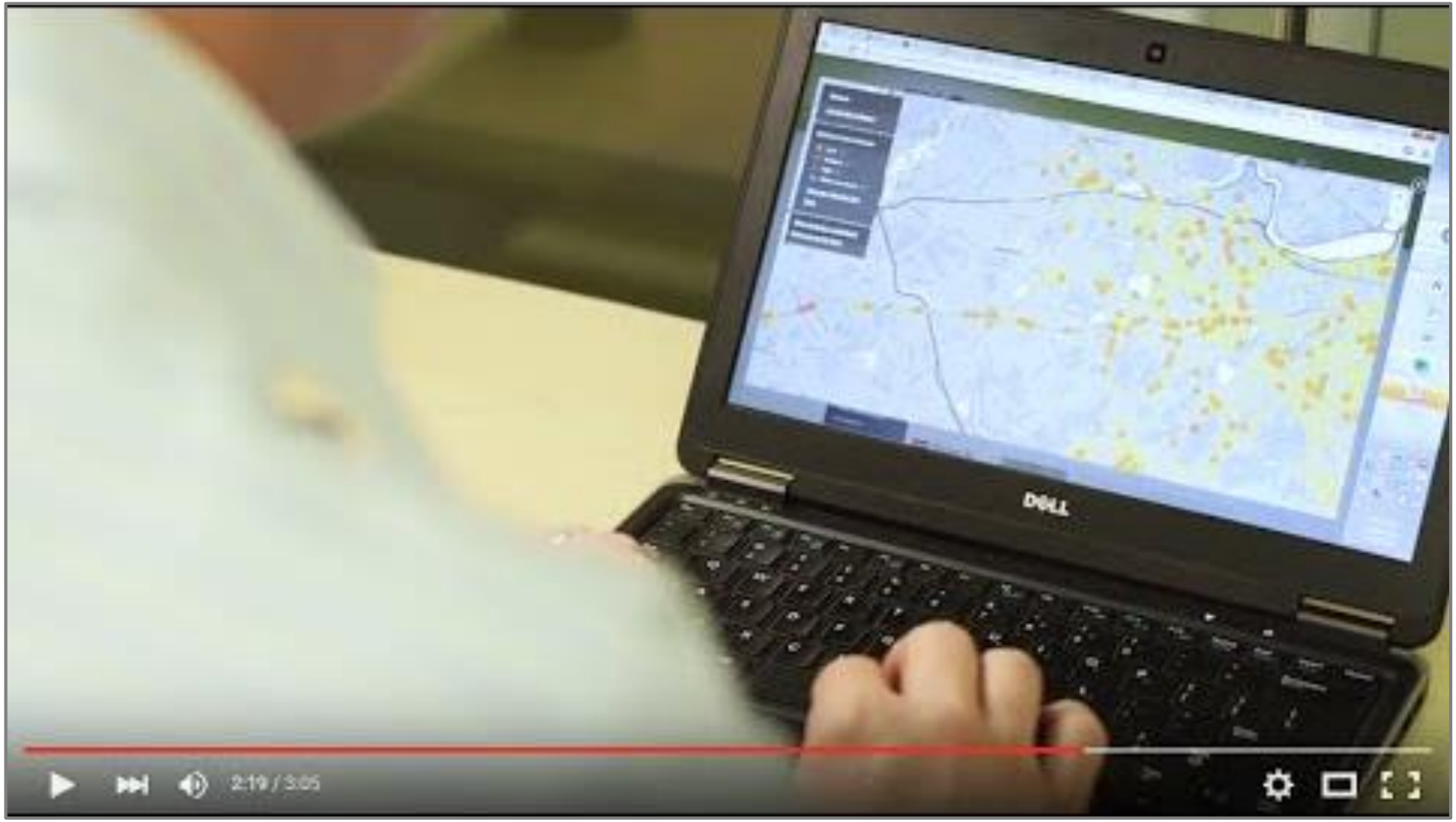
Emissions Quantification Data								
Segment ID	Segment Rank	Emissions Rate (SCFH)	Emissions range (confidence)	Segment Length (ft)	Emissions Factor (SCFH/ft)	Estimated # of leaks	# Leaks/ft	Emissions Rate / Leak
4	1	7.0	4 – 16 SCFH (90%)	1579	0.0044	5	0.0032	1.14
1	2	5.1	2 – 8 SCFH (90%)	3090	0.0017	5	0.0016	1.0
3	3	2.4	1 – 4 SCFH (90%)	2535	0.001	4	0.0016	0.6
2	4	1.5	0.5 – 2 SCFH (60%)	2514	0.0006	1	0.0004	1.5

Figure 2. EQ report data table and map for pipeline replacement

A proven method to maximize leak reductions per $$

Source: Picarro, Inc.
Surveyor use case

Video



PHMSA LDC 101

- Pipeline and Hazardous Materials Administration (DOT) ensures safe and secure movement of hazardous materials
- Local Gas Distribution Companies must submit annual reports to PHMSA on pipe composition, miles of pipe, leaks found, repaired and backlogs
- Service territories must be surveyed for leaks every 5 years, business districts once every year
- Leaks are determined based on concentrations (ppb)
- Leaks are graded in terms of risk based on concentration and proximity to buildings/populations
- Leaks can be Grade 1 Hazardous, Grade 2 Potentially Hazardous, and Grade 3 Non-Hazardous
- Hazardous leaks must be repaired "promptly"

LDC Infrastructure

Large Number of Methane Leaks from Aging Urban Infrastructure

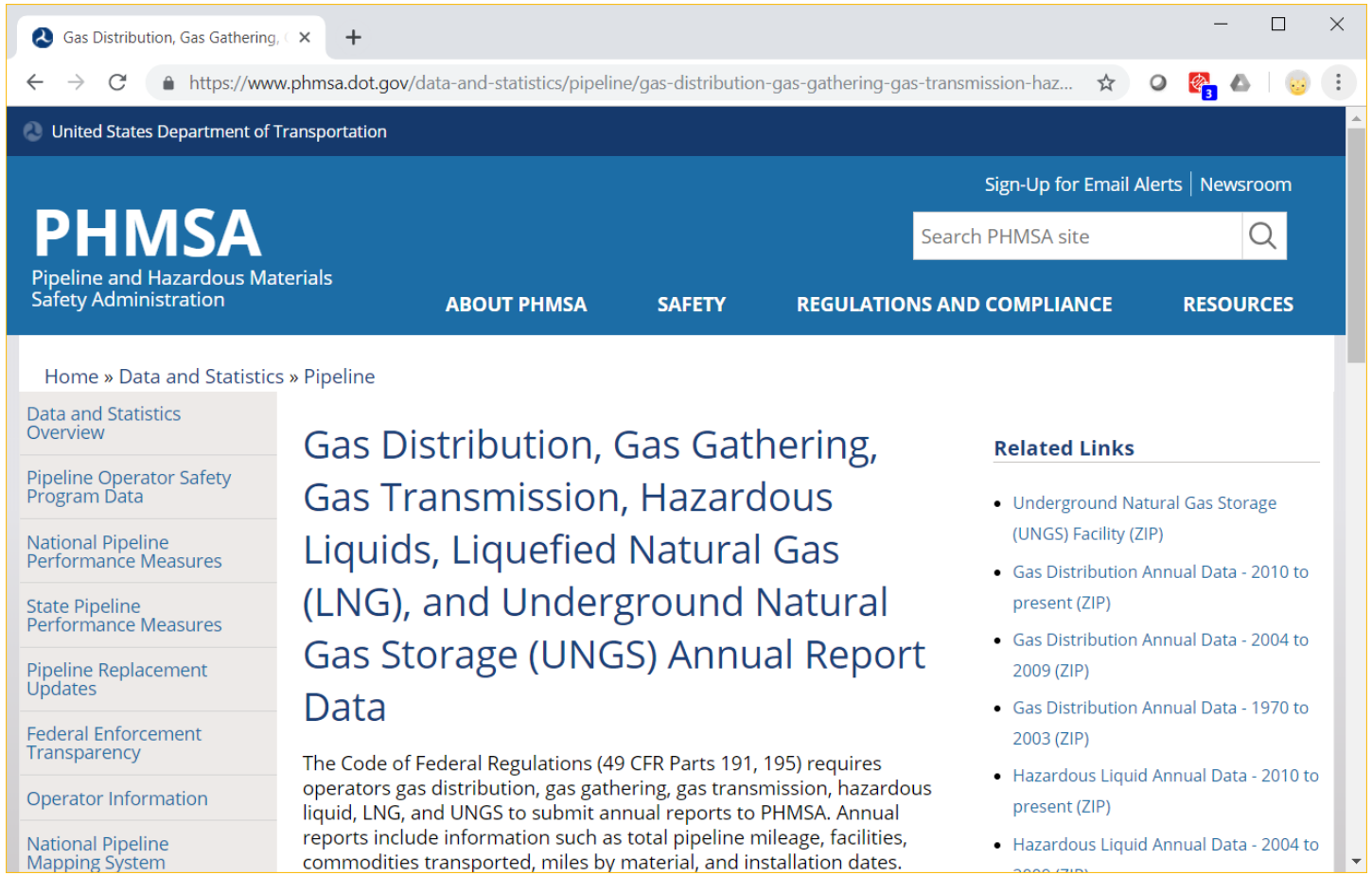
State	Miles of Leak-Prone Pipe	% of U.S. Leak-Prone Pipe
NY	16,442	17%
TX	10,652	11%
PA	10,313	11%
OH	10,282	11%
CA	8,358	9%
NJ	6,368	7%

PHMSA 2016 Data

- New Jersey utilities have more cast iron distribution pipelines than any other state, 3911 miles as of 2019.
- Nationally, **10.6 percent** of the safety incidents occurring on gas distribution mains involved cast iron mains. However, less than **2 percent** of distribution mains are cast iron.

How to Find Out about LDCs in Your State?

Viewing PHMSA Annual Report Data by Pipeline Type and Year

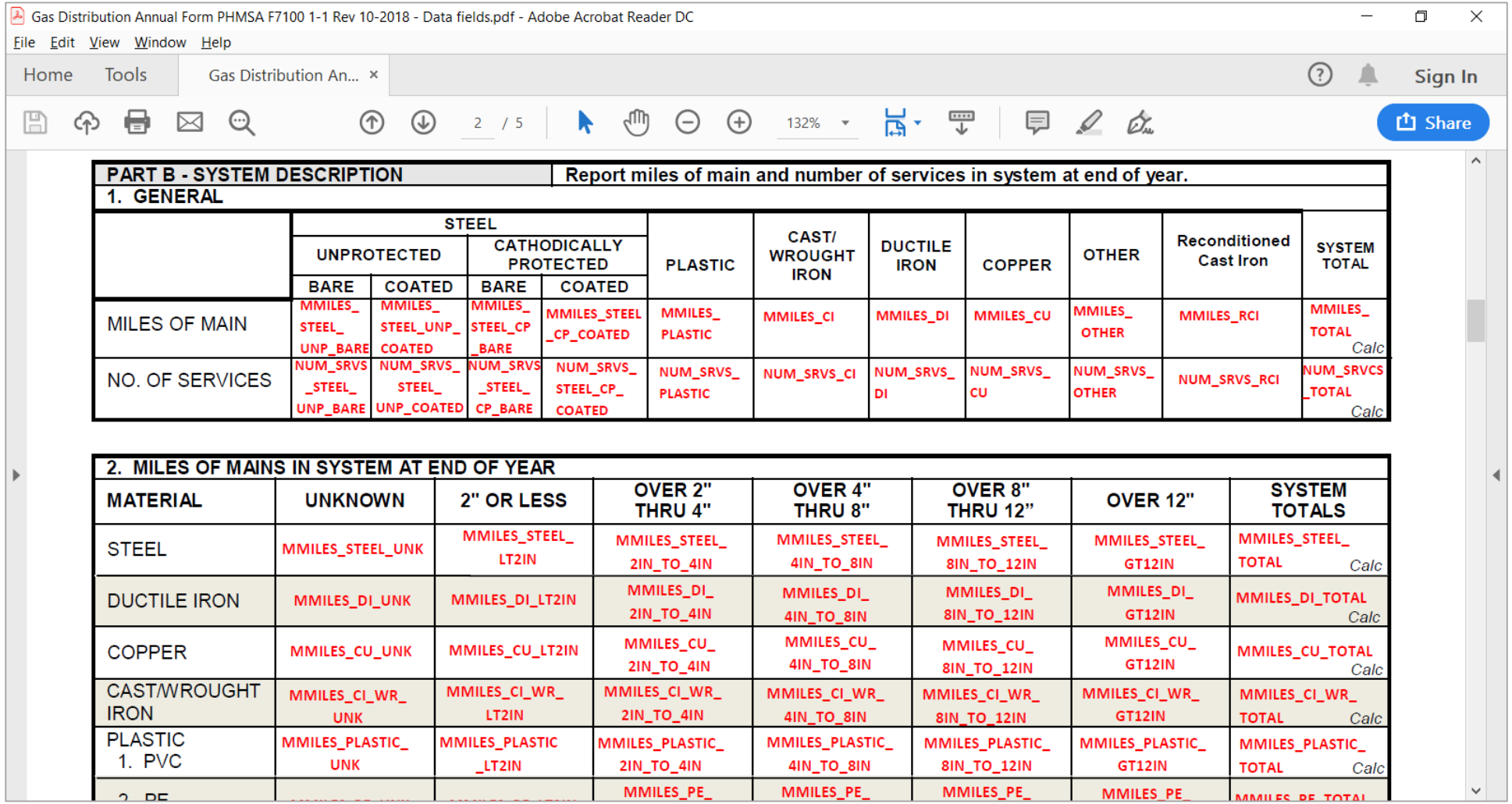


- Select link on the right to download years of data you want.
  - Zipped folder includes PDF of the **Gas Distribution Annual Form PHMSA F7100 1-1**.
  - PDF is filled in with data fields that are used as column headers in the Excel data sheets, so that you can see how each column header is defined in the form.

Resources

- Left: Annual Report Data
- Blank forms and Detailed Instructions: Operator Reports Submitted to PHMSA - Forms and Instructions

Data fields used as column headers in Excel sheets



PART B - SYSTEM DESCRIPTION | Report miles of main and number of services in system at end of year.

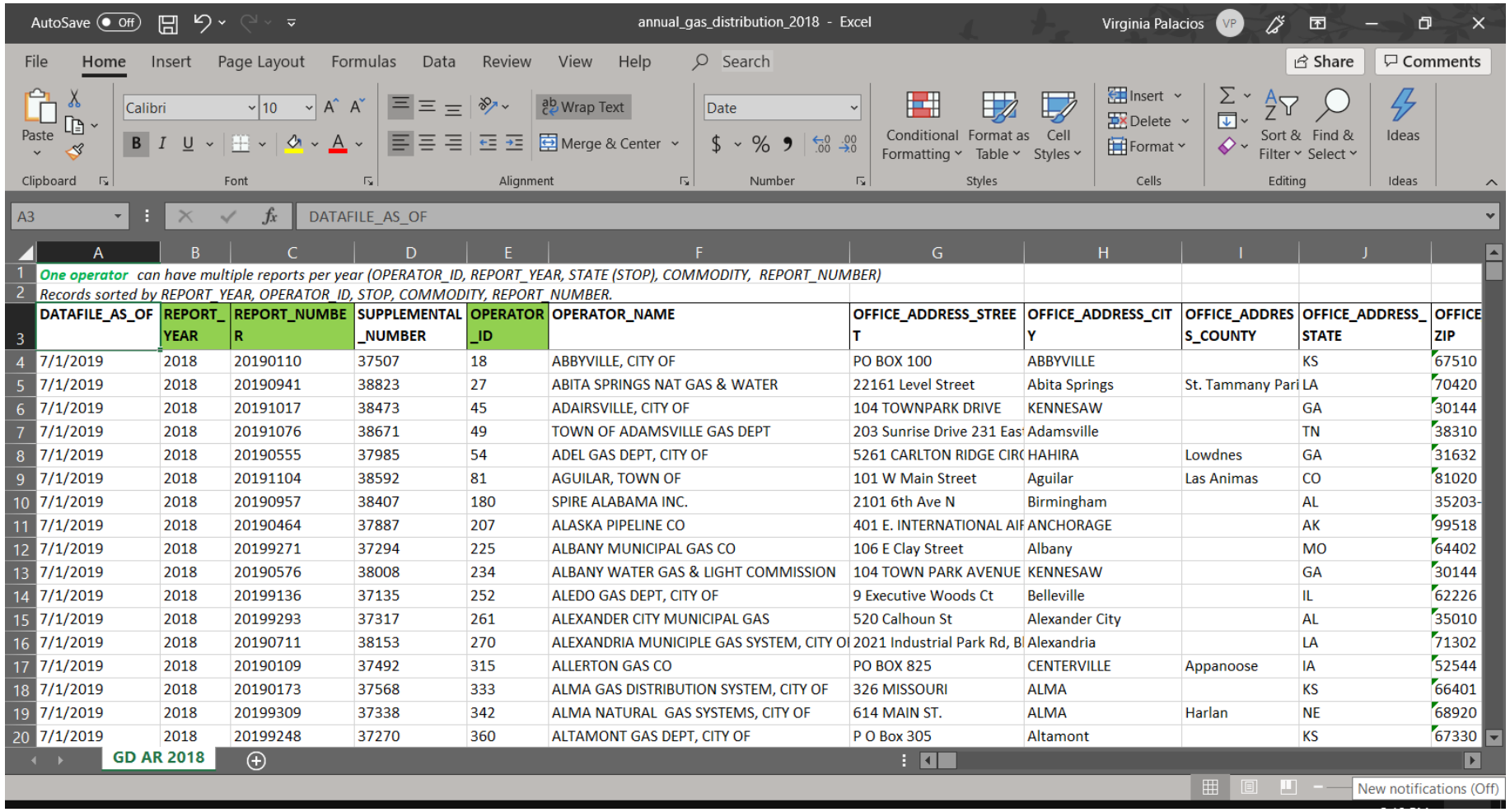
1. GENERAL

	STEEL				PLASTIC	CAST/ WROUGHT IRON	DUCTILE IRON	COPPER	OTHER	Reconditioned Cast Iron	SYSTEM TOTAL
	UNPROTECTED		CATHODICALLY PROTECTED								
	BARE	COATED	BARE	COATED							
MILES OF MAIN	MMILES_ STEEL_ UNP_BARE	MMILES_ STEEL_UNP_ COATED	MMILES_ STEEL_CP _BARE	MMILES_STEEL _CP_COATED	MMILES_ PLASTIC	MMILES_CI	MMILES_DI	MMILES_CU	MMILES_ OTHER	MMILES_RCI	MMILES_ TOTAL Calc
NO. OF SERVICES	NUM_SRVS _STEEL_ UNP_BARE	NUM_SRVS_ STEEL_ UNP_COATED	NUM_SRVS _STEEL_ CP_BARE	NUM_SRVS_ STEEL_CP_ COATED	NUM_SRVS_ PLASTIC	NUM_SRVS_CI	NUM_SRVS_ DI	NUM_SRVS_ CU	NUM_SRVS_ OTHER	NUM_SRVS_RCI	NUM_SRVCS _TOTAL Calc

2. MILES OF MAINS IN SYSTEM AT END OF YEAR

MATERIAL	UNKNOWN	2" OR LESS	OVER 2" THRU 4"	OVER 4" THRU 8"	OVER 8" THRU 12"	OVER 12"	SYSTEM TOTALS
STEEL	MMILES_STEEL_UNK	MMILES_STEEL_ LT2IN	MMILES_STEEL_ 2IN_TO_4IN	MMILES_STEEL_ 4IN_TO_8IN	MMILES_STEEL_ 8IN_TO_12IN	MMILES_STEEL_ GT12IN	MMILES_STEEL_ TOTAL Calc
DUCTILE IRON	MMILES_DI_UNK	MMILES_DI_LT2IN	MMILES_DI_ 2IN_TO_4IN	MMILES_DI_ 4IN_TO_8IN	MMILES_DI_ 8IN_TO_12IN	MMILES_DI_ GT12IN	MMILES_DI_TOTAL Calc
COPPER	MMILES_CU_UNK	MMILES_CU_LT2IN	MMILES_CU_ 2IN_TO_4IN	MMILES_CU_ 4IN_TO_8IN	MMILES_CU_ 8IN_TO_12IN	MMILES_CU_ GT12IN	MMILES_CU_TOTAL Calc
CAST/WROUGHT IRON	MMILES_CI_WR_ UNK	MMILES_CI_WR_ LT2IN	MMILES_CI_WR_ 2IN_TO_4IN	MMILES_CI_WR_ 4IN_TO_8IN	MMILES_CI_WR_ 8IN_TO_12IN	MMILES_CI_WR_ GT12IN	MMILES_CI_WR_ TOTAL Calc
PLASTIC 1. PVC	MMILES_PLASTIC_ UNK	MMILES_PLASTIC _LT2IN	MMILES_PLASTIC_ 2IN_TO_4IN	MMILES_PLASTIC_ 4IN_TO_8IN	MMILES_PLASTIC_ 8IN_TO_12IN	MMILES_PLASTIC_ GT12IN	MMILES_PLASTIC_ TOTAL Calc
2. PE			MMILES_PE_	MMILES_PE_	MMILES_PE_	MMILES_PE_	MMILES_PE_TOTAL

Snapshot of Excel sheet showing 2018 gas distribution annual data



AutoSave Off | annual_gas_distribution_2018 - Excel | Virginia Palacios

File Home Insert Page Layout Formulas Data Review View Help Search | Share | Comments

Paste | Calibri | 10 | Wrap Text | Merge & Center | Date | Conditional Formatting | Format as Table | Cell Styles | Insert | Delete | Format | Sort & Filter | Find & Select | Ideas

Clipboard | Font | Alignment | Number | Styles | Cells | Editing | Ideas

A3 | DATAFILE_AS_OF

One operator *can have multiple reports per year (OPERATOR_ID, REPORT_YEAR, STATE (STOP), COMMODITY, REPORT_NUMBER)*

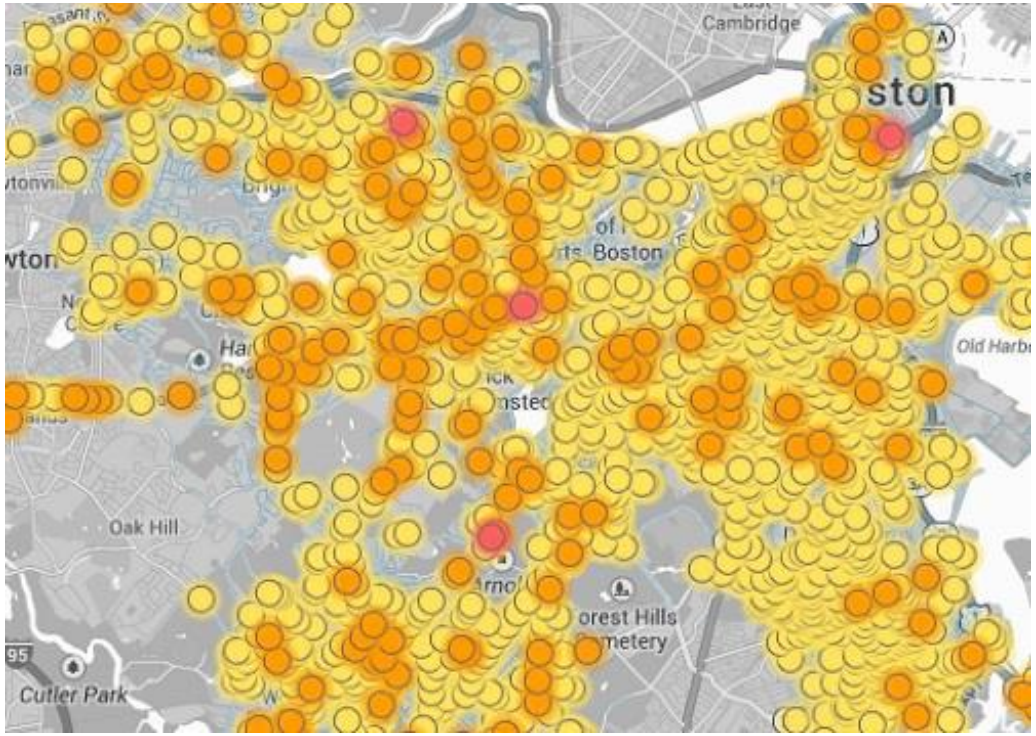
Records sorted by REPORT_YEAR, OPERATOR_ID, STOP, COMMODITY, REPORT_NUMBER.

DATAFILE_AS_OF	REPORT_YEAR	REPORT_NUMBER	SUPPLEMENTAL_NUMBER	OPERATOR_ID	OPERATOR_NAME	OFFICE_ADDRESS_STREET	OFFICE_ADDRESS_CITY	OFFICE_ADDRESS_COUNTY	OFFICE_ADDRESS_STATE	OFFICE ZIP
7/1/2019	2018	20190110	37507	18	ABBYVILLE, CITY OF	PO BOX 100	ABBYVILLE		KS	67510
7/1/2019	2018	20190941	38823	27	ABITA SPRINGS NAT GAS & WATER	22161 Level Street	Abita Springs	St. Tammany Pari	LA	70420
7/1/2019	2018	20191017	38473	45	ADAIRSVILLE, CITY OF	104 TOWNPARK DRIVE	KENNESAW		GA	30144
7/1/2019	2018	20191076	38671	49	TOWN OF ADAMSVILLE GAS DEPT	203 Sunrise Drive 231 Eas	Adamsville		TN	38310
7/1/2019	2018	20190555	37985	54	ADEL GAS DEPT, CITY OF	5261 CARLTON RIDGE CIR(	HAHIRA	Lowdnes	GA	31632
7/1/2019	2018	20191104	38592	81	AGUILAR, TOWN OF	101 W Main Street	Aguilar	Las Animas	CO	81020
7/1/2019	2018	20190957	38407	180	SPIRE ALABAMA INC.	2101 6th Ave N	Birmingham		AL	35203-
7/1/2019	2018	20190464	37887	207	ALASKA PIPELINE CO	401 E. INTERNATIONAL AIF	ANCHORAGE		AK	99518
7/1/2019	2018	20199271	37294	225	ALBANY MUNICIPAL GAS CO	106 E Clay Street	Albany		MO	64402
7/1/2019	2018	20190576	38008	234	ALBANY WATER GAS & LIGHT COMMISSION	104 TOWN PARK AVENUE	KENNESAW		GA	30144
7/1/2019	2018	20199136	37135	252	ALEDO GAS DEPT, CITY OF	9 Executive Woods Ct	Belleville		IL	62226
7/1/2019	2018	20199293	37317	261	ALEXANDER CITY MUNICIPAL GAS	520 Calhoun St	Alexander City		AL	35010
7/1/2019	2018	20190711	38153	270	ALEXANDRIA MUNICIPLE GAS SYSTEM, CITY OI	2021 Industrial Park Rd, Bl	Alexandria		LA	71302
7/1/2019	2018	20190109	37492	315	ALLERTON GAS CO	PO BOX 825	CENTERVILLE	Appanoose	IA	52544
7/1/2019	2018	20190173	37568	333	ALMA GAS DISTRIBUTION SYSTEM, CITY OF	326 MISSOURI	ALMA		KS	66401
7/1/2019	2018	20199309	37338	342	ALMA NATURAL GAS SYSTEMS, CITY OF	614 MAIN ST.	ALMA	Harlan	NE	68920
7/1/2019	2018	20199248	37270	360	ALTAMONT GAS DEPT, CITY OF	P O Box 305	Altamont		KS	67330

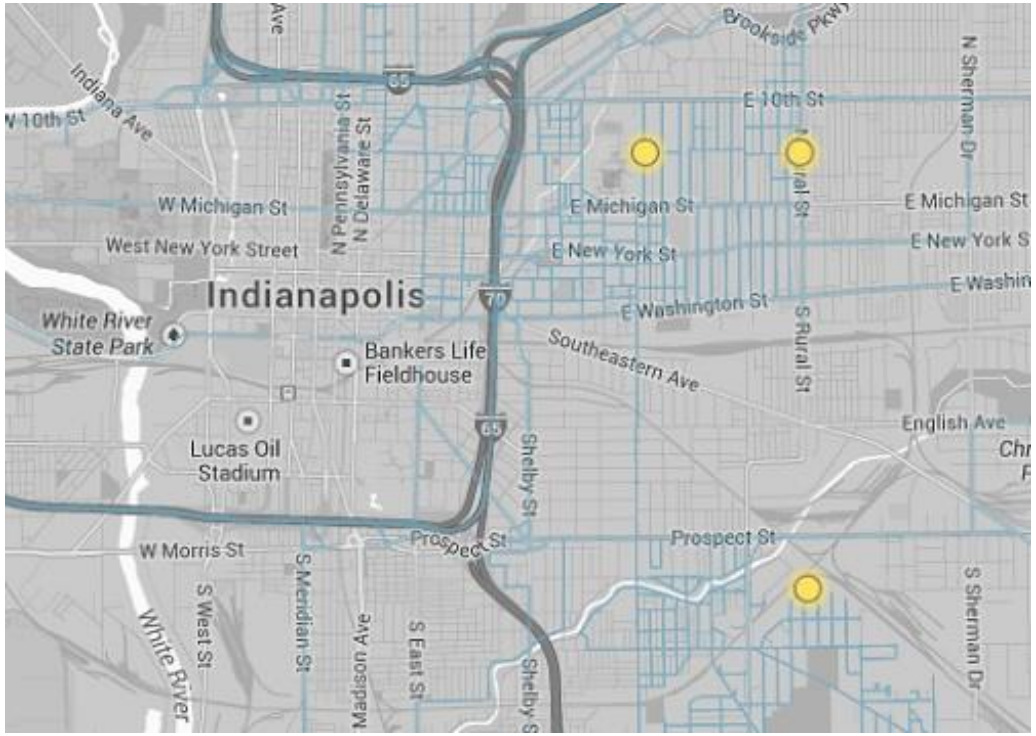
GD AR 2018 | New notifications (Off)

Mapping Results

Boston: Older Pipes, More Leaks



Indianapolis: Newer Pipes, Fewer Leaks

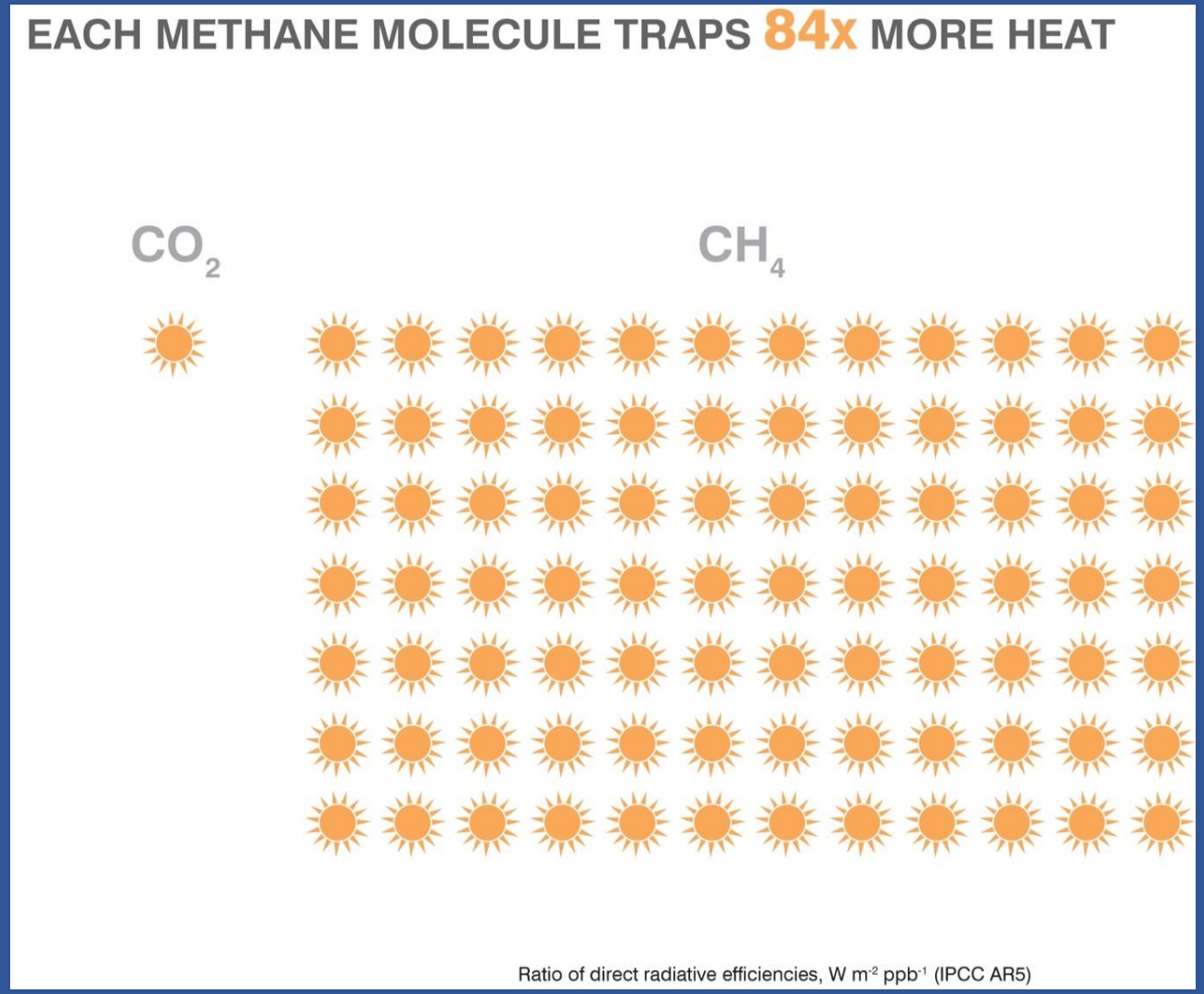


Why Addressing LDC Methane Emissions Matters?

- Climate Benefits
- Ozone Air Quality
- Ratepayer Savings
- Public Safety

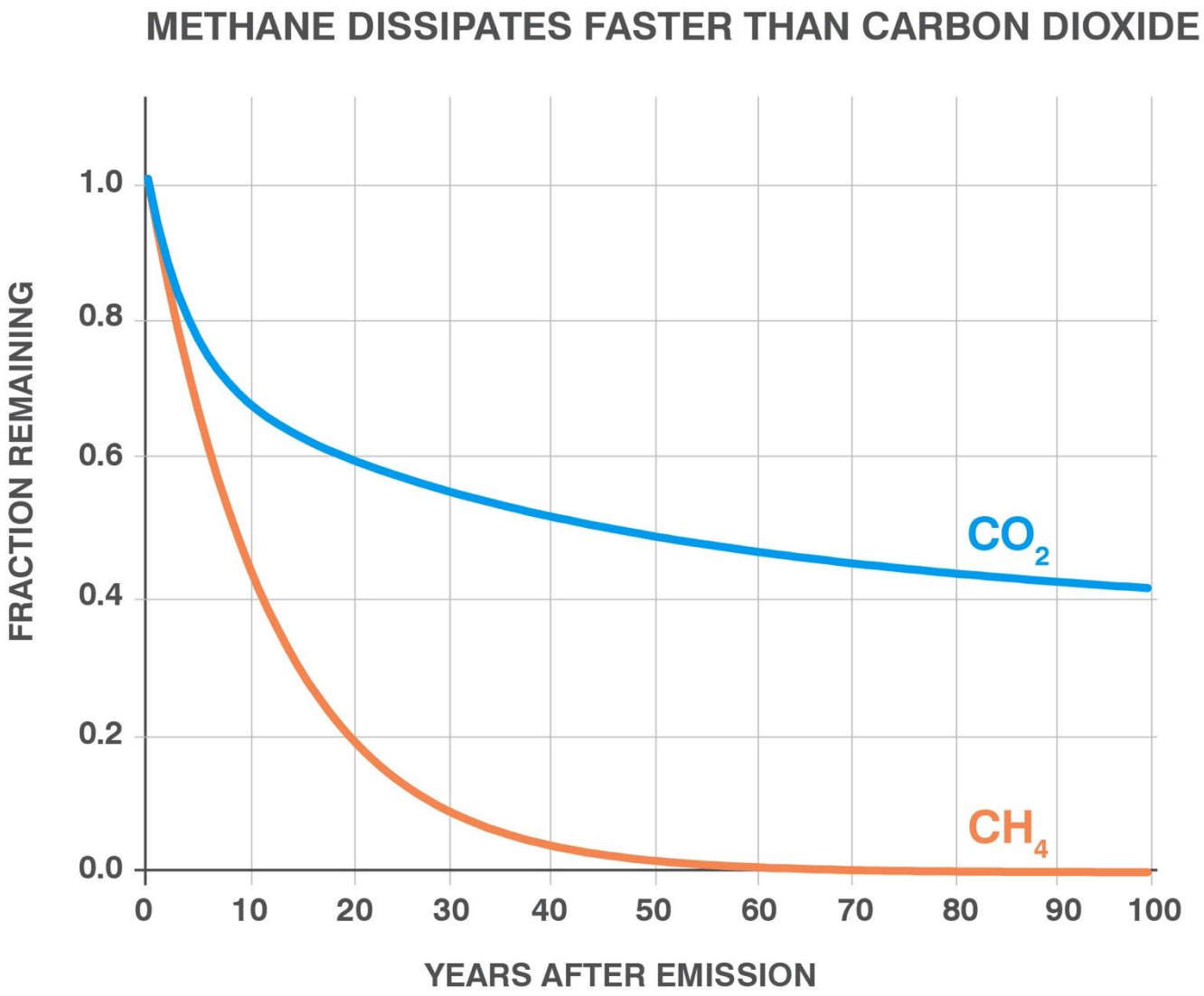
Methane Facts

CH4 traps more heat than CO2…



Methane Facts

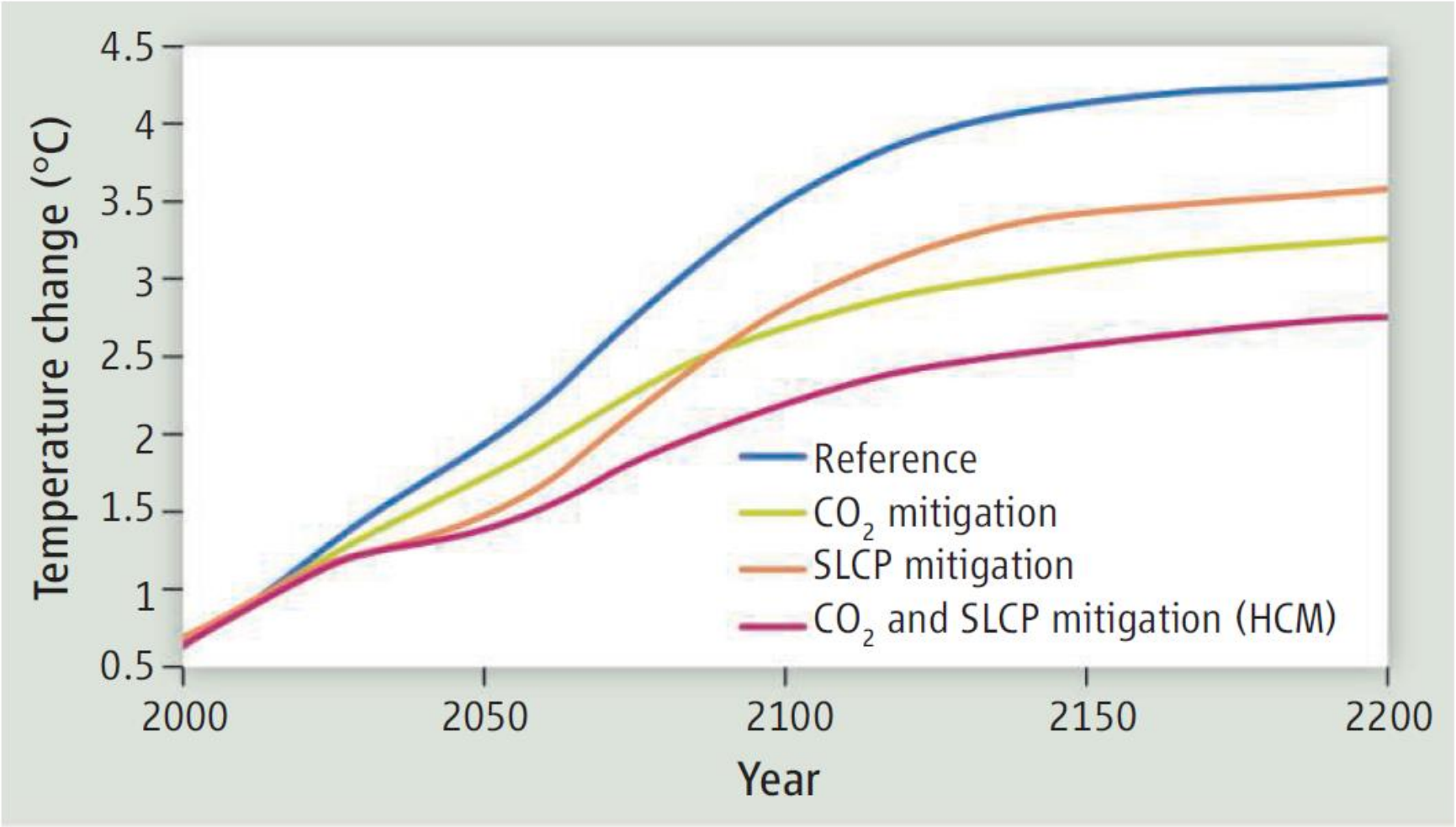
…but breaks down faster than CO2



- CH_4 produces tropospheric ozone and stratospheric water vapor as it decays
- Increases the direct warming effect by 65% (IPCC AR5)

Climate Impacts

Methane *and* CO_2 reductions required



Ozone Air Quality

Increasing Methane has Important Effects on Levels of Atmospheric Ozone

- Oxidation of methane produces ozone in the troposphere and lower stratosphere.
  - Complex series of chemical reactions of methane produce up to two ozone molecules per molecule of methane
  - In the lower atmosphere, this adds to air quality concerns (“bad ozone”)
- Reactions of methane destroy ozone in the upper stratosphere
  - Destruction of methane in the upper stratosphere produce hydrogen oxides that react with ozone.
  - This leads to the destruction of “good ozone” – the levels of ozone in the stratosphere that protect us from biologically-harmful ultraviolet radiation

Ozone Air Quality

The Link between Methane and Tropospheric Ozone

- Less of a link to individual local ozone episodes, BUT, part of global background concentrations
- Global tropospheric O3 decreases linearly with reductions in CH4 emissions
- Efficacy of CH4 emission reductions for air quality/climate goals is INDEPENDENT OF LOCATION
- Implications for seeking cost-effective pre-cursor source controls when traditional sources are “tapped out”

What We Thought and What We Know NOW About Methane Emissions System-Wide

- EPA estimates emissions of 400 billion cubic feet per year system wide
- New estimates are 640 billion cubic feet per year (Alverez et al. Science)
- A 60% increase!

LAUF – Ratepayer Pays!

- At 1.2 cents a cubic foot—retail value of $7.7 billion a year LOST
- For local systems, true leak count is 2.4 times higher than currently estimated. Even more millions of dollars in losses (Waller et al ACS)
- EPA estimates leaked gas itself costs $194M a year

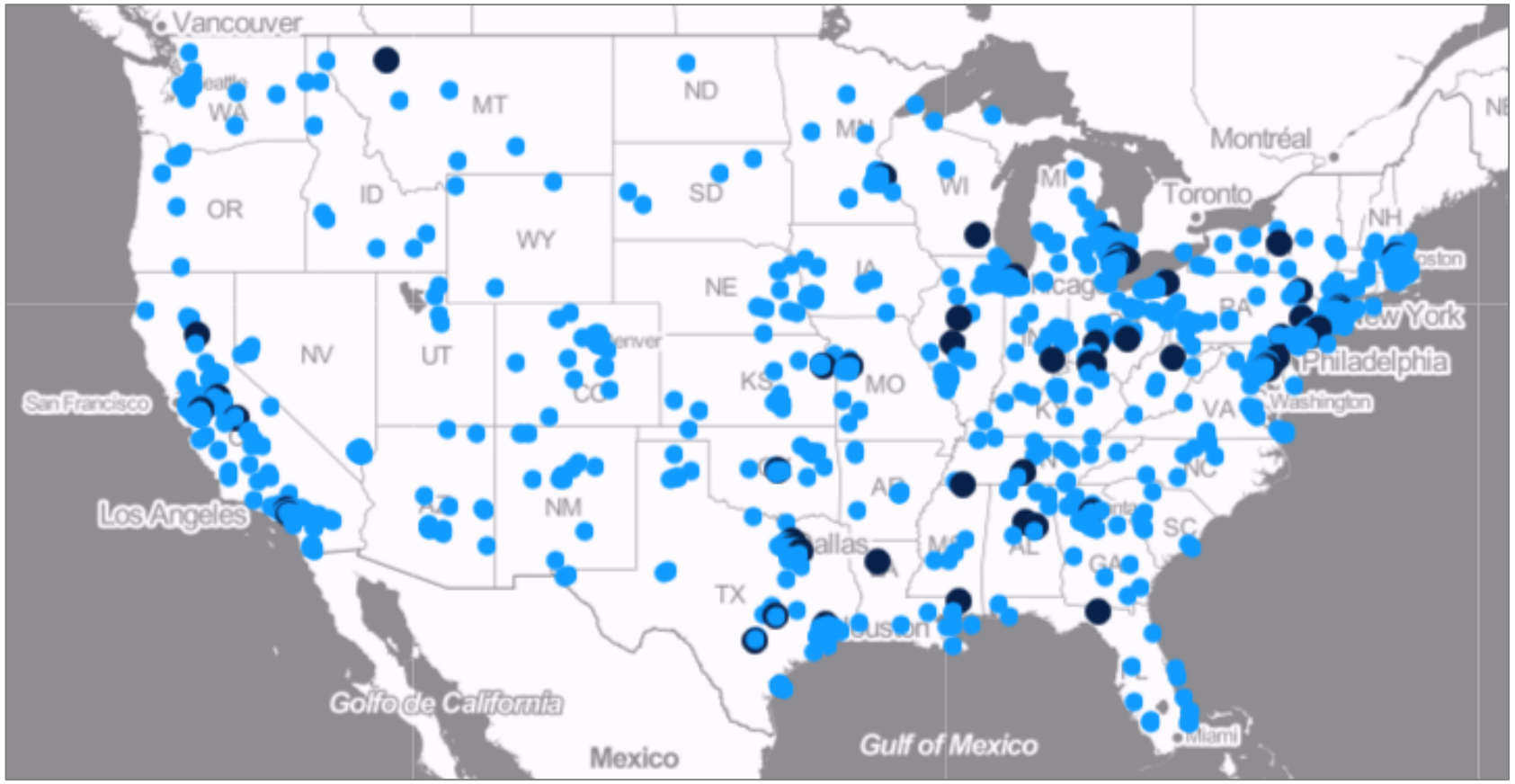
Safety

San Bruno pipeline explosion

“Safety?”

Pipeline peril: Natural gas explosions reveal silent danger lurking in old cast iron pipes

USA Today
Nov 12, 2018

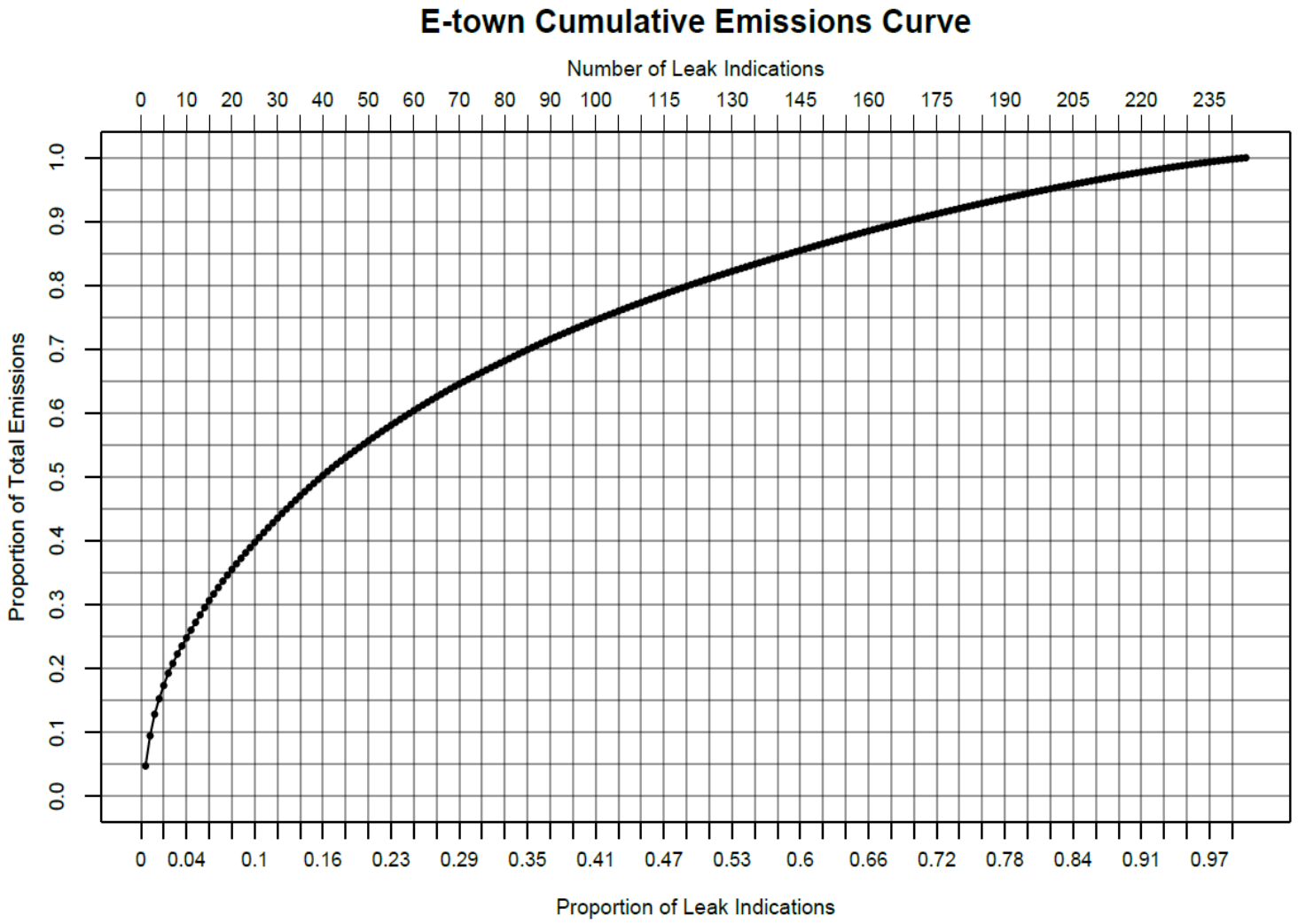


ALD and Leak Quantification Applications

- Pipeline Replacement Prioritization
- Leak Repair Prioritization
- Climate Action Contributions Quantified
- Tropospheric Ozone Abatement

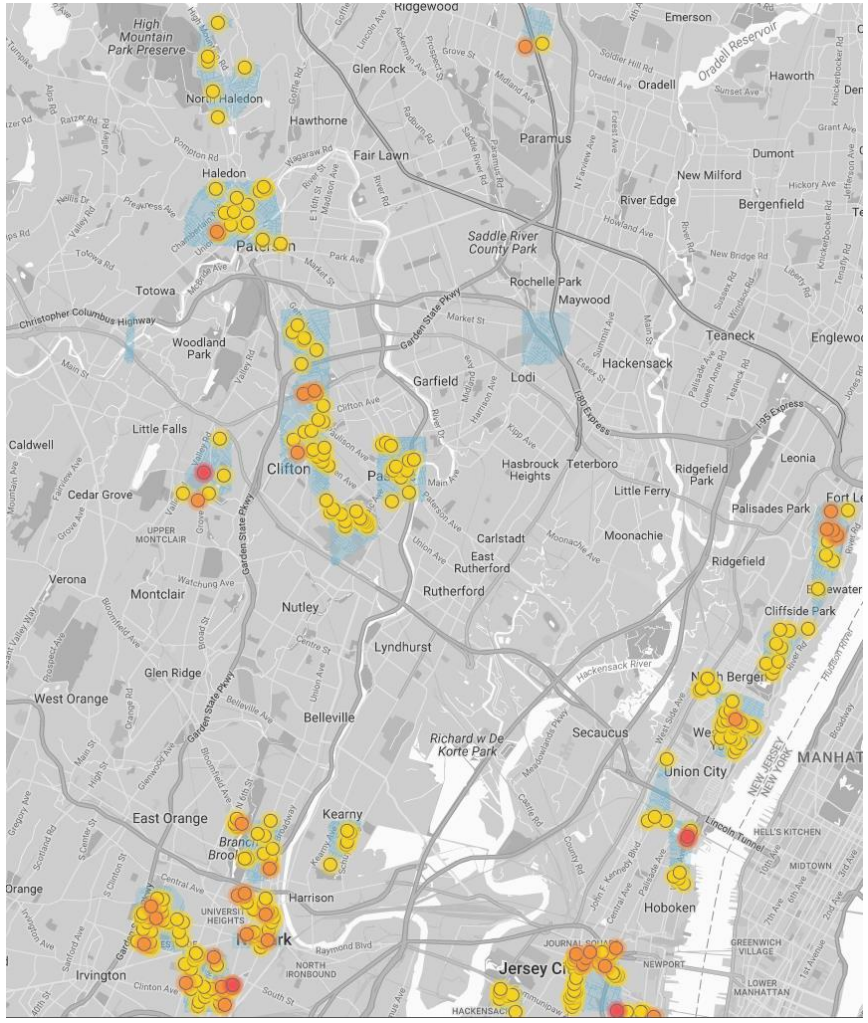
Advance Leak Detection

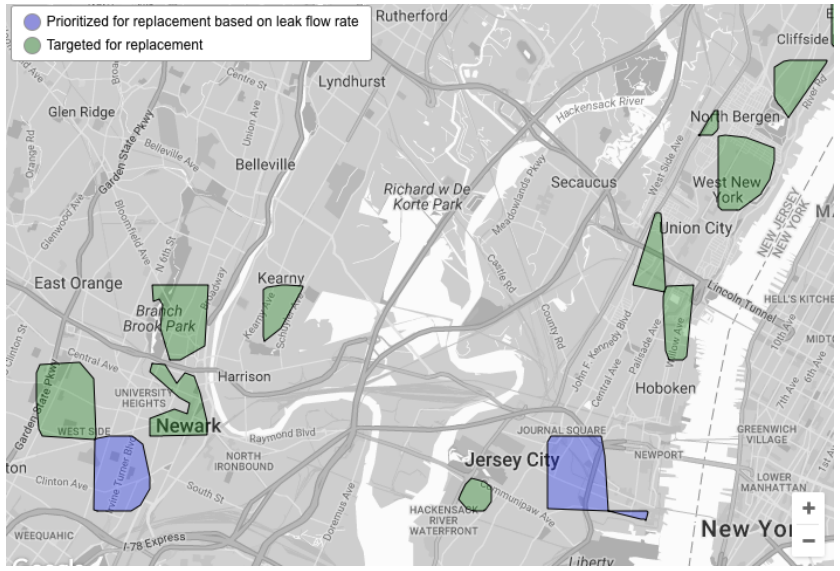
Targeting the Largest Leaks Results in Greatest Benefits: Less Cost



Pipeline Replacement Prioritization

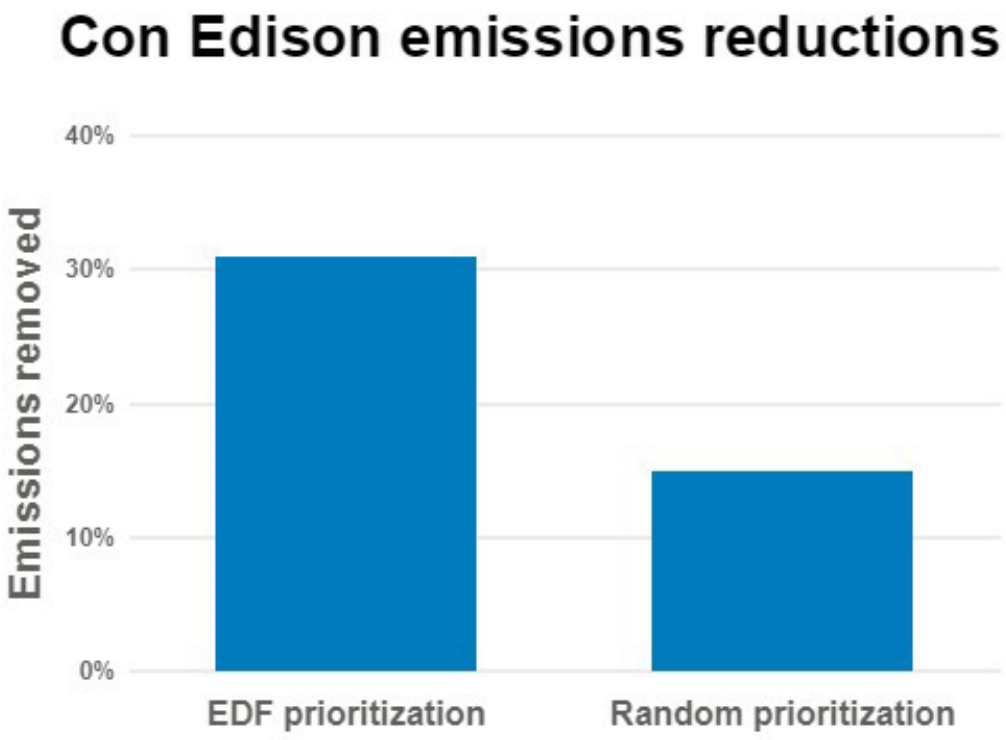
PSE&G: ALD+ methods helped prioritize $900M in pipeline replacement

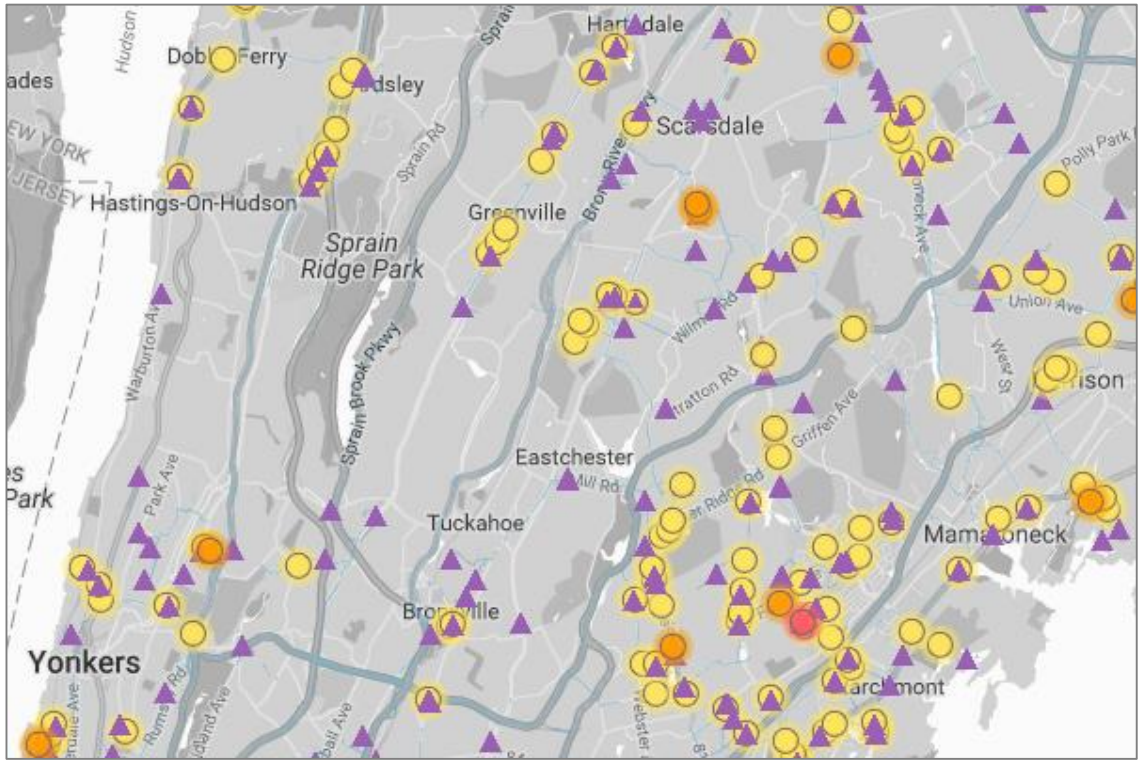




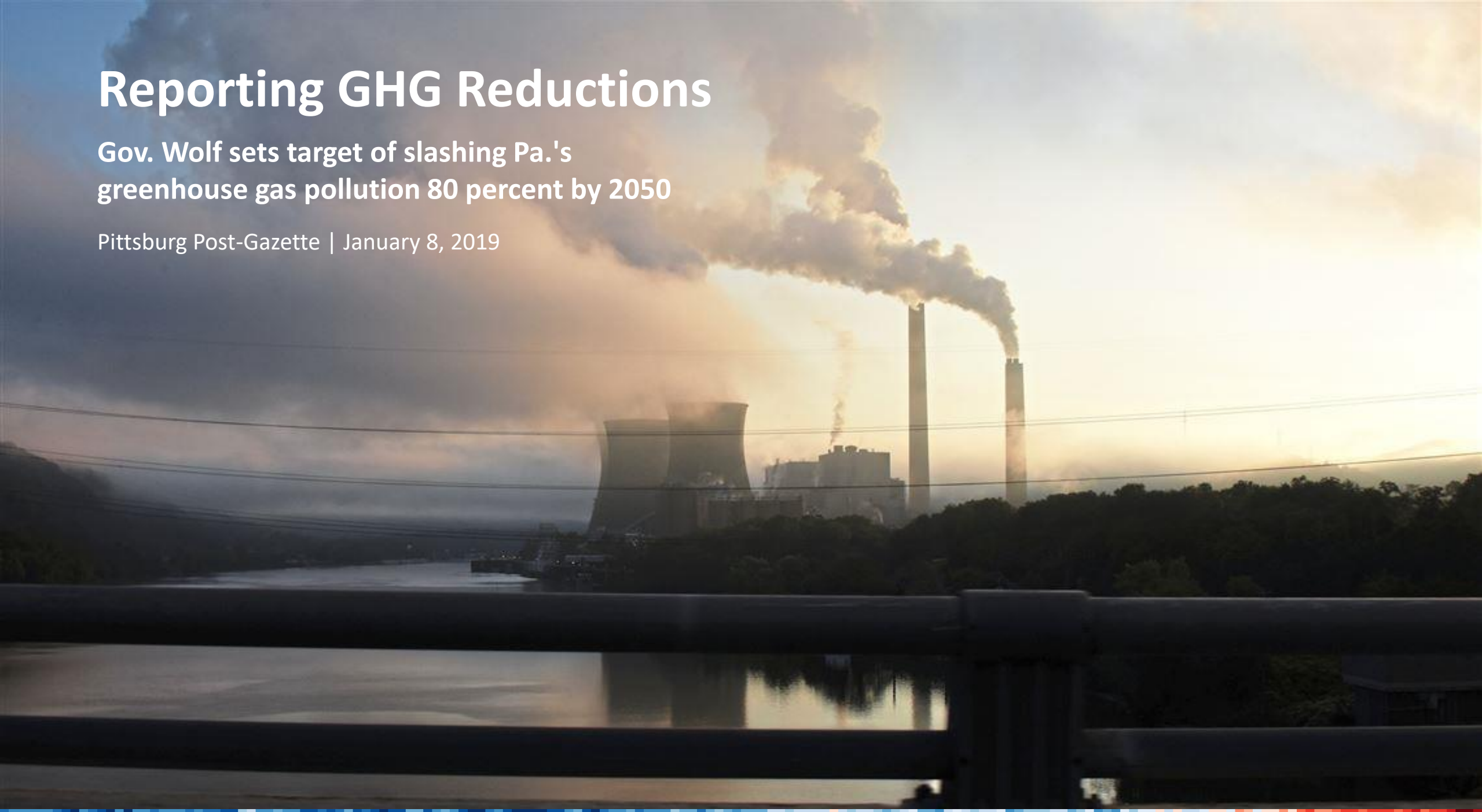
Leak Repair Prioritization

Con Ed: Fixing Non-Hazardous Leaks Faster





Reporting GHG Reductions



Gov. Wolf sets target of slashing Pa.'s greenhouse gas pollution 80 percent by 2050

Pittsburg Post-Gazette | January 8, 2019

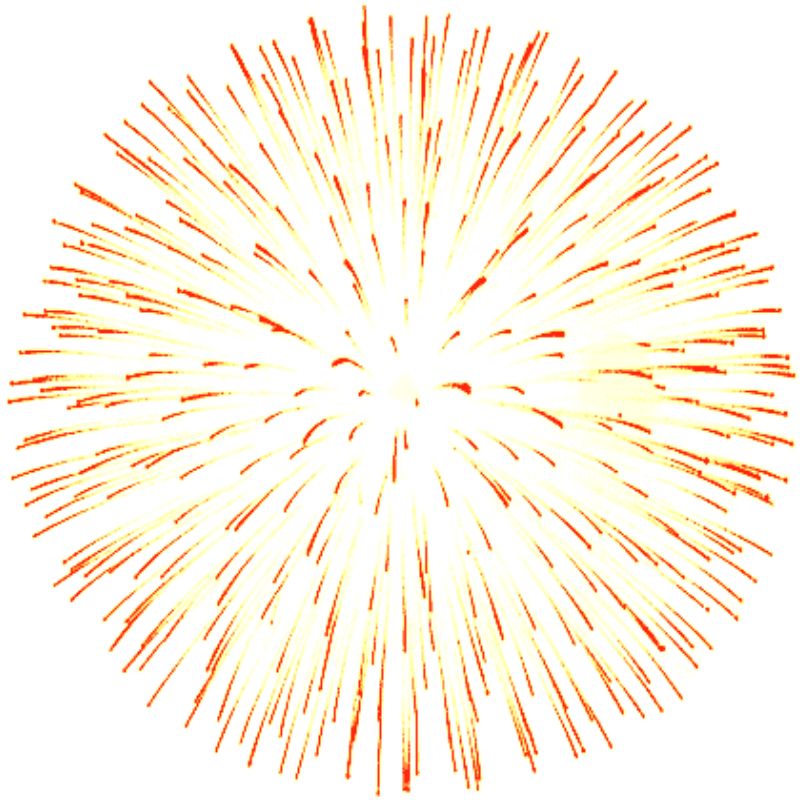
The Quadruple Win of Reducing LDC Methane Emissions

1. ECONOMIC BENEFITS TO RATEPAYERS

2. SAFETY

3. CLIMATE MITIGATION

4. IMPROVED AIR QUALITY



Traditional Methodologies vs Advanced Leak Detection

"It...defies belief that, despite the widespread availability 21st century technology, the primary leak detectors for natural gas pipelines are the public's own eyes and noses. Methane is a climate change super-pollutant and we don't even know how much is being released from pipelines. This needs to change."

New Mexico Senator Tom Udall announcing Amendments to Improve the PIPES Act of 2019 (S.2299) on July 30, 2019

Findings and Recommendations

Findings:

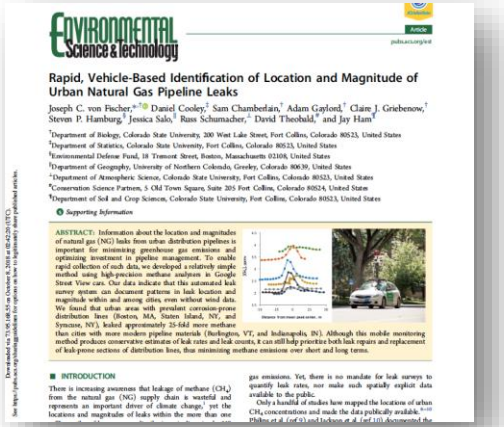
- Advanced leak detection methods would reduce more than 50% of methane emissions by repairing only the largest 20% of leaks.
- Advanced leak detection finds more leaks including hazardous Grade 1 leaks.
- Advanced leak detection allows for quantification and reporting of emissions reductions.
- Advanced leak detection creates opportunities for more frequent, less resource-intensive leak surveys.

Recommendations

- Require use of ALD to establish inventory
- Mandate abatement of environmentally significant non-hazardous leaks (by leak flow volume)
- Track emissions
- Partner with PUC to address LDC costs and incentives
- Advocate for utility inclusion of ALD in DIMP program, after safety

Relevant CSU EDF Research publications

1) Description of methodology
von Fischer *et al.*
EnvSci&Tech 2017


Environmental Science & Technology

Rapid, Vehicle-Based Identification of Location and Magnitude of Urban Natural Gas Pipeline Leaks

Joseph C. von Fischer, Daniel Cooley, Sam Chamberlain, Adam Gaylord, Claire J. Griebenow, Steven P. Hamburg, Jessica Salo, Russ Schumacher, David Theobald, and Jay Ham

Supporting Information

ABSTRACT: Information about the location and magnitudes of natural gas (NG) leaks from urban distribution pipelines is important for minimizing greenhouse gas emissions and optimizing investment in pipeline management. To enable rapid collection of such data, we developed a relatively simple method using high-precision methane analyzers in Google Street View cars. Our data indicate that this automated leak survey system can document patterns in leak location and magnitude within and among cities, even without wind data. We found that urban areas with prevalent corrosion-prone distribution lines (Boston, MA, Staten Island, NY, and Syracuse, NY), leaked approximately 25-fold more methane than cities with more modern pipeline materials (Burlington, VT, and Indianapolis, IN). Although this mobile monitoring method produces conservative estimates of leak rates and leak counts, it can still help prioritize both leak repairs and replacement of leak-prone sections of distribution lines, thus minimizing methane emissions over short and long terms.

INTRODUCTION

2) Incorporation into utility operations
Palacios *et al.*
PublUtilFortn 2017


Integrating Leak Quantification into Natural Gas Utility Operations

Virginia Palacios, Senior Research Analyst, Environmental Defense Fund
Simi R. George, Manager of Natural Gas Distribution Regulation, Environmental Defense Fund
Joseph C. von Fischer, Associate Professor at Colorado State University
Kristina Mohlin, Senior Economist, Environmental Defense Fund

May 2017

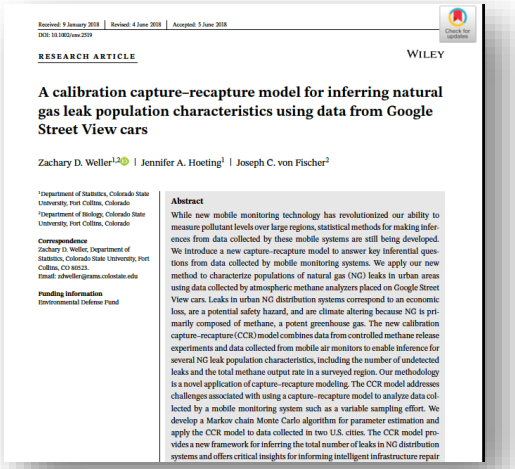
Abstract

Natural gas utilities can incorporate leak flow rate data into existing pipeline replacement and leak repair prioritization frameworks to more rapidly and efficiently reduce leakage on their system. Leak distributions typically demonstrate a "fat-tail," where a few, large leaks are responsible for the majority of lost gas volumes. Through ranking and ordering leak flow rate data, utilities can identify a subset of the largest leaks to repair or the leakiest pipelines to replace, and capture more gas per dollar spent on leak repair or pipeline replacement. This benefits ratepayers, who pay for the cost of lost gas, and also carries broader environmental and societal benefits.

1. Introduction

Studies of natural gas distribution pipeline leaks indicate that a relatively small subset of leaks is responsible for a disproportionate share of total observed emissions (Brandt et al., 2016; Lamb et al., 2015; Hendrick et al., 2016; von Fischer et al., 2017). Even though natural gas distribution utilities must expeditiously repair hazardous leaks, many large leaks can persist for months or years prior to repair

3) Advanced statistics for estimating total leakage
Weller *et al.*
Environmetrics 2018


Received: 9 January 2018 | Revised: 4 June 2018 | Accepted: 5 June 2018

DOI: 10.1002/env.2519

RESEARCH ARTICLE

WILEY

A calibration capture–recapture model for inferring natural gas leak population characteristics using data from Google Street View cars

Zachary D. Weller | Jennifer A. Hoeting | Joseph C. von Fischer

Abstract

While new mobile monitoring technology has revolutionized our ability to measure pollutant levels over large regions, statistical methods for making inferences from data collected by these mobile systems are still being developed. We introduce a new capture–recapture model to answer key inferential questions from data collected by mobile monitoring systems. We apply our new method to characterize populations of natural gas (NG) leaks in urban areas using data collected by atmospheric methane analyzers placed on Google Street View cars. Leaks in urban NG distribution systems correspond to an economic loss, are a potential safety hazard, and are climate altering because NG is primarily composed of methane, a potent greenhouse gas. The new calibration capture–recapture (CCR) model combines data from controlled methane release experiments and data collected from mobile air monitors to enable inference for several NG leak population characteristics, including the number of undetected leaks and the total methane output rate in a surveyed region. Our methodology is a novel application of capture–recapture modeling. The CCR model addresses challenges associated with using a capture–recapture model to analyze data collected by a mobile monitoring system such as a variable sampling effort. We develop a Markov chain Monte Carlo algorithm for parameter estimation and apply the CCR model to data collected in two U.S. cities. The CCR model provides a new framework for inferring the total number of leaks in NG distribution systems and offers critical insights for informing intelligent infrastructure repair

4) Validation of false positives & leak size estimation
Weller *et al.*
EnvSci&Tech 2018


Environmental Science & Technology

Vehicle-Based Methane Surveys for Finding Natural Gas Leaks and Estimating Their Size: Validation and Uncertainty

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Supporting Information

ABSTRACT: Managing leaks in urban natural gas (NG) distribution systems is important for reducing methane emissions and costly waste. Mobile surveying technologies have emerged as a new tool for monitoring system integrity, but this new technology has not yet been widely adopted. Here, we establish the efficacy of mobile methane surveys for managing local NG distribution systems by evaluating their ability to detect and locate NG leaks and quantify their emissions. In two cities, three-quarters of leak indications from mobile surveys corresponded to NG leaks, but local distribution companies' field crews did not find most of these leaks, indicating that the national CH_4 activity factor for leaks in local NG distribution pipelines is underestimated by a factor of 2.4. We found the median distance between mobile-estimated leak locations and actual leak locations was 19 m. A comparison of emission quantification methods (mobile-based, surface enclosure, and tracer-ratio) found that the mobile method overestimated leak magnitude for the smallest leaks but accurately estimated size for the largest leaks that are responsible for the majority of total emissions. Across leak sizes, mobile methods adequately rank relative emission rates for repair prioritization, and they are easily deployed and offer efficient spatial coverage.

1. INTRODUCTION

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