Unitil –System Overview and Next Steps

Methane Emission Assessment

April 4, 2024

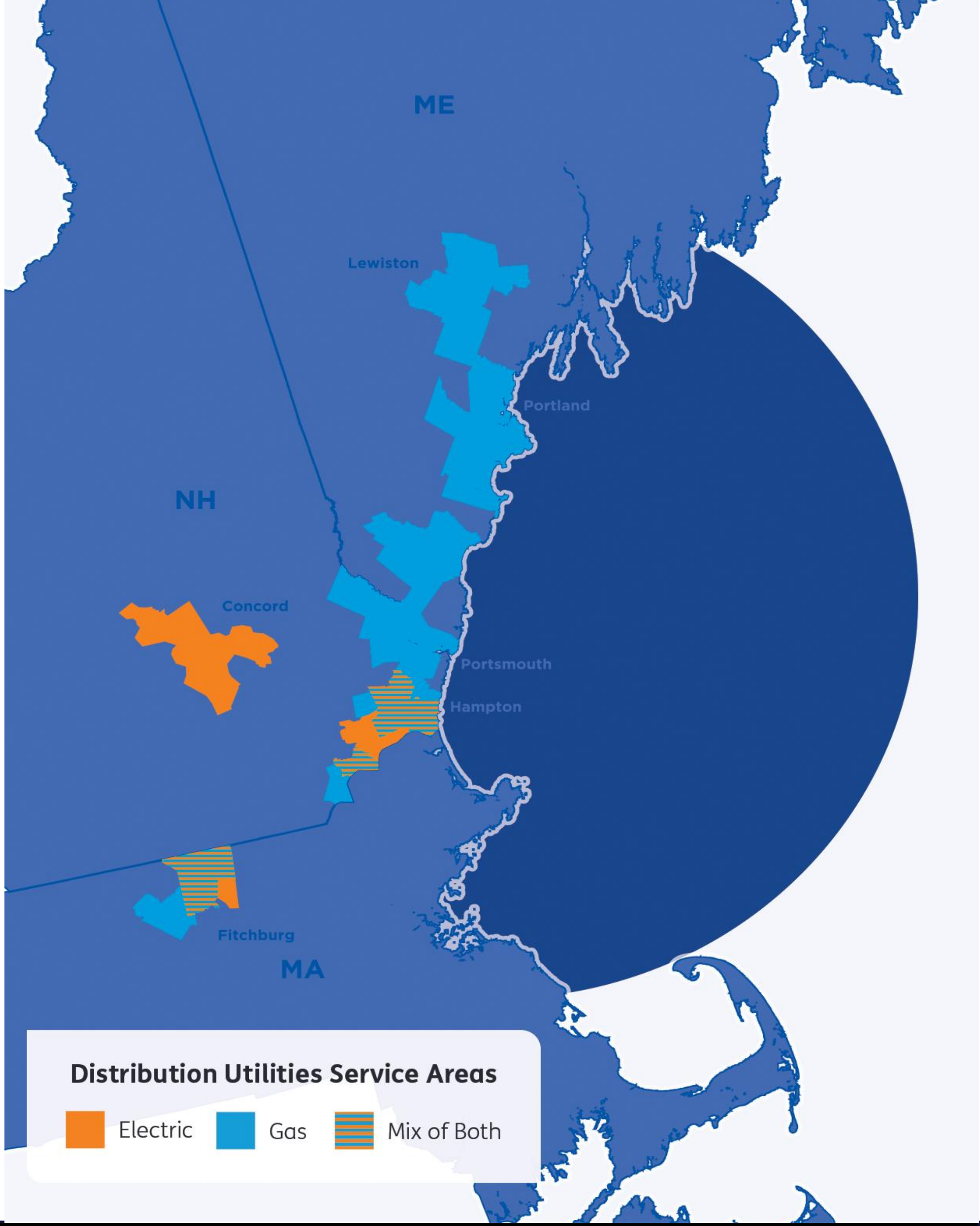
ABOUT UNITIL

An investor owned utility

Northern Utilities, Inc.	Fitchburg Gas and Electric Light Company	Granite State Gas Transmission, Inc.	Unitil Energy Systems, Inc.
Natural gas distribution utility	Natural gas & electric distribution utility	Natural gas transmission pipeline	Electric distribution utility
Maine and New Hampshire	Massachusetts	Maine, Massachusetts, and New Hampshire	New Hampshire
71,156 customers	16,417 gas customers & Approx. 30,827 electric customers	Approx. 85 miles of underground pipe	Approx. 79,494 customers

87,573
Natural Gas Customers

110,321
Electric Customers



Gas Main - Infrastructure

Gas Main (2022)				
Type of Material	**Maine**	**New Hampshire**	**Massachusetts**	**Total**
Leak Prone Inventory				
Bare Steel	0	0	3.3	3.3
Unprotected Coated	0.4	0.14	4.66	5.2
Cast Iron/Ductile Iron	13.69	0	31.15	44.84
Other	0	0	0	0
Sub-Total	**14.09**	**0.14**	**39.11**	**53.34**
Modern Inventory				
CP Coated Steel	101.26	79.06	114.28	294.6
Plastic	490.03	496.13	117.85	1104.01
Sub-Total	**591.29**	**575.19**	**232.13**	**1398.61**
Leak Prone and Modern Inventory				
Total	**605.38**	**575.33**	**271.24**	**1451.95**
% Modern Material	98%	100%	86%	96%
% Leak Prone	2%	0%	14%	4%
Pipe Replacement Completion Date	2024	Complete	2035	

Massachusetts – Key Operational Data

2022 Annual Reports (F7100.1-1 and Excavation Damage Data)

- Approximately 16,417 customers/ 11,242 services in 6 cities and towns
  - Fitchburg
  - Gardner
  - Lunenburg
  - Westminster
  - Townsend
  - Ashby

Cause of Leak	Mains		Services	
	Total	Hazardous	Total	Hazardous
Corrosion Failure	10	4	14	7
Natural Force Damage	12	12	0	0
Excavation Damages	1	1	10	10
Other Outside Force Damage	0	0	0	0
Pipe, Weld or Joint Failure	0	0	3	3
Equipment Failure	0	0	37	36
Incorrect Operations	0	0	0	0
Other	59	4	92	69
Total	**82**	**21**	**156**	**125**

Unrepaired Leak Backlog	
Grade 1	0
Grade 2	0
Grade 3	0

Excavation Damages	
Dig Safe Tickets	5,506
Total Damages	12
Damages per 1000 Tickets	2.17
Damages per mile of main	.05
At Fault Damages	1
At Fault %	8%

Unitil –Lessons Learned and Next Steps

Based on 2023 Picarro Methane Emission Assessment

- The assessment provided a more accurate representation of emissions in relation to the Company’s system
  - GHGI factor was almost 3 times greater
  - EPA factor was almost 10 times greater
- The assessment identified a small subset of leakage associated with the larger percentage of emissions.
  - The Company conducted field investigations on 6 leaks identified through the methane emission assessment and was either able to identify the leak or confirm the leak had since been repaired.
- The Company is now evaluating how to leverage this methodology to drive its sustainability strategy in the future

NGA

NORTHEAST GAS ASSOCIATION

Unitil Massachusetts network emission assessment

April 4th, 2024

François Rongere





Picarro is a global leader in the measurement, quantification, and reduction of methane emissions.

25 Years of Innovation

Serving the gas industry since 2012

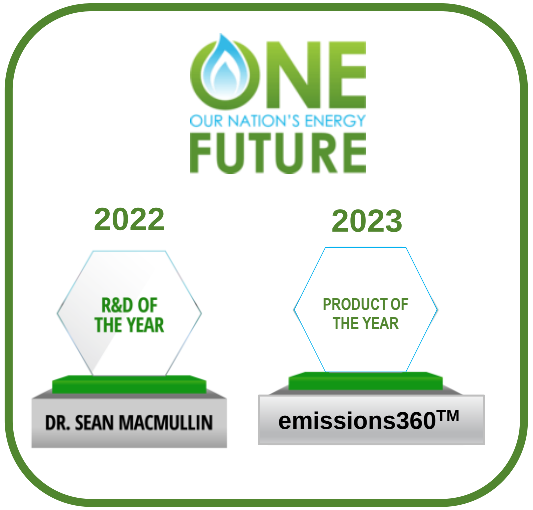
- **1000s** of Picarro instruments deployed worldwide
- R&D, engineering, and manufacturing in Santa Clara HQ
- Offices in US, Europe, LATAM, India and APAC regions
- **>40 PhDs** on staff with an extensive IP portfolio
- **60+** double-blind studies since 2012
- Pioneers of Cavity Ring-Down Spectroscopy (CRDS)
- ISO 9001, ISO 27001, SOC2 Certified

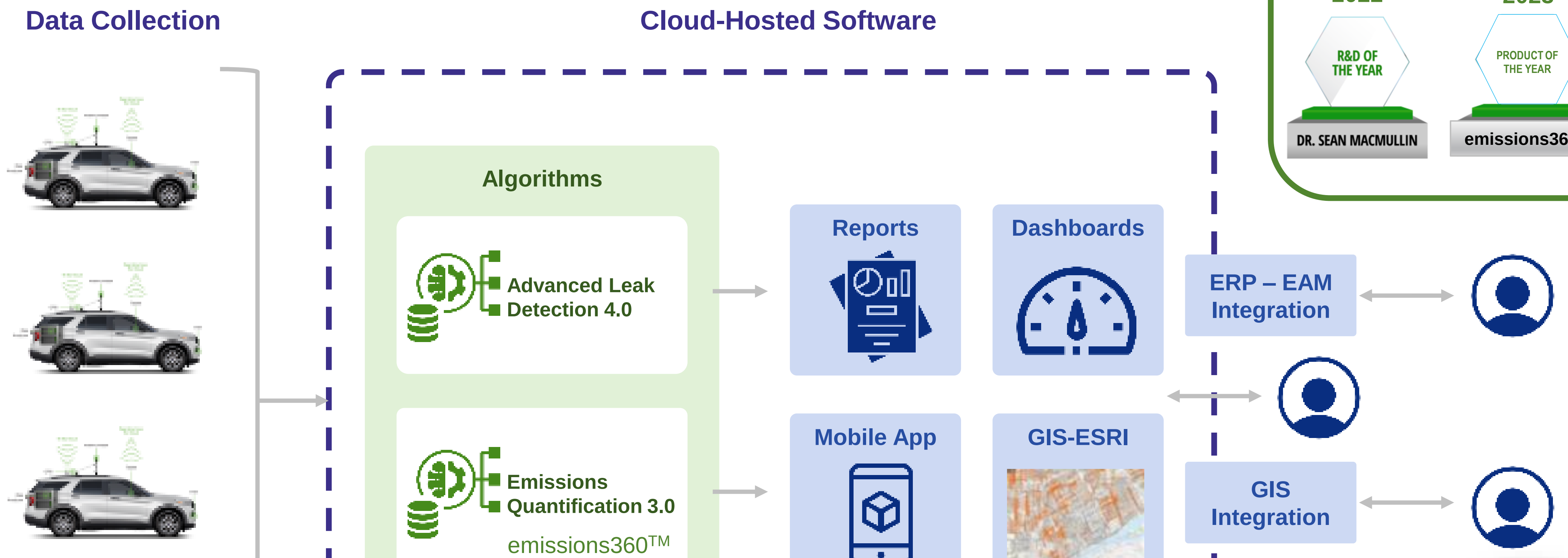
30+ Global Userbase
Natural Gas Operators

Proud Members Of

- MEA Energy Association
- SGA – Linking People, Ideas, Information
- Ohio Gas Association
- Northeast Gas Association
- Western Energy Institute
- IGU – International Gas Union
- eurogas 30 years
- American Public Gas Association
- AGA – American Gas Association – Associate Member

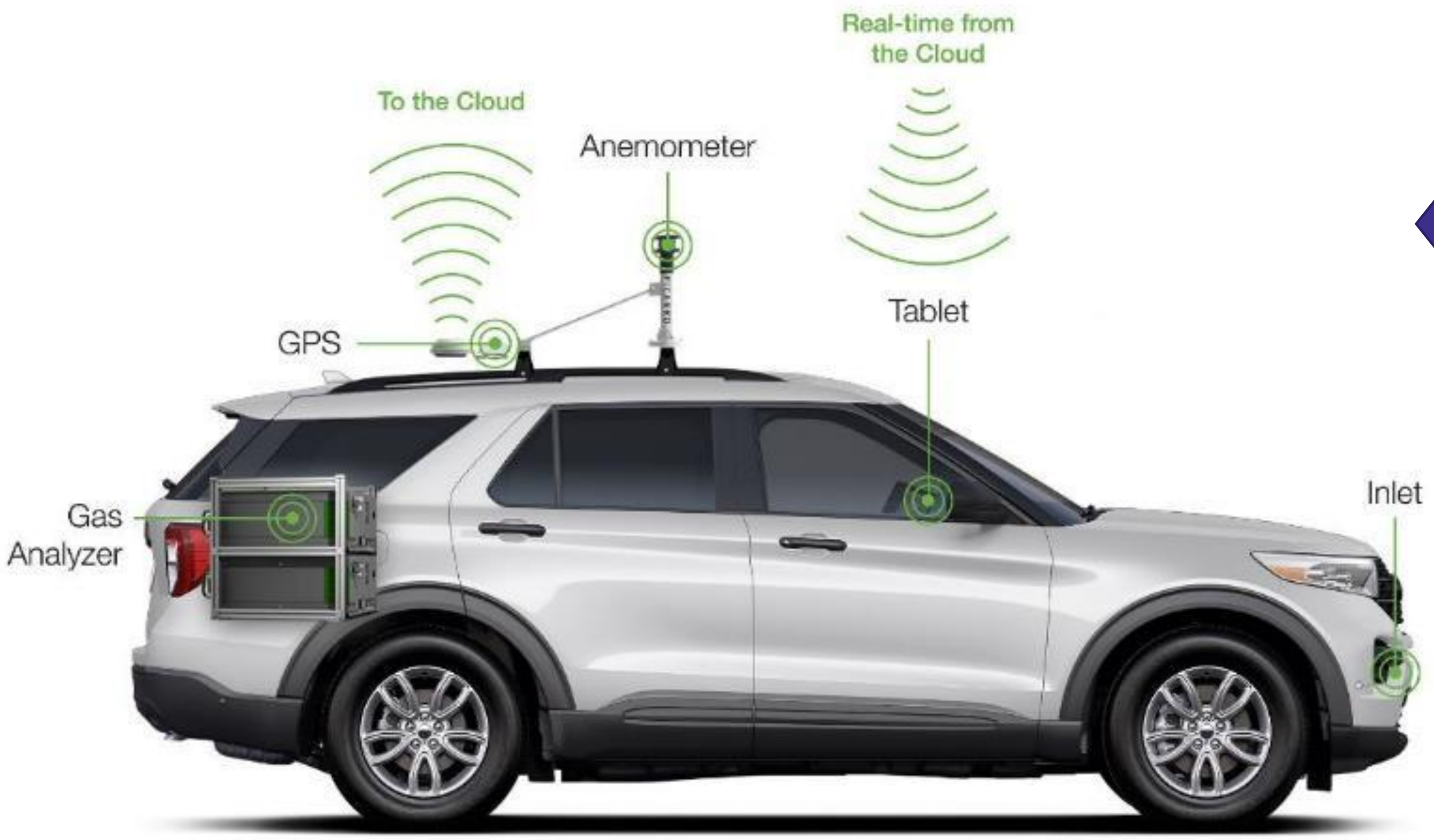
Picarro Hardware-Software Architecture





ERP: Enterprise Resource Planning
EAM: Enterprise Asset Management

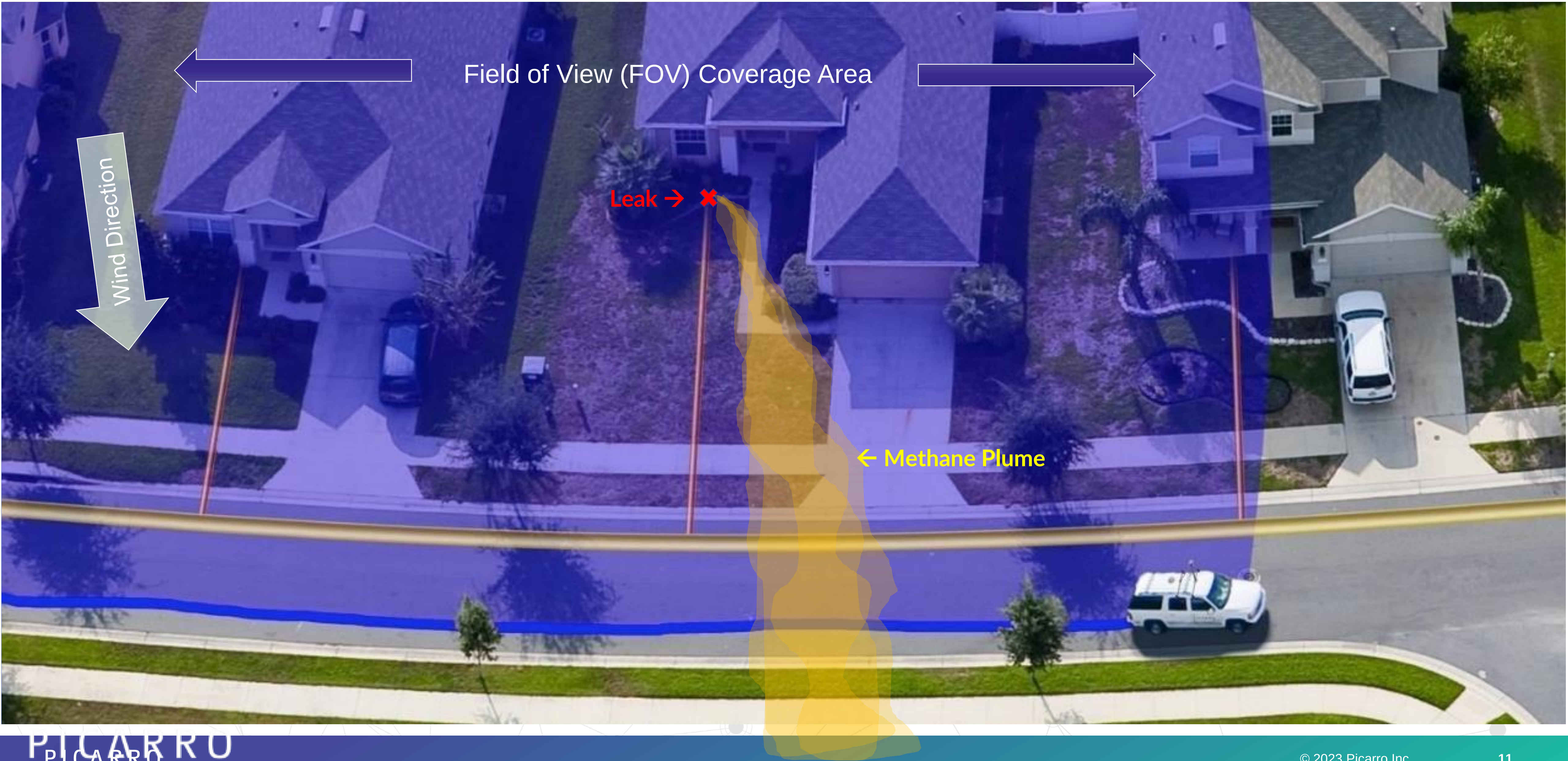
Picarro Proprietary Hardware, Software & Analytics



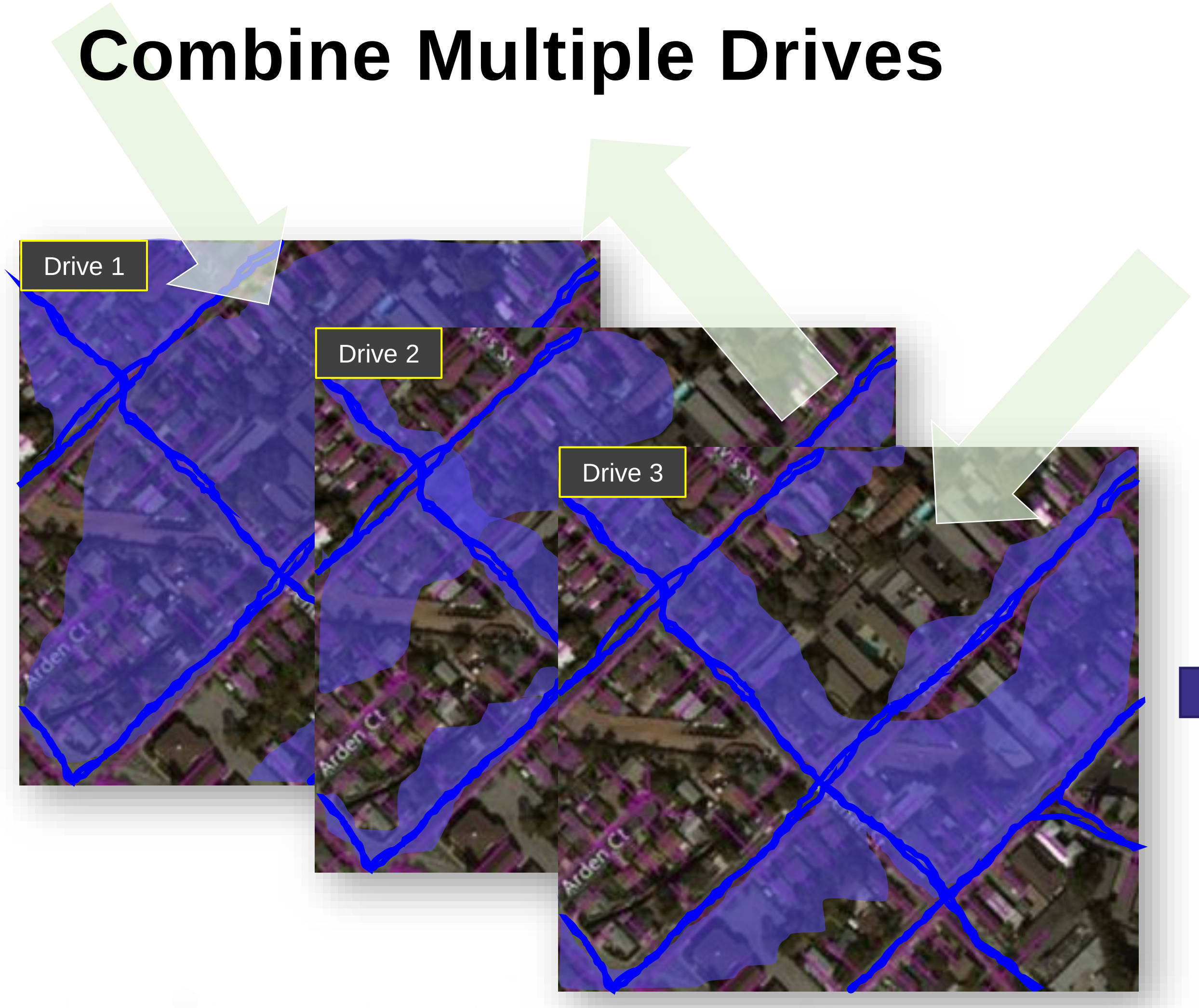
Hardware
- All Weather gas inlet system
- PPB methane/ethane sensor
- Anemometer – wind-speed / direction
- iGPS
- Cloud connected
- Driver UI tablet

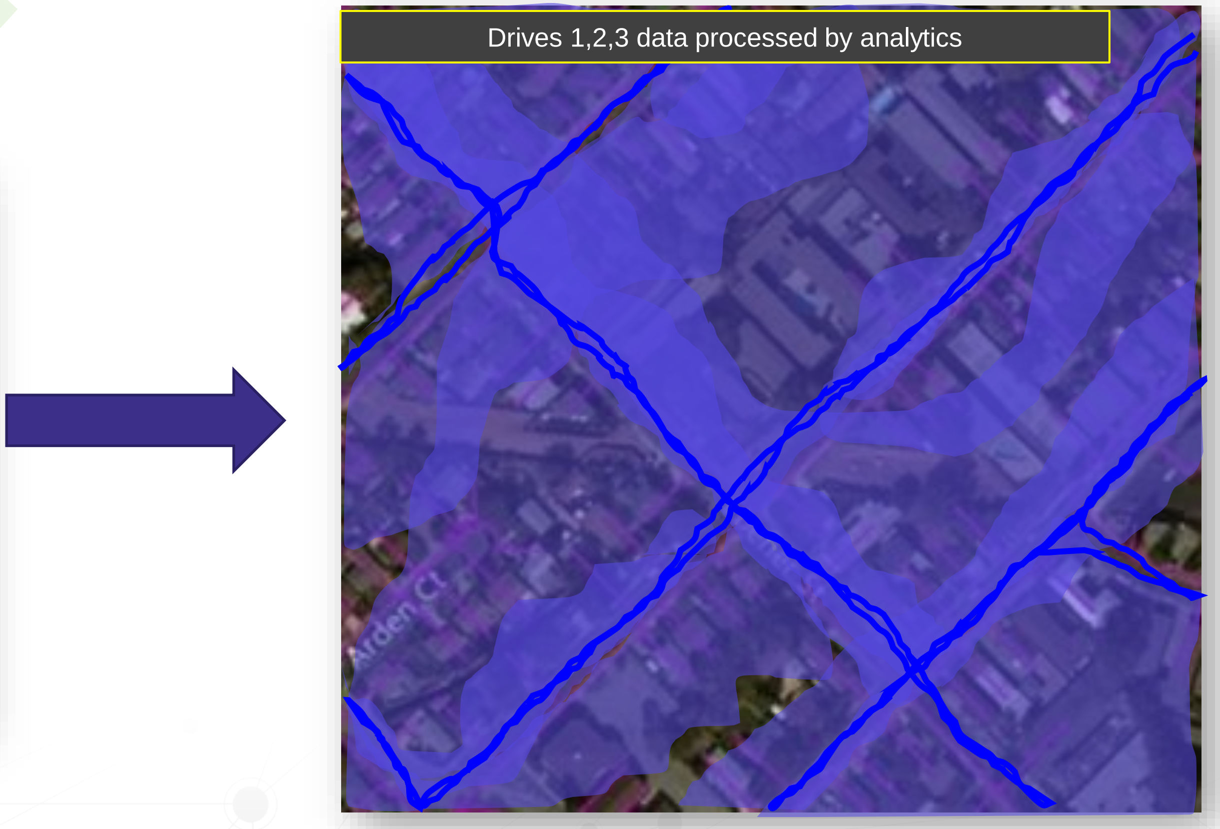
Software & Analytics
- Multi-pass data collection protocols
- Atmospheric and methane plume modeling
- Source discrimination to avoid false positives
- Risk assessment and flow rate quantification

Advanced Leak Detection and Emissions Quantification



Combine Multiple Drives





Picarro Solutions

Emissions Measurement (Network)
- Quantify methane leaks at scale, report on total network emissions
- Supports OGMP2.0 gold standard and other upcoming regulations

Emissions Reduction
- Super Emitter Program
- Find top 10% of highest emitting leaks, reduce network emissions by up to 50%

Pipeline Replacement (Optimization)
- Identify high priority network areas and pipe assets for accelerated replacement
- Combine methane data with your own infrastructure pipeline integrity variables
- Optimize your capital investment and reduce your operational repair budget

Advanced Leak Survey
- Advanced Leak Detection (ALD) for leaks measurement at speed and scale
- Prioritizing leak indications to increase network safety, reduce odor calls, reduce emissions

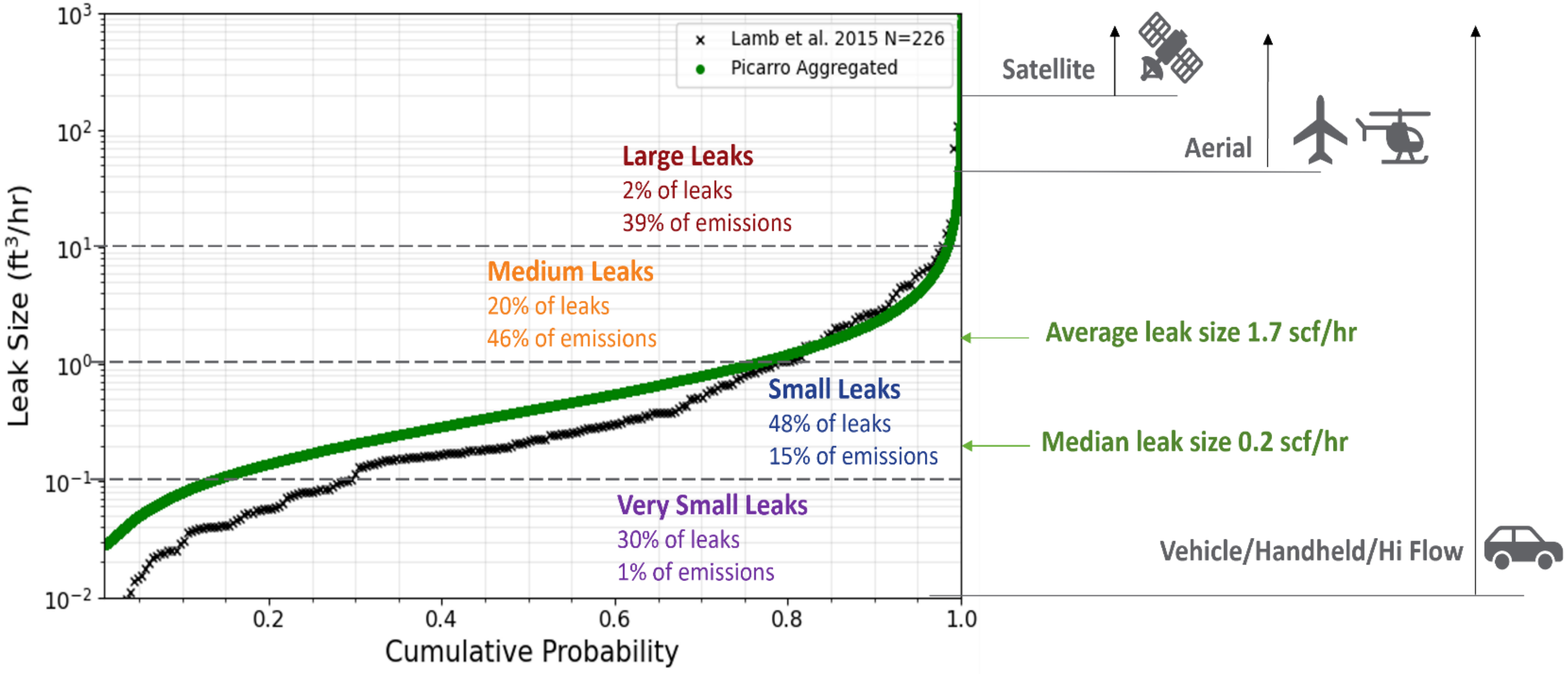
Emissions Measurement (Network)

Measurement-Informed Emissions Inventory Yields Improved Accuracy

Emissions Measurement – The Challenge

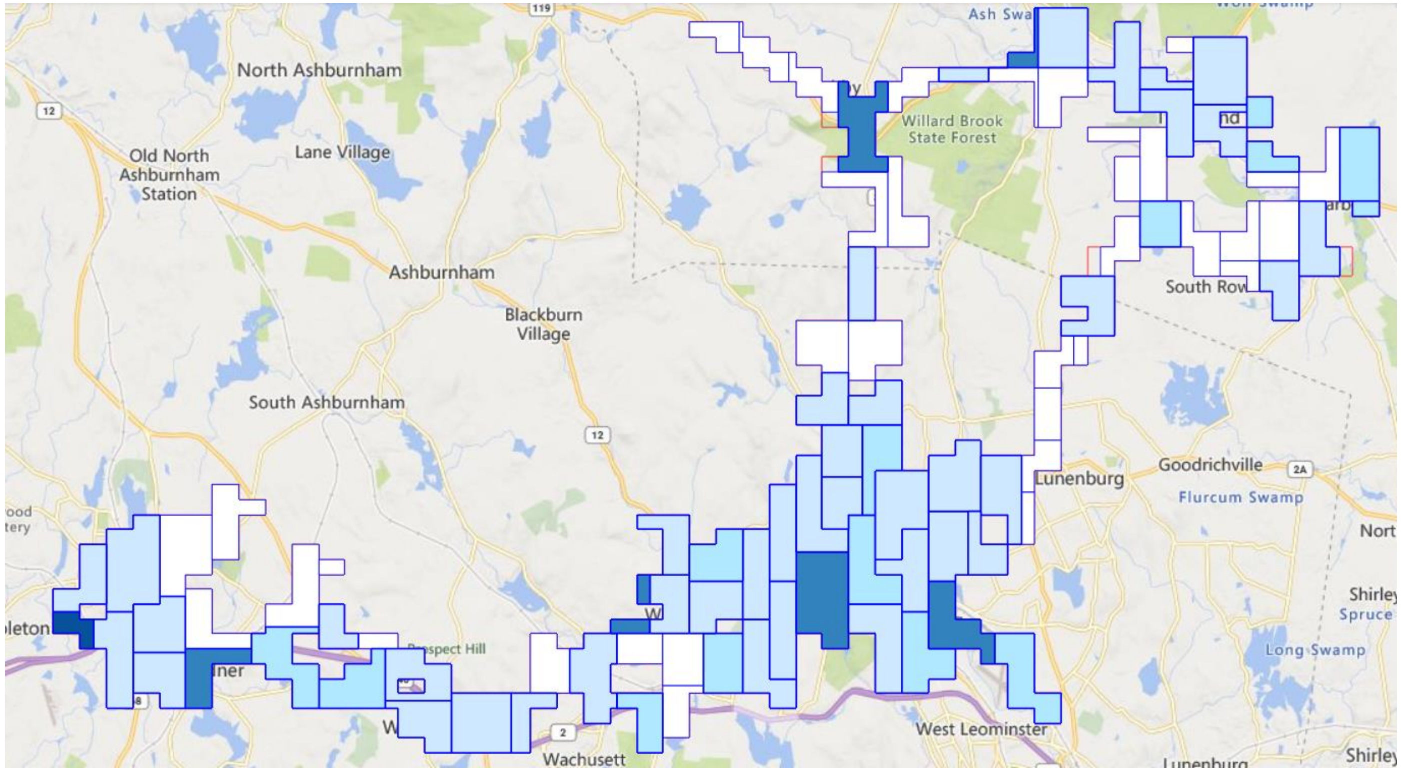
In a typical distribution network:

- Leak flow rates span > 4 orders of magnitude
- Total methane emissions in a distribution network are driven by a small number of larger leaks
- Top 5% of emitters can typically contribute up to 50% of total emissions
- Picarro AMLD low MDL enables the measurement of entire network emissions and classification of all emission sources



Source: A. Brandt et al. "Methane Leaks from Natural Gas Systems Follow Extreme Distributions" Environ. Sci. Technol., 2016, 50 (22), pp 12512–12520

Unitil Demo



Demonstrate Picarro's emissions measurement capabilities and its ability to prioritize leaks by flow rate over Unitil's MA assets.

- 2 drive / 4 pass protocol performed on two different nights to achieve the minimum of 4 passes
- 92% coverage

Mains Miles	Start Date	Completion Date
249	9/21/2023	10/14/2023

Measured-based Emission Assessment:

The 10-Step process addresses all elements contributing to methane emission calculations

PICARRO
emissions360
Playbook

Operator

Step 1: Define the reporting period

Step 2: Define the system

Step 3: Define the data collection schedule

Step 4: Collect Data

Picarro's Algorithms

Step 5: Assign detections to sources

Step 6: Leak size bias removal

Step 7: Account for the data collection schedule

Step 8: Adjust to FOV Gaps

Step 9: Account for repairs

Step 10: Assess uncertainties and report result

Aligned with Veritas and OGMP 2.0 protocols

Step 10: Final Results & Uncertainties

Measurement-based emission reporting:

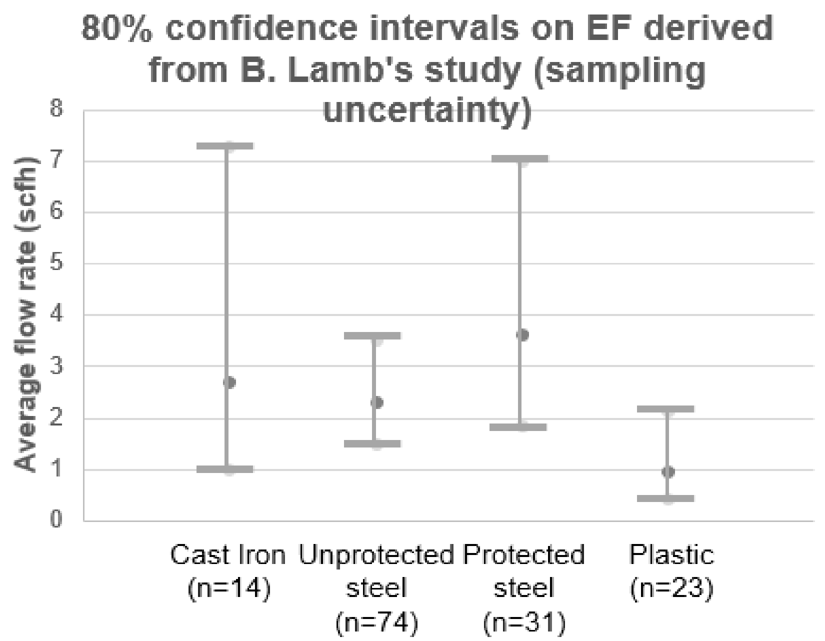
Emissions Using Picarro Area Based Quantification [MMSCF/Yr]	Uncertainty	Total Emissions -EPA [MMSCF/Yr]	Total Emissions - GHGI [MMSCF/Yr]
0.96	**+/- 18%**	9.54	3.05

Comparing to emission Factor-based emission reporting:

Mains						
Material Type	Length Covered In Reporting Period [Miles]	EPA Subpart W Emissions Factors [SCF/Hr/Mile]	GHGI Emissions Factors [SCF/Hr/Mile]	Emissions - EPA [MMSCF/Yr]	Total Emissions - GHGI [MMSCF/Yr]	Measured Emissions [MMSCF/yr]
Protected Steel	118.20	0.35	0.58	0.4	0.6	0.33
Unprotected Steel	3.26	12.58	5.12	0.4	0.1	0.02
Plastic	119.26	1.13	0.17	1.2	0.2	0.23
Cast Iron	30.69	27.25	6.88	7.3	1.8	0.21
				9.2	**2.8**	**0.79**

Services						
Material Type	Number of Services Covered In Reporting Period	EPA Subpart W Emissions Factors [SCF/Hr/Service]	GHGI Emissions Factors [SCF/Hr/Service]	Emissions - EPA [MMSCF/Yr]	Emissions - GHGI [MMSCF/Yr]	Measured Emissions [MMSCF/yr]
Protected Steel	848	0.020	0.010	0.15	0.07	0.04
Unprotected Steel	44	0.190	0.090	0.07	0.03	0.00
Plastic	10350	0.001	0.002	0.09	0.16	0.13
				0.31	**0.27**	**0.17**

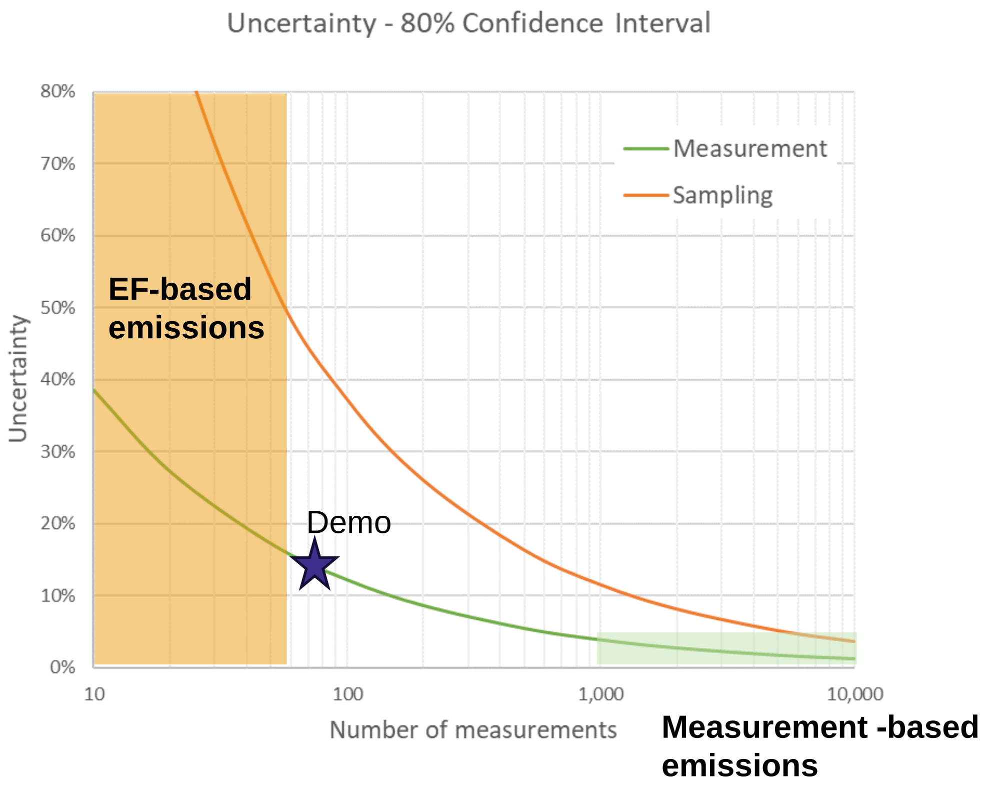
Emission Factor-based emission reporting is inaccurate because of sampling limitations



EF based emissions may be anywhere between 0.3 and 3 times the reported value because of sampling limitations

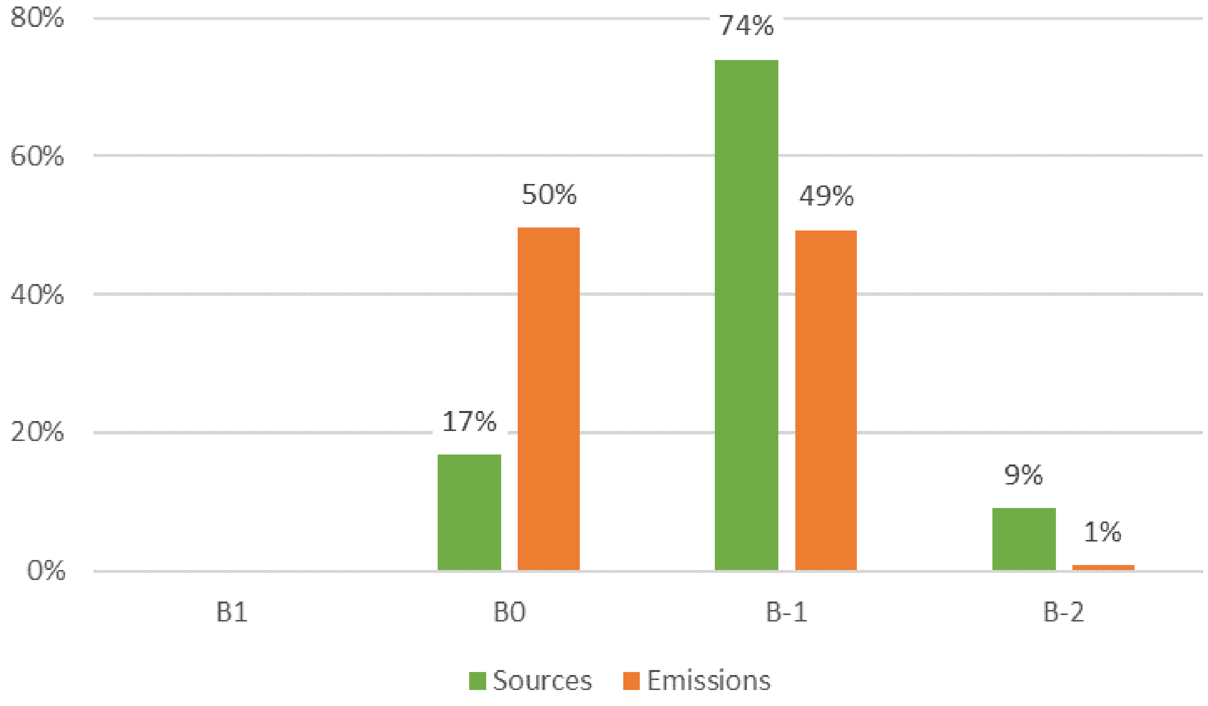
Accurate Emissions at Network Scale

Emission factor-based inventories are inaccurate because of limited sampling
Direct measurement provides accurate emissions at the system level
Vehicle-based measurement offers the scalability, and the sensitivity required for Distribution systems



Emission Abatement

Emission Rate Measurements



Source Size Bin	Measured Flow Rate (SCF/Hr)
B_1	>10
B_0	1 – 10
B_{-1}	0.1 – 1
B_{-2}	< 0.1

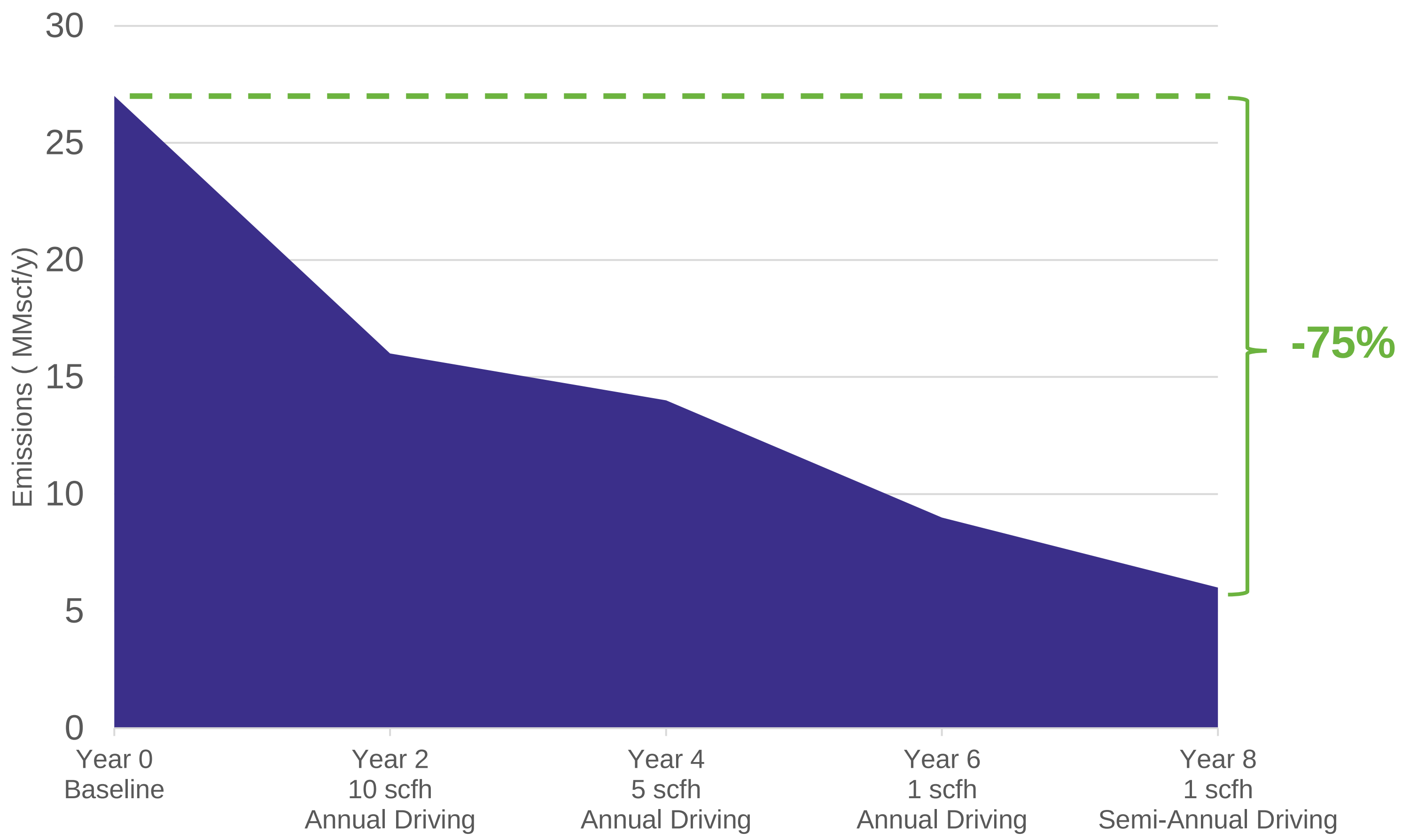
Note: The limited data set from this demo cannot be extrapolated across the full distribution network.

17%
% of Sources that are B_0

50%
% of Emissions that are B_0

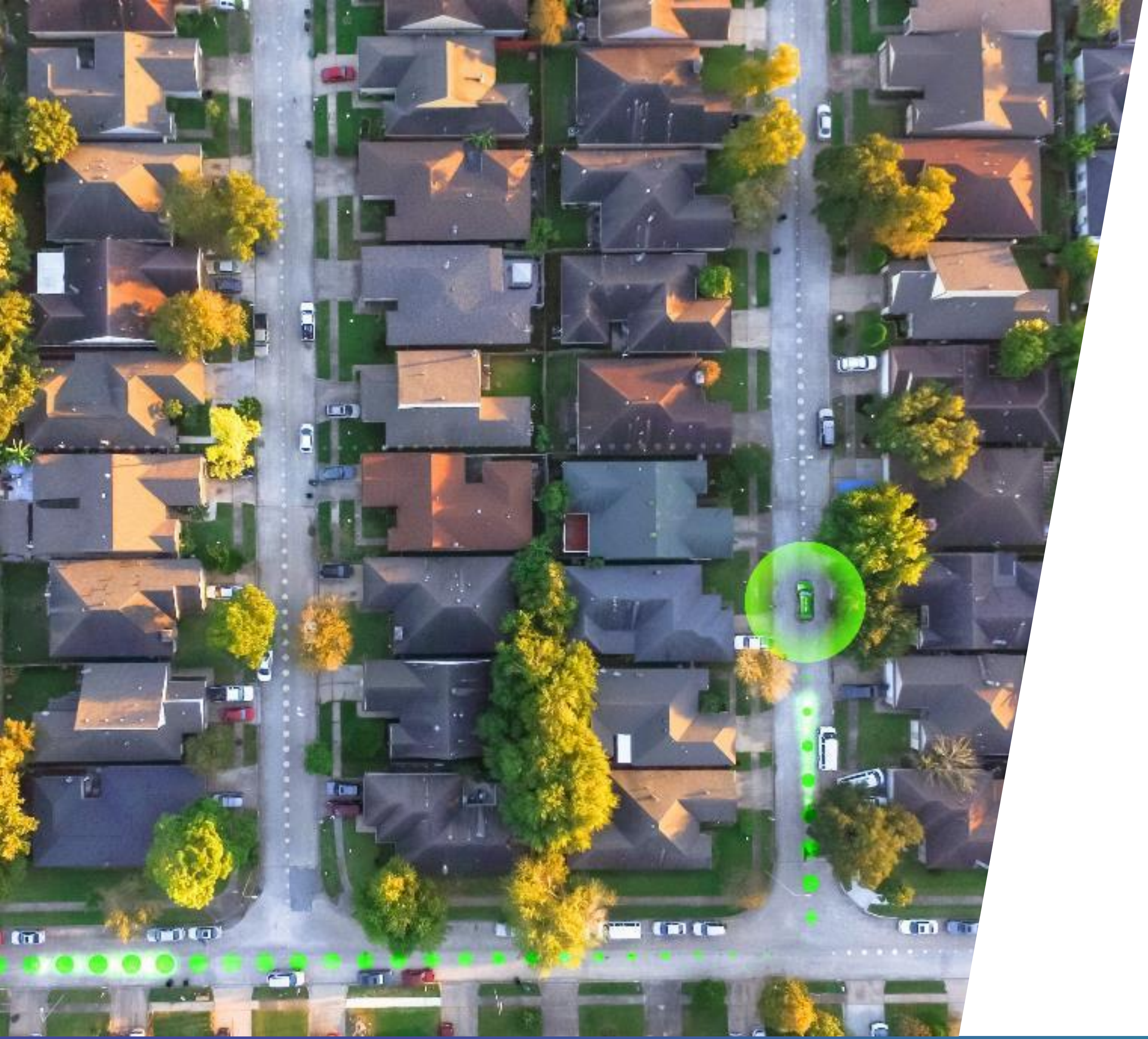
Prioritizing the B_0 sources generates the most effective and less disruptive emission abatement

Example Emissions Reduction Program



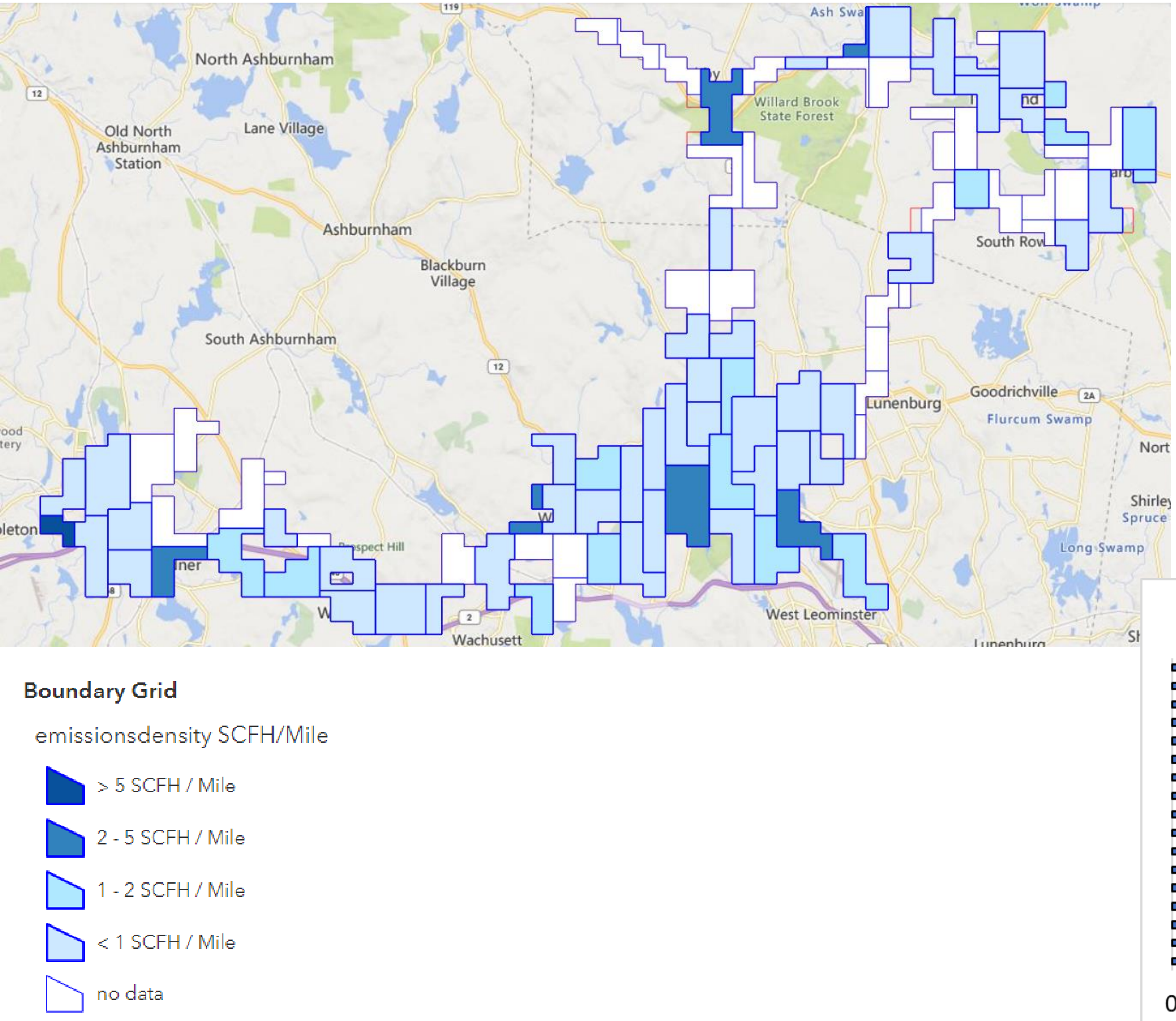
Multi-Staged Program

- Quickly find and repair the largest leaks without overwhelming operational resources.
- Progressively reduce the threshold toward Net Zero.
- Quantify the impact of the program relative to a baseline.

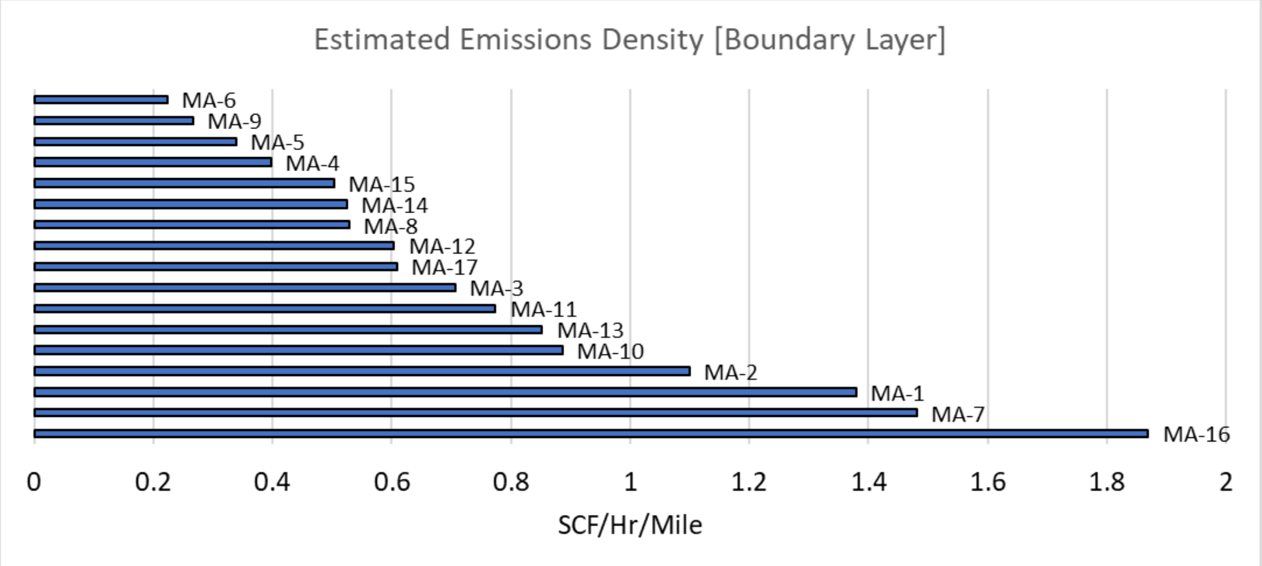


In-depth Analysis

Emissions by Boundary Grid



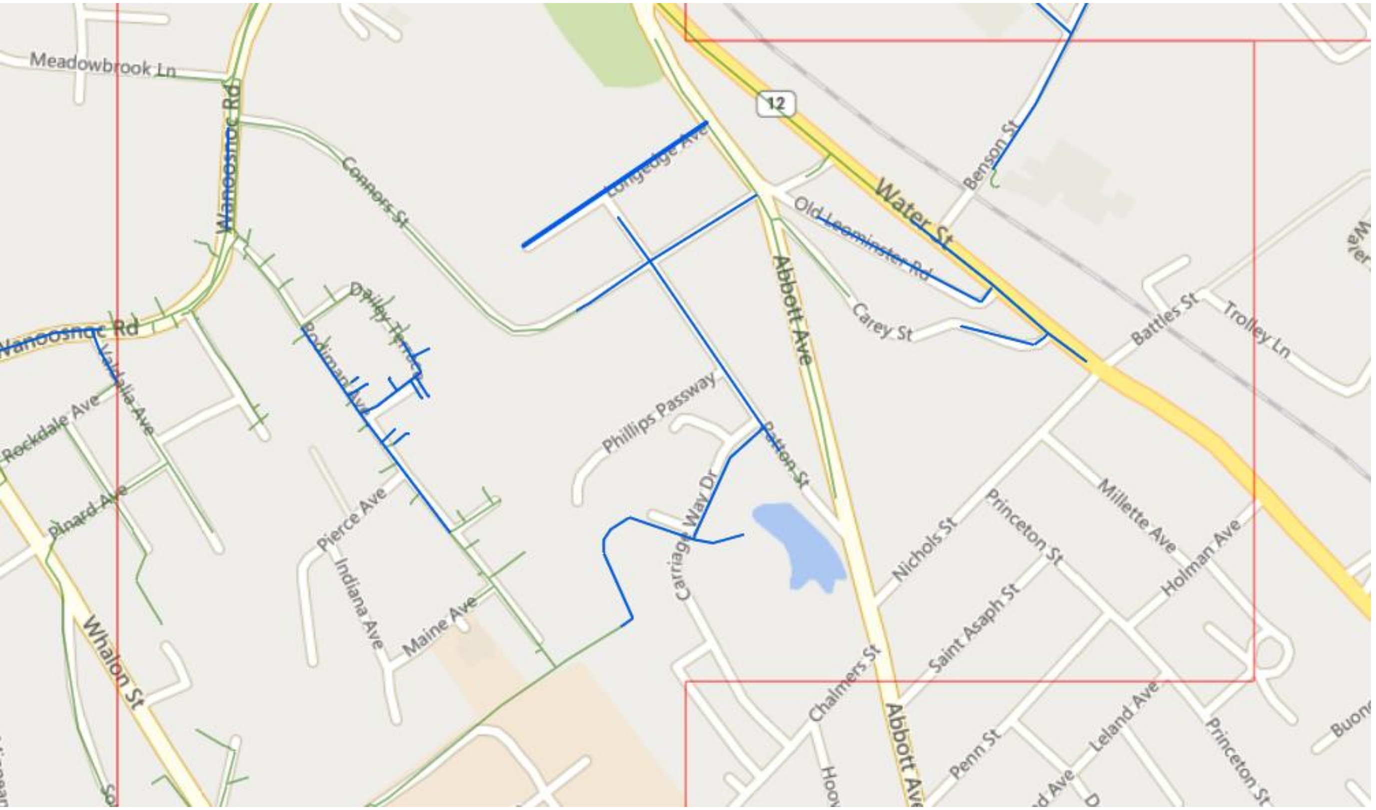
Identify grids with highest estimated emissions density

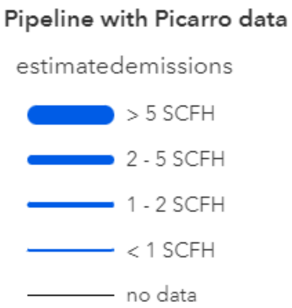


Asset Level Outputs – Estimate Emissions

Identify pipe segments with highest estimated emissions density

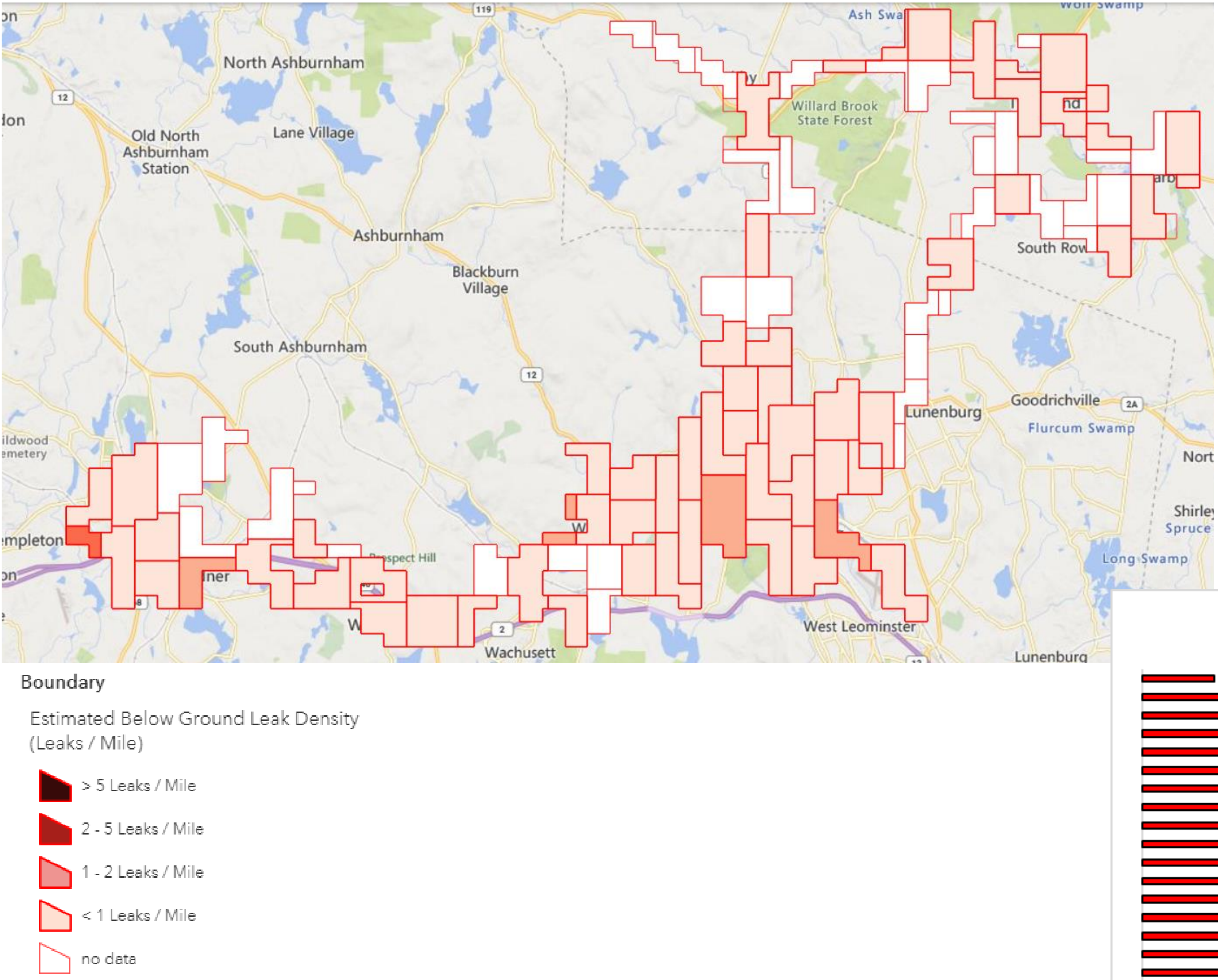
Example: Boundary MA - 10

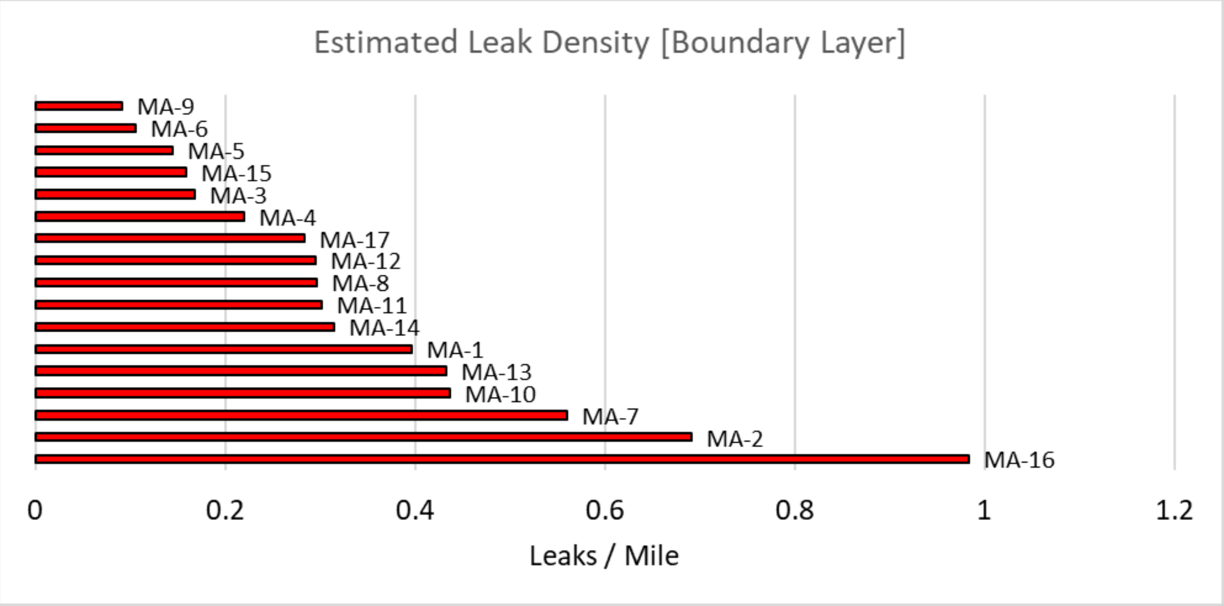




Leak Density by Boundary Grid

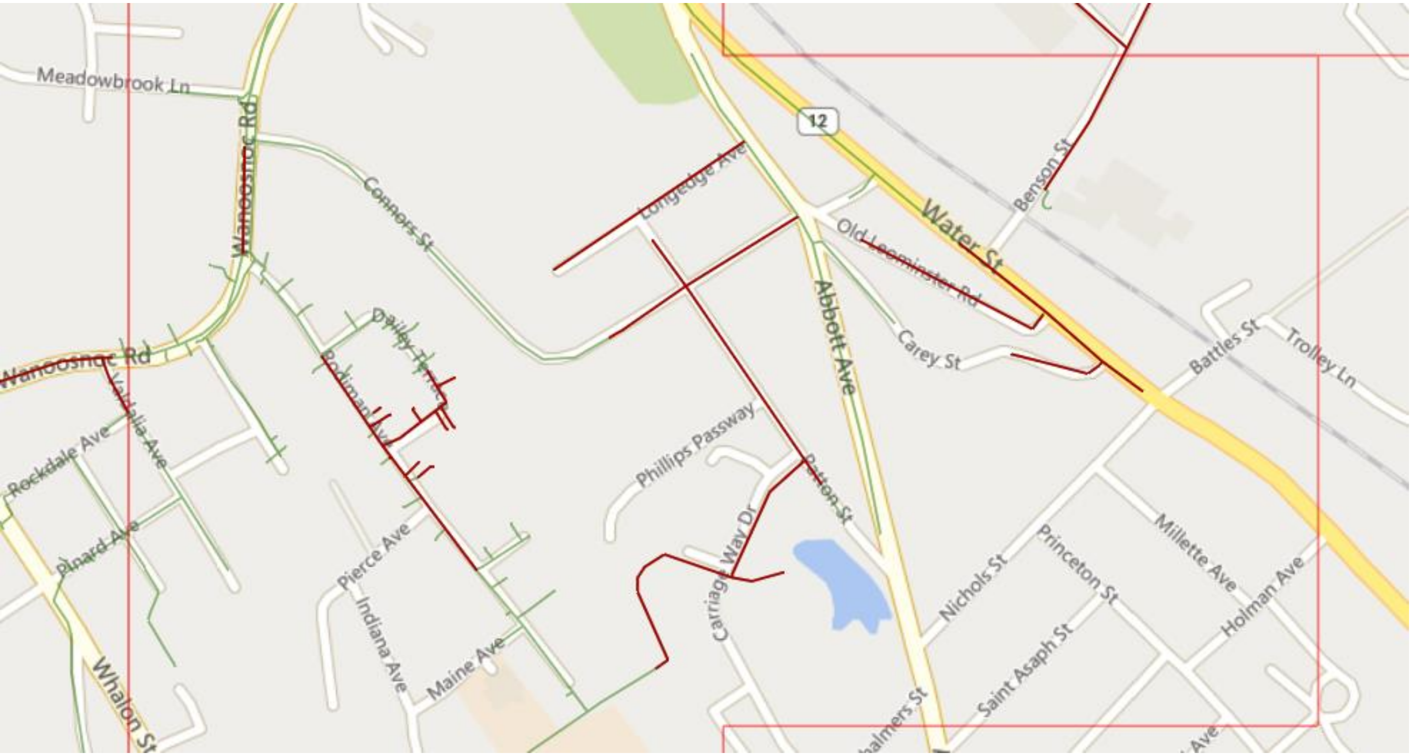
Identify grids with highest estimated leak density





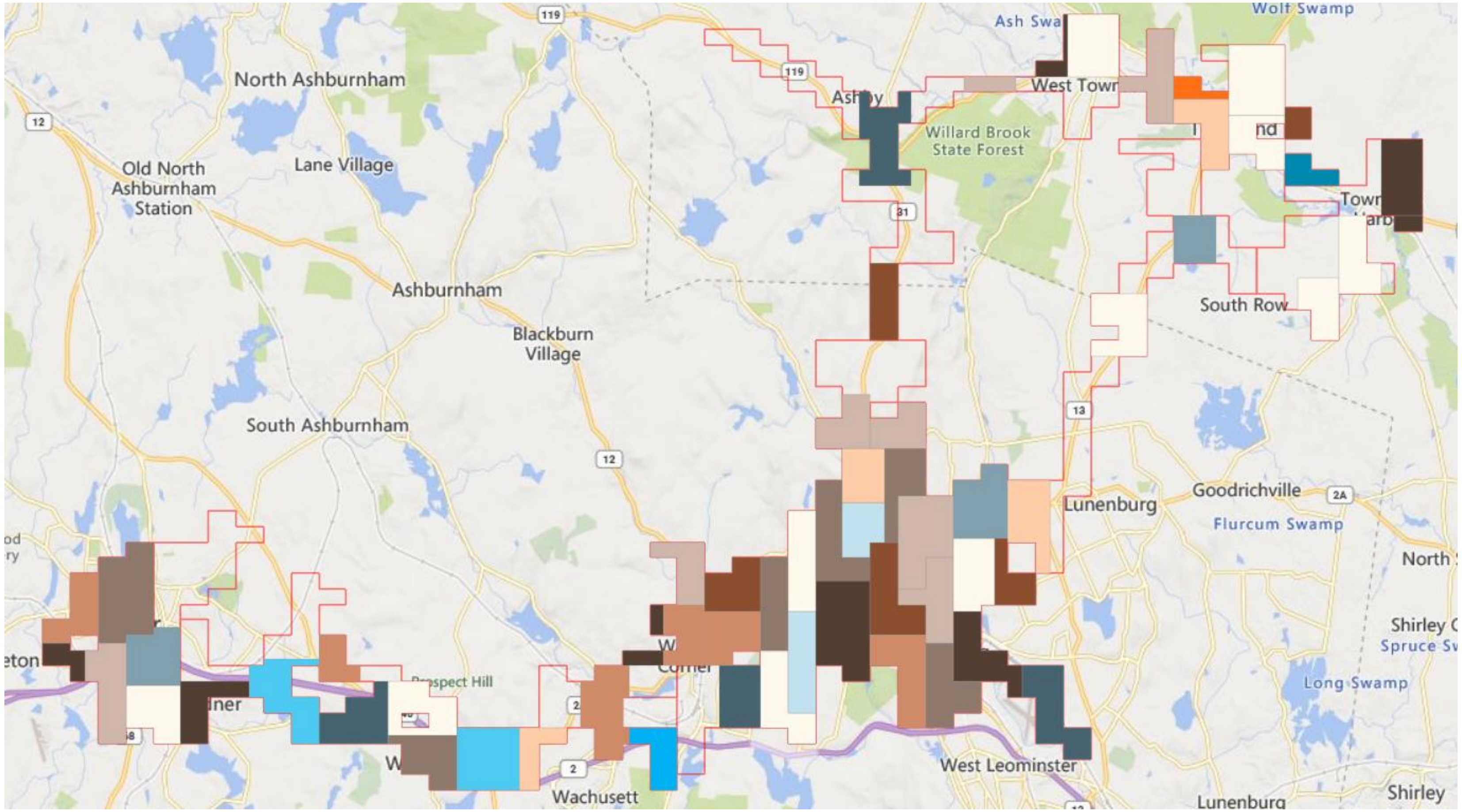
Asset Level Outputs – Estimate Below Ground Leaks

Example - Boundary MA - 10



Identify pipe segments with highest estimated leak density

Boundary Grid Correlation Layer (Leak/Emissions)

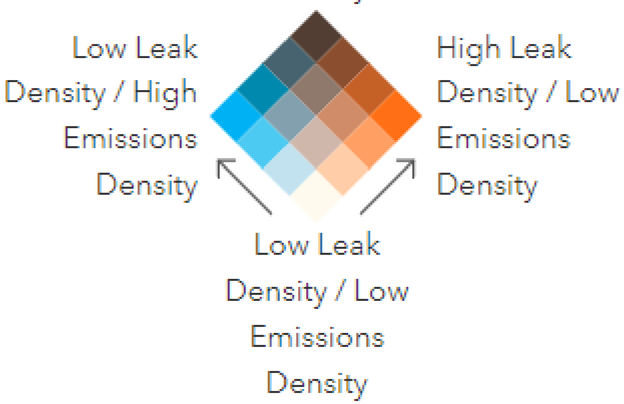


Boundary Grid

Relationship

↖ emissionsdensity SCFH/Mile

↗ Estimated Leak Density (Leaks / Mile)



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Appendices

Assign Sources and Compute Flow Rates

Emissions Measurement and Quantification Playbook

Step 5: Assign sources to each indication (ex. meter set leak, below-ground leak on main)

- *Leak survey data* – Sources are defined based on LISA investigations.
- *Emissions data* – Sources are assigned probabilistically based on confirmed leak data. Model is based on a large set of data collected at Picarro's customers.

Every detection has a probability, BGP_i, to be associated with a below ground pipeline leak.

Step 6: Compute a Representative Flow Rate (RFR) for each measured source.

- Remove bias introduced by measurement of skewed leak size distribution. https://doi.org/10.1016/j.aeaoa.2023.100201

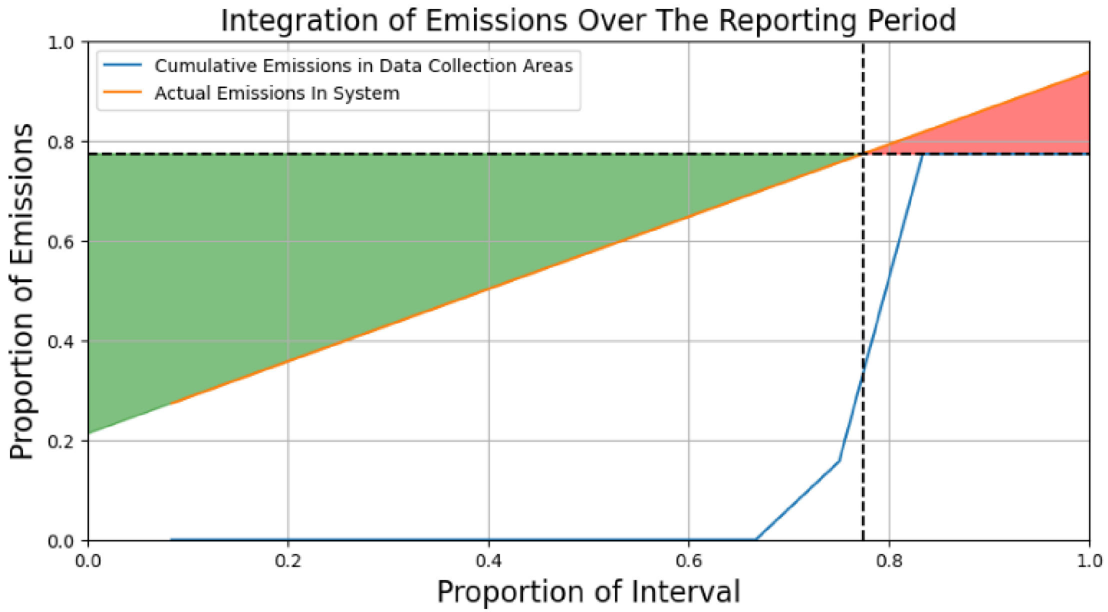
$$Flow\ Rate = \sum_i^{N_i} RFR_i \cdot BGP_i$$

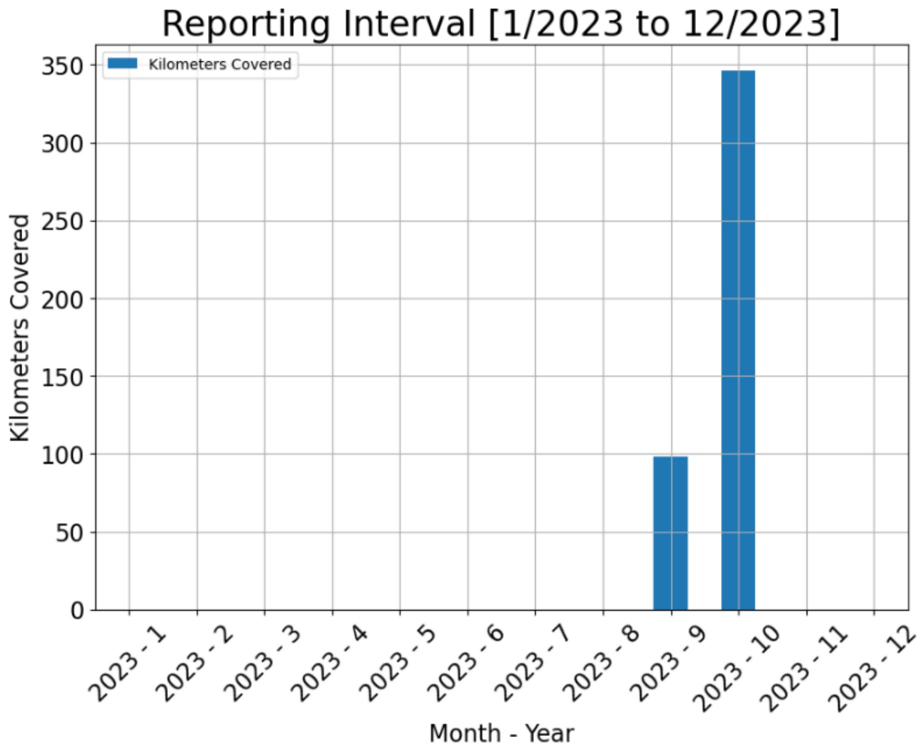
Time Integration

Emissions Measurement and Quantification Playbook

Step 7: Account for the pace of data collection. Each covered asset has one measurement during the reporting period. We must account for two cases:

1. Measured leaks may have existed since the start or during the reporting period.
2. New leaks will develop after the measurement.





$$Emissions = 0.81 \cdot (t_{end} - t_{start}) \cdot \sum_{i}^{N_i} RFR_i \cdot BGP_i$$

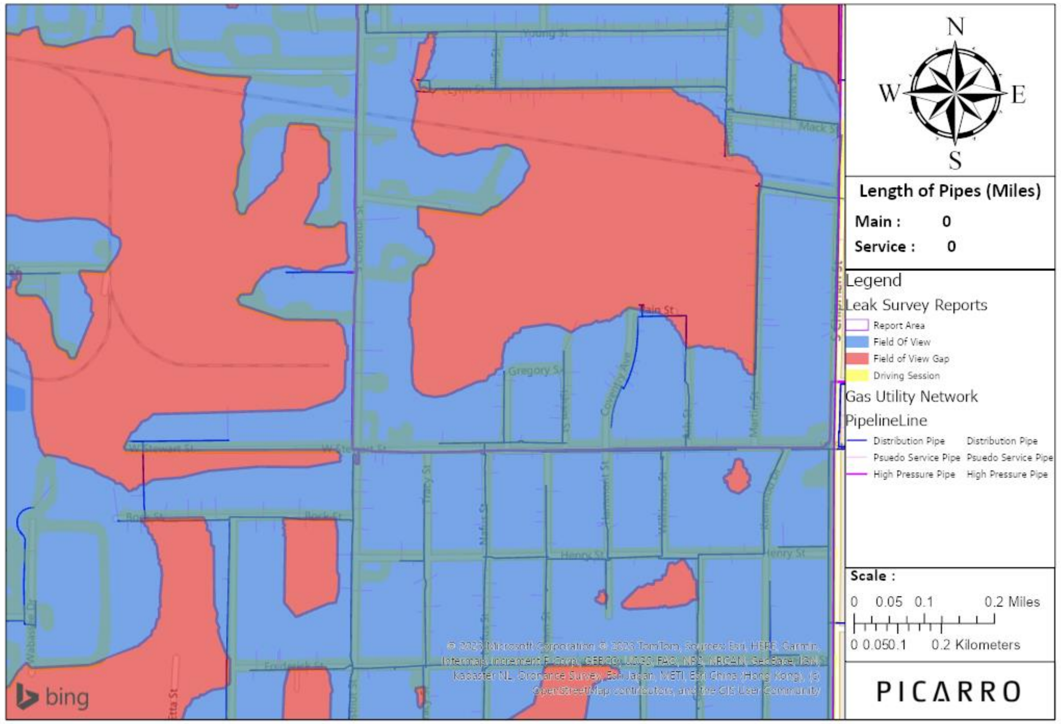
Adjust for Gaps

Remaining assets in the “report” area.

Step 8: Apply a linear extrapolation to account for gaps in Field of View.

- The field of view for the example area below is shown in blue.

CE, A4 Landscape, PNG32



Report Year	Mains Covered In Data Collection Areas [Miles]	Number Of Services Covered In Data Collection Areas	Percent Asset Coverage In Data Collection Areas [%]
Project (1 Month)	249	6135	90%

$$Emissions = 0.81 \cdot \left(\frac{1}{0.90}\right) \cdot (t_{end} - t_{start}) \sum_{i}^{N_i} RFR_i \cdot BGP_i$$

Account for Leak Repairs

Emissions Measurement and Quantification Playbook

Step 9: Account for leak repairs.

- Account for leak repairs before and after data collection.
- Take credit for emissions mitigated through current repair practices.
- Further reductions will come from faster repairs, reducing the time new leaks stay open.

Leak Grade	Percent of Total	Average Time to Repair
1	64%	0.4 days
2	29%	14.5 days
3	7%	31.7 days

$$Emissions = 0.81 \cdot \frac{1}{0.90} \cdot 1.97 \cdot (t_{end} - t_{start}) \sum_{i}^{N_i} RFR_i \cdot BGP_i$$

Accounting for Uncertainties

Emissions Measurement and Quantification Playbook

- Measurement uncertainty (a component of the overall uncertainty) is established through controlled testing.
- Other sources of uncertainty are due to sampling and extrapolation and are determined by the number of sources measured and the distribution of leak sizes in the network. If whole system is measured by Picarro, then there is no sampling uncertainty.