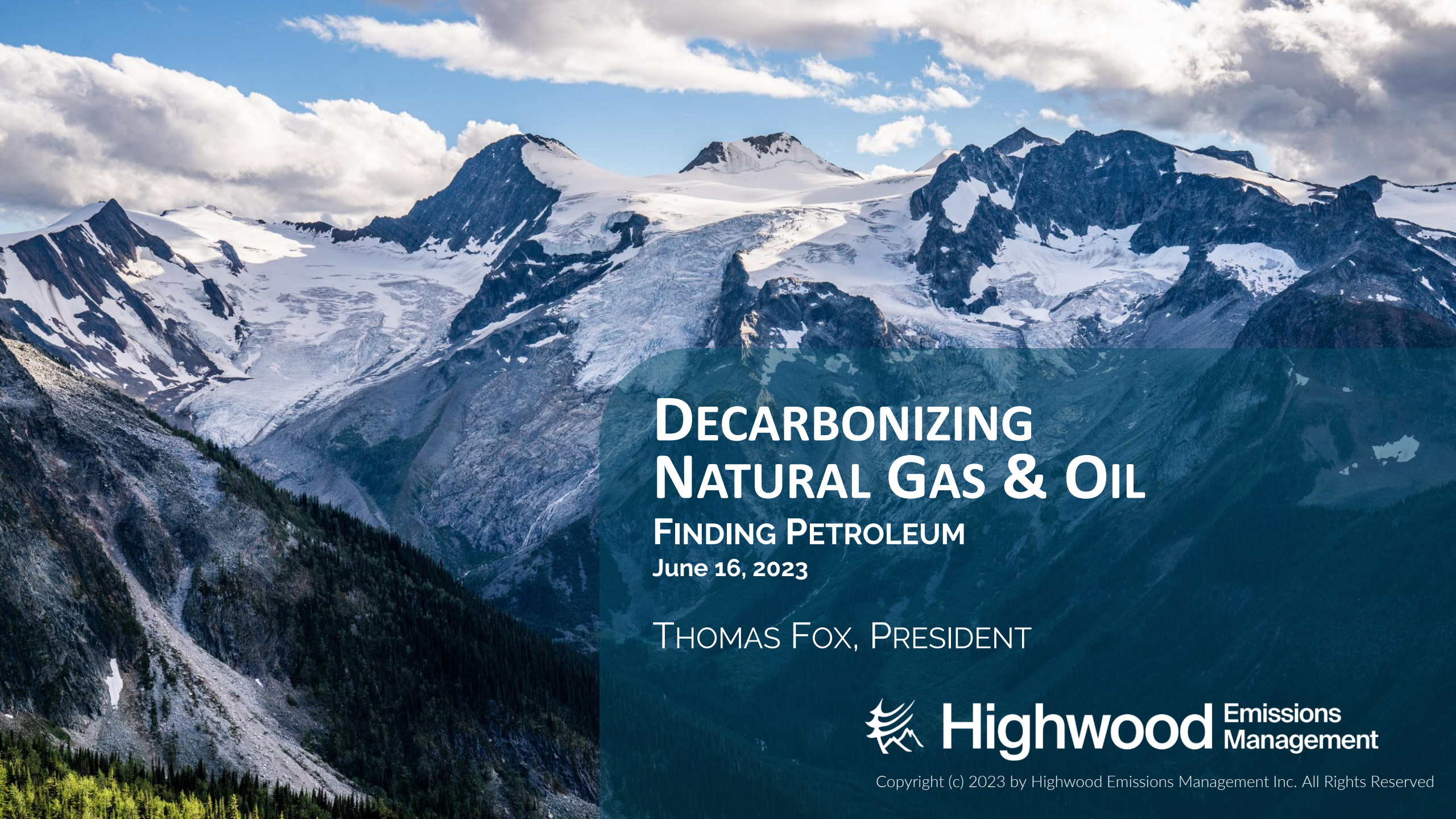

Decarbonizing Natural Gas & Oil

Finding Petroleum

June 16, 2023

Thomas Fox, President

Highwood Emissions Management

Section 1: Lighting a Fire
Section 2: Grasping the Challenge
Section 3: Making a Dent
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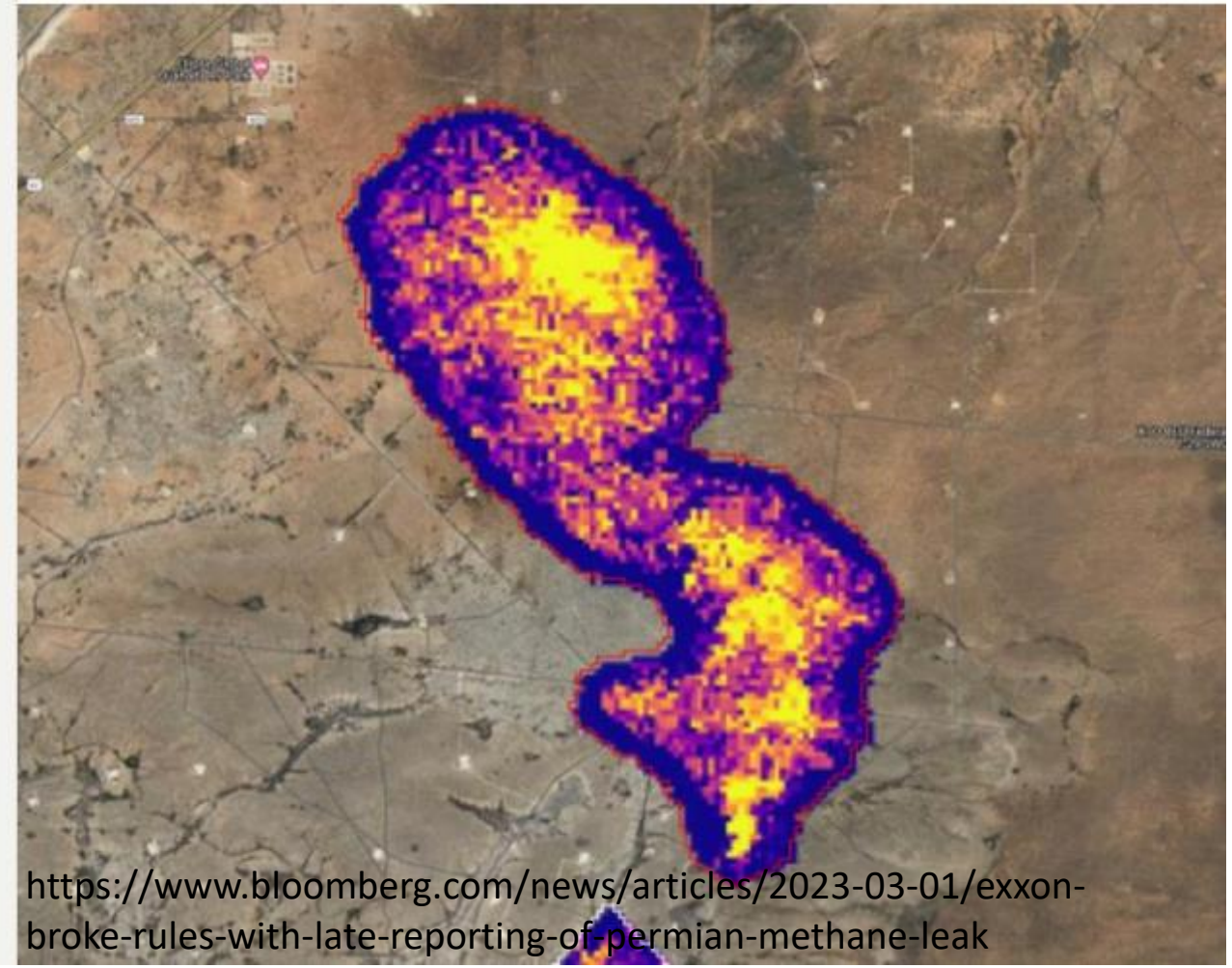
Section 5: Preparing for the Future

Highwood Emissions Management

Highwood Emissions Management

Drivers: Growing Availability of Public Methane Data

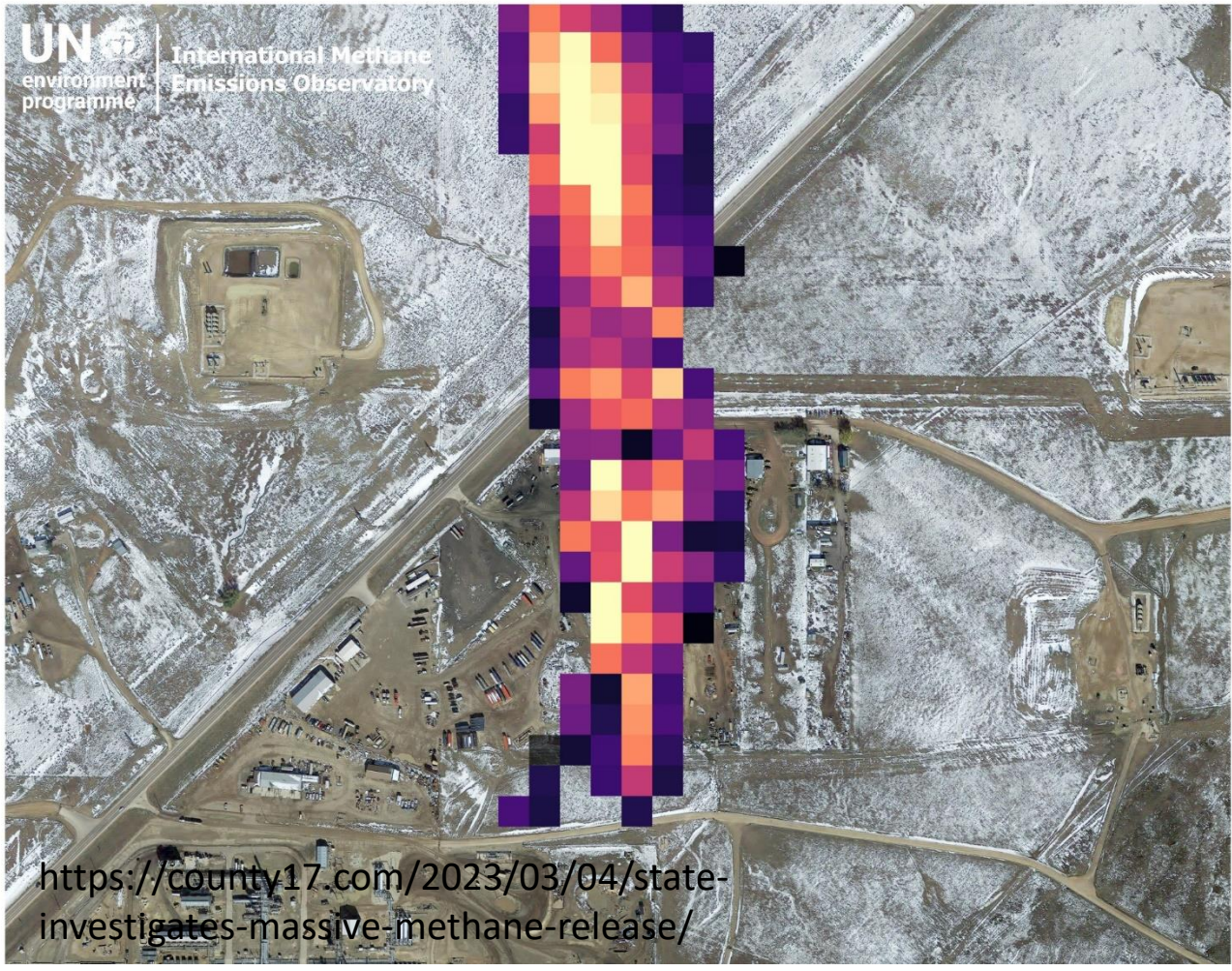
Exxon Broke Rules With Late Reporting of Permian Methane Leak Bloomberg, 2023-Mar-01



https://www.bloomberg.com/news/articles/2023-03-01/exxon-broke-rules-with-late-reporting-of-permian-methane-leak

State investigates massive methane release

Tallgrass Energy, Bloomberg, County17, 2023-Mar-04



https://county17.com/2023/03/04/state-investigates-massive-methane-release/

Highwood Emissions Management

Drivers: Wasted Methane is Lost Revenue

Each circle is an aerial measurement.
Free data on carbonmapper.org

Methane Source Points at This Position

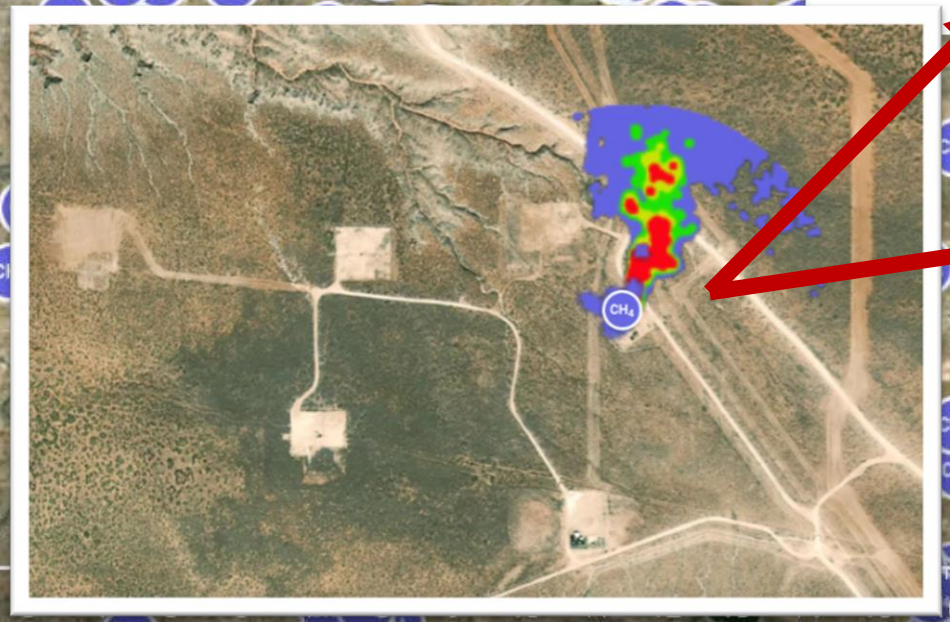
Methane Sources.

Date: October 27th, 2019, 17:53

Source Id: P00685

175323p0000-D

Average Emissions: 921.12 ± 482.71 kg/hr



$1.3MM/year

Basemap

5 km

32.182°N, 103.911°W

Months

4Days

Hours

6 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 1 2 3 4

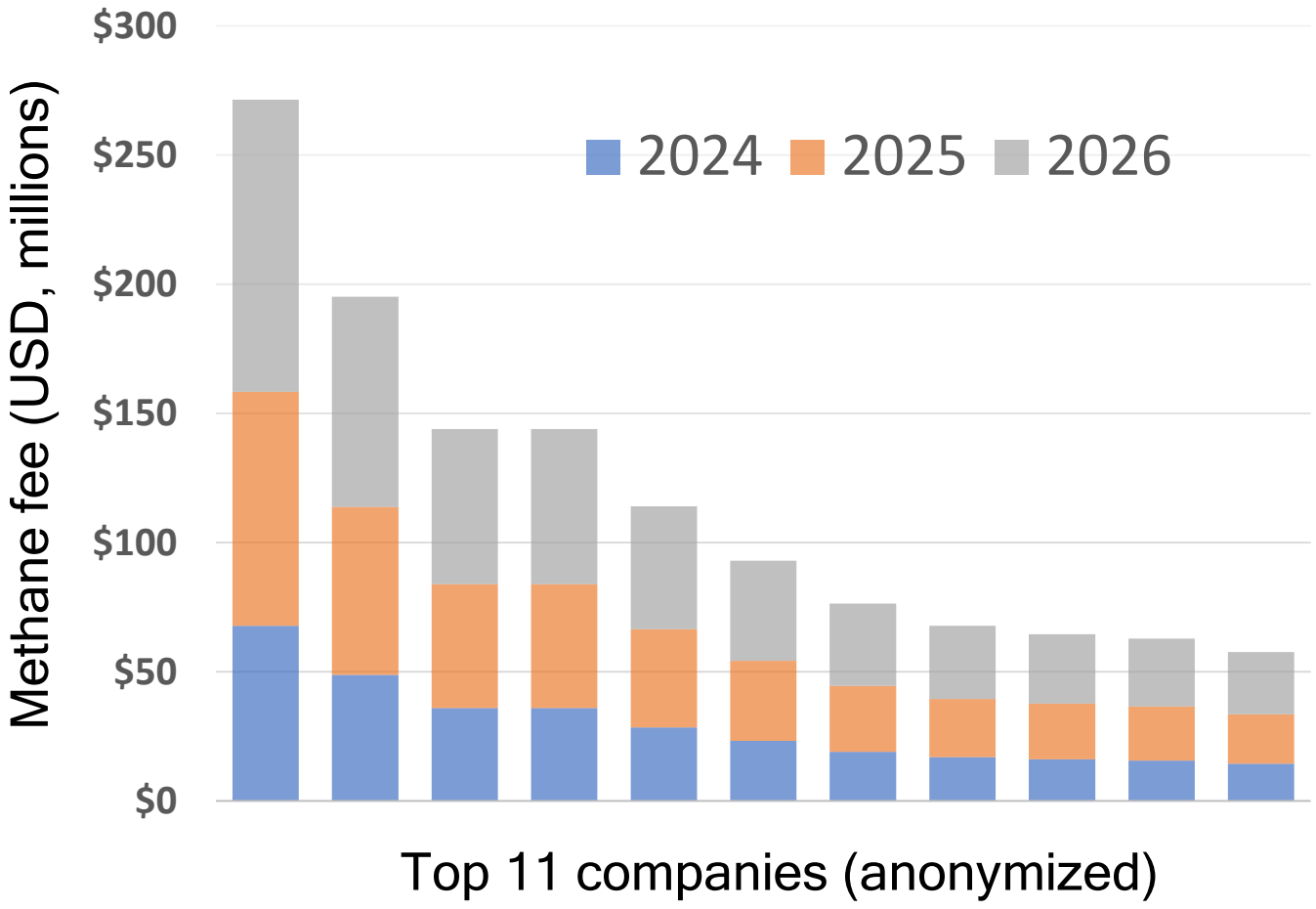
Drivers: Targets & Regulations

Regulations are rapidly evolving, driven by a 0.2% intensity target in the US and a 75% reduction target in Canada.

	ECCC Framework	EPA Supplemental
Destruction	Must achieve ≥ 99% efficiency.	Must achieve ≥ 95% efficiency.
Routine flaring (associated gas)	Prohibited.	Prohibited.
Gas-driven pneumatic controllers/pumps	Prohibited.	Prohibited.
Leak detection – conventional	**Monthly inspections at all sites**	Up to monthly AVO and quarterly OGI/M21.
Leak detection – alternative	Not specified. Expected to be allowed.	Streamlined approvals.
Super-emitters	Not specified.	**A super-emitter response program is implemented for sources ≥ 100 kg/h.**

Canada vs. United States Proposed Methane Rules - Highwood Emissions Management

Drivers: IRA Methane Fee



Facts:

- 2024: EPA data, $900/t
- 2026: Empirical, $1500/t

Highwood Analysis:

- 207 companies will pay
- $700m in 2024
- $1.2 – $6b in 2026
- 17 companies > $100m

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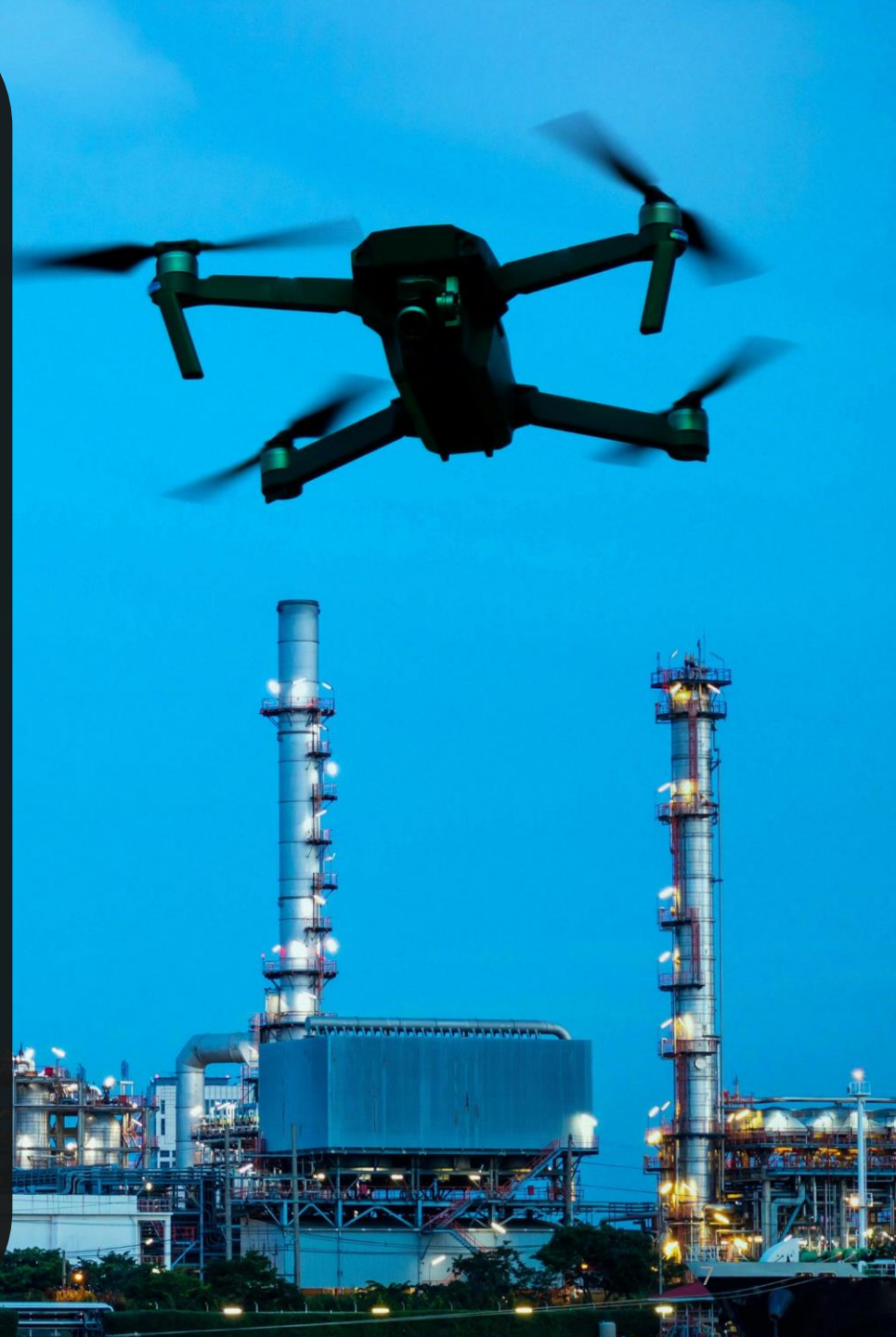


Highwood Emissions Management

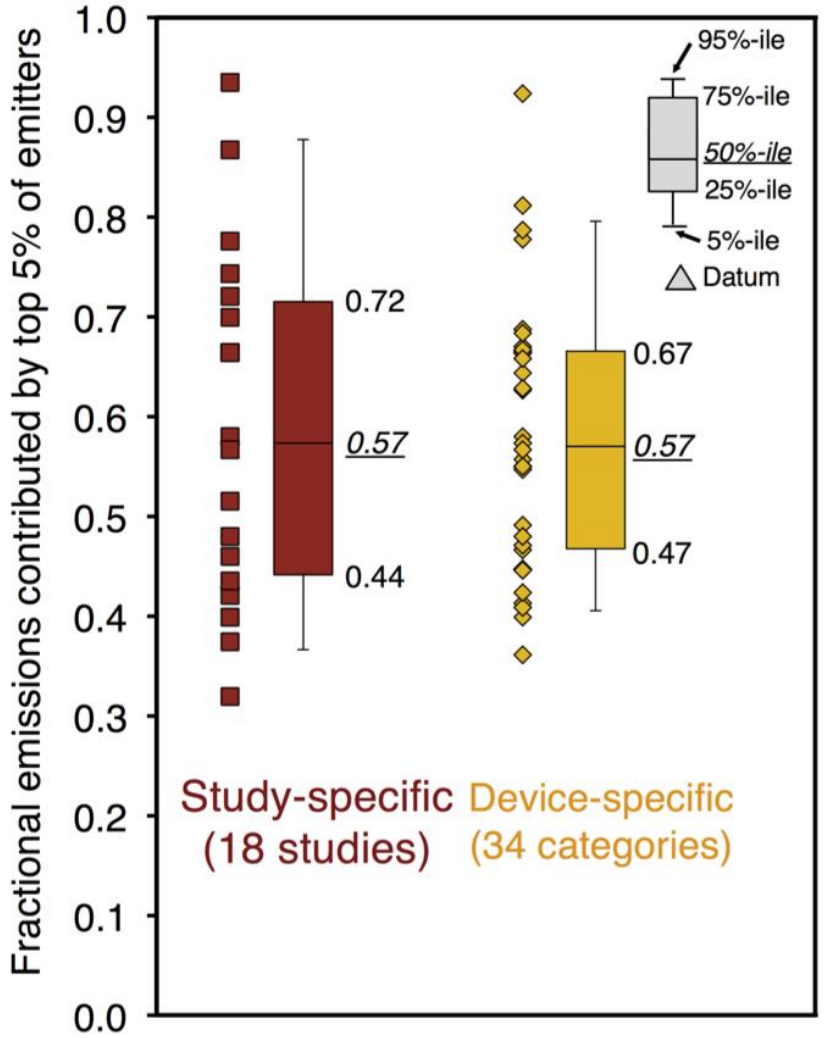
Highwood Emissions Management

Brandt et al., 2016, ES&T

Analysis of ~15,000 measurements from 18 studies

- First methane meta-analysis
- Source-level measurements

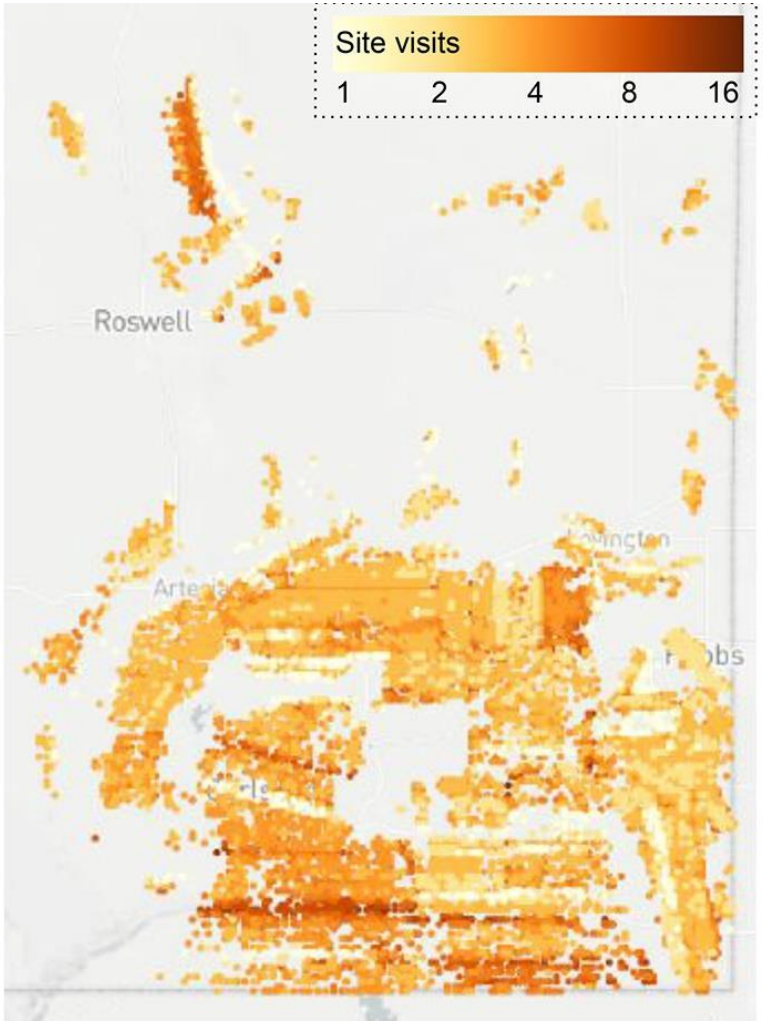
Opportunity: 50% of emissions from only 5% of sources



Brandt, Adam R., Garvin A. Heath, and Daniel Cooley. "Methane leaks from natural gas systems follow extreme distributions." *Environmental science & technology* 50.22 (2016): 12512-12520.

Best data: Measurements 650% higher than Reported Emissions

Large methane plumes are not accounted for in your inventory

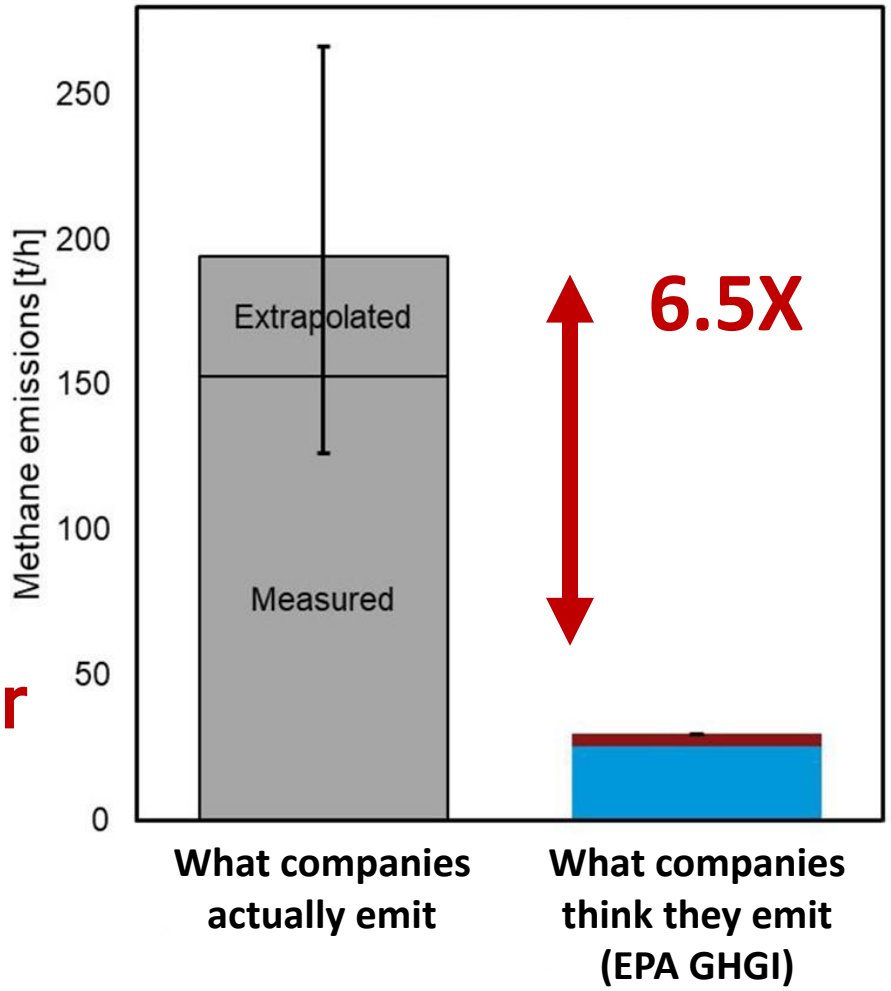


Largest ever measurement campaign in history

98,000 aerial well site visits

50% emissions from sources above 375 MCF per day

9.4% of production is lost in NM Permian, or $275MM per year



Chen et al., Environmental Science & Technology **2022** *56* (7), 4317-4323

Highwood Emissions Management

Measurement is new and (very) complicated

Highwood's database contains > 200 commercially available solutions

Satellite

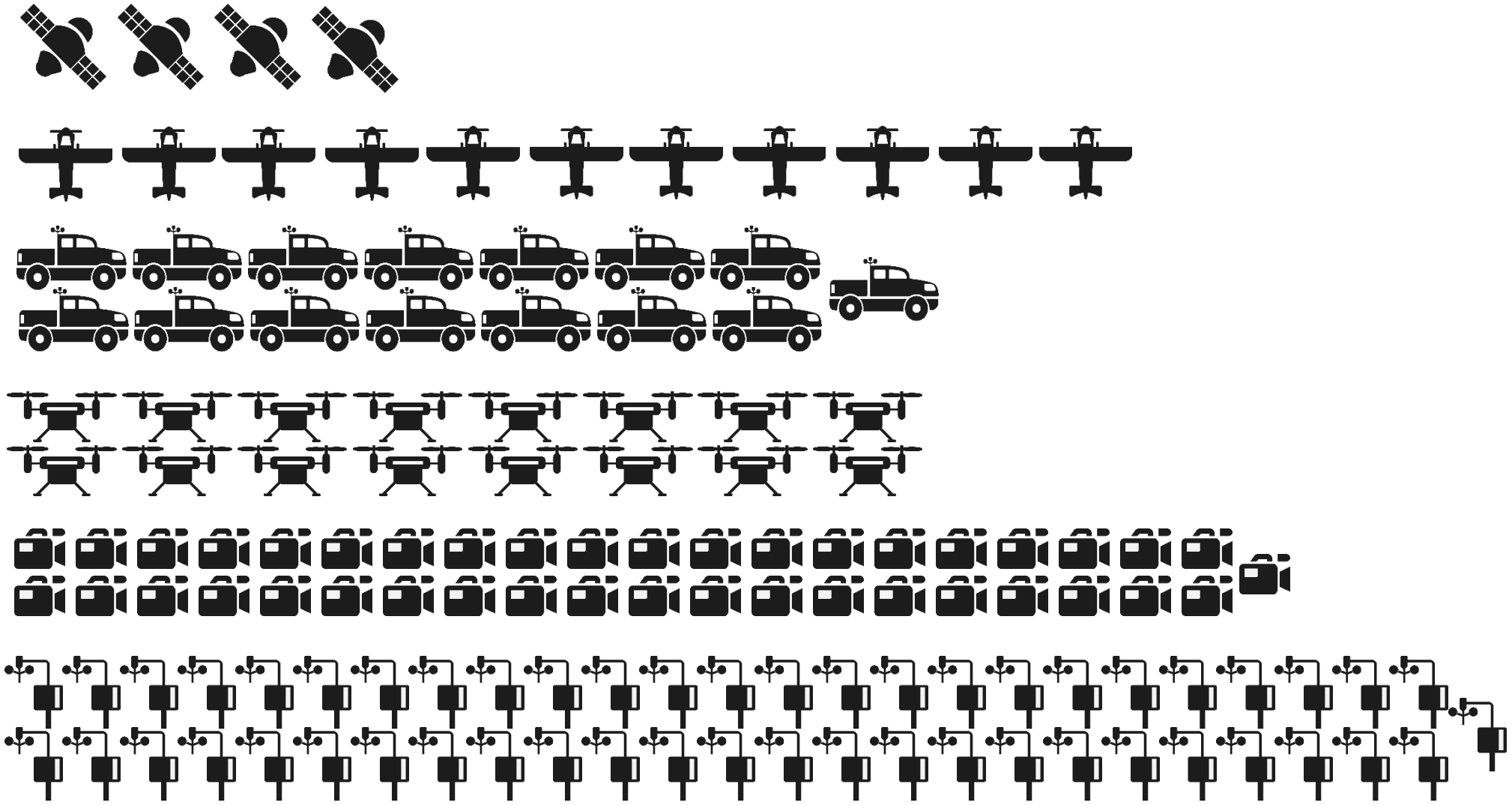
Aircraft

Mobile Ground Lab

UAV (Drone)

Handheld

Stationary



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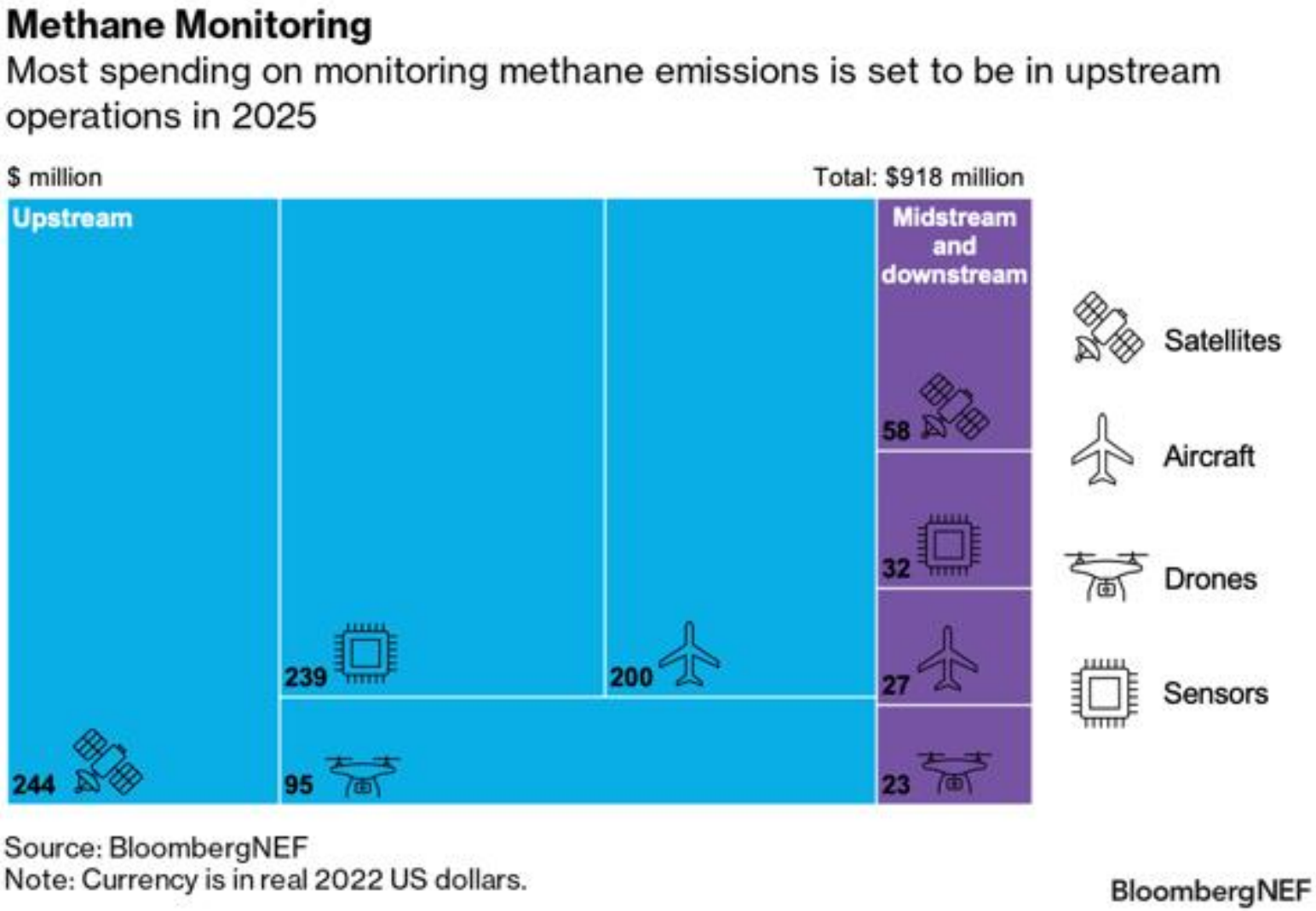
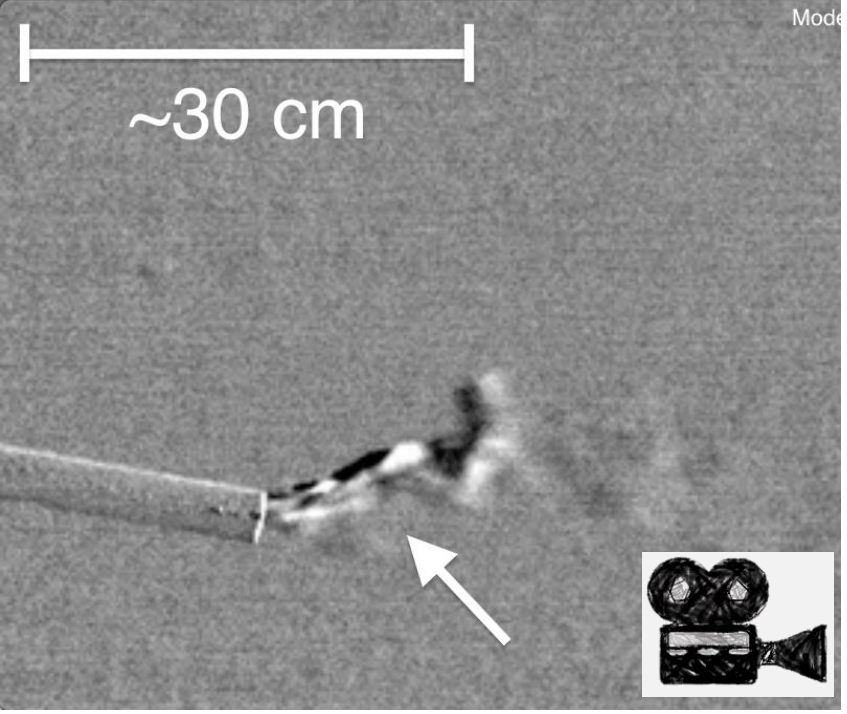
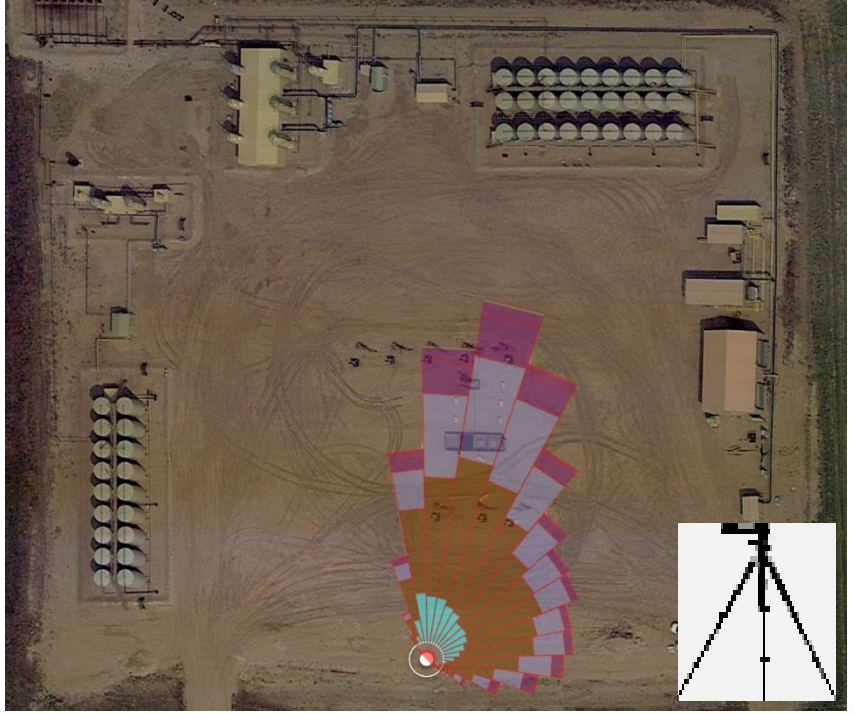
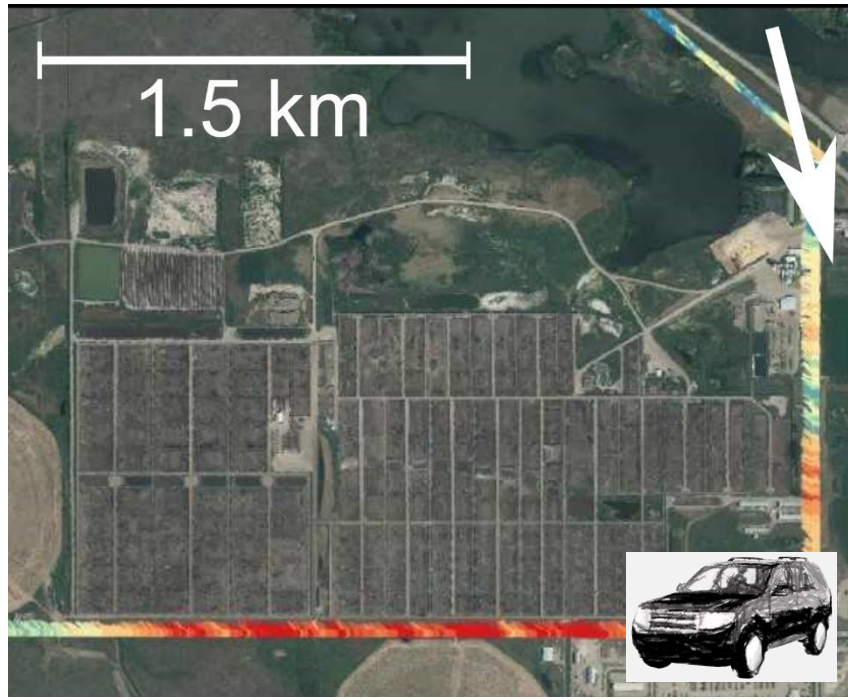
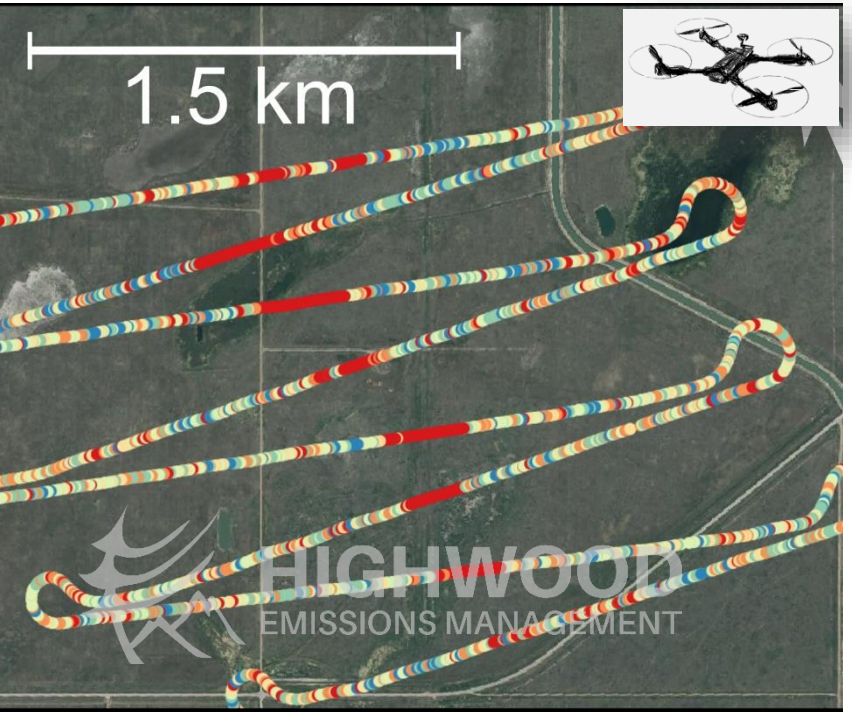
Methane Detection Growth in North America

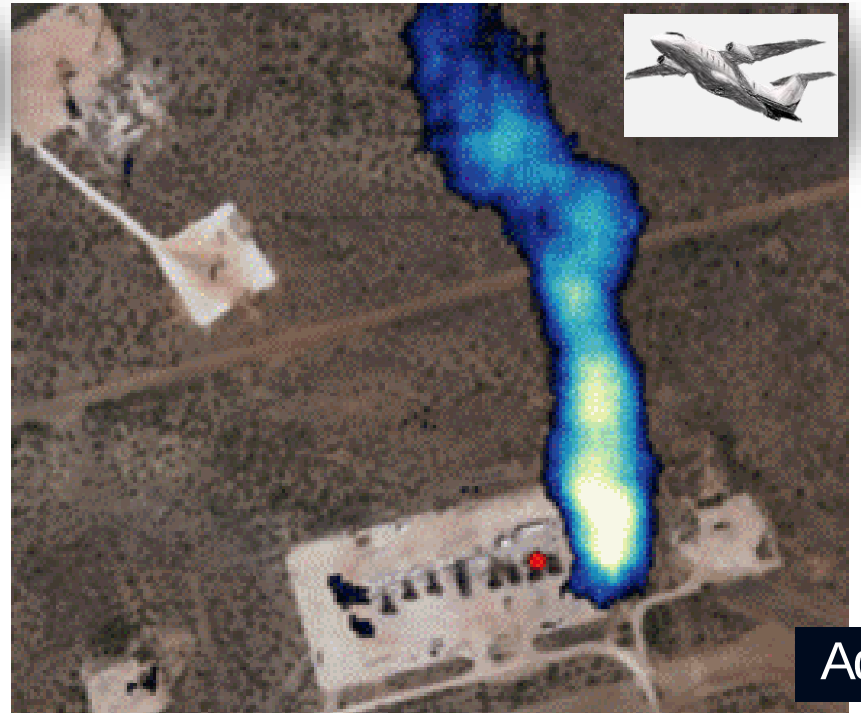


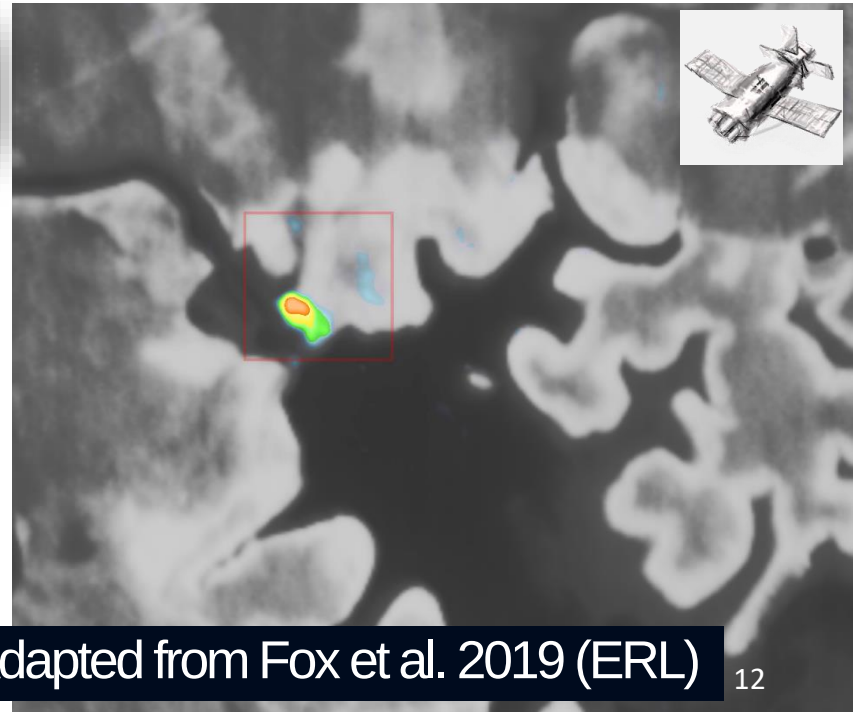












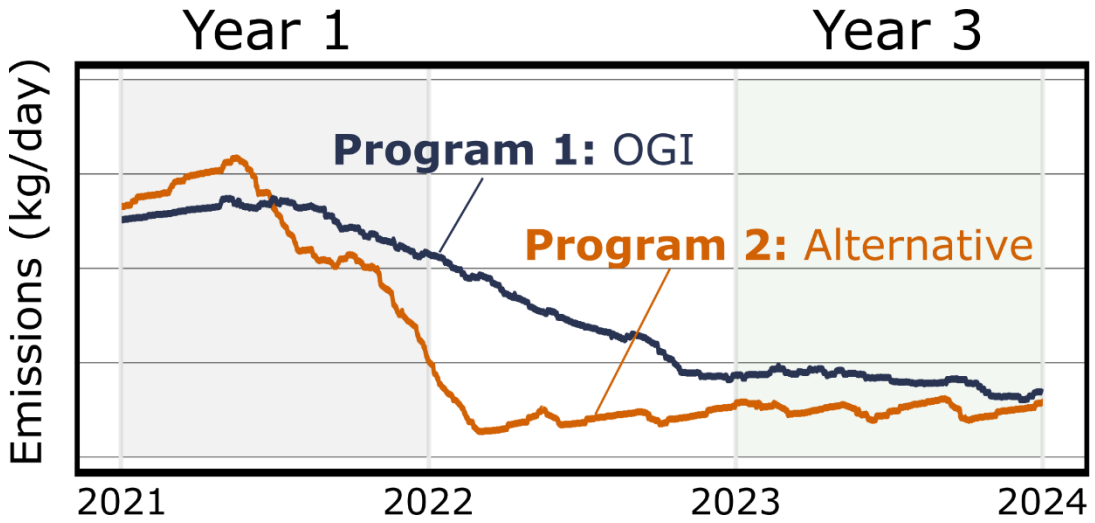
Adapted from Fox et al. 2019 (ERL)

Highwood Emissions Management

Plan your technology deployment strategy

LDARSim

The Leak Detection and Repair Simulator (LDAR-Sim) is a virtual world that predicts emissions mitigation and cost-effectiveness of different LDAR programs.



Who uses LDAR-Sim?

Designed by a team of industry experts, regulators, and academics

Published, peer-reviewed, open source, and transparent

Industry to optimize detection and quantification technology deployment

Innovators to get regulatory approval and understand product-market fit

Regulators to evaluate policy and inform compliance assurance strategy

Academics to build the next generation of methane monitoring solutions

Methane Technology & LDAR-Sim Training

[LDAR-Sim Training - Highwood Emissions Management]

LDAR-Sim information and resources

Peer-reviewed article
LDAR-Sim paper 1
The original LDAR-Sim journal article
Explore →

Peer-reviewed article
LDAR-Sim paper 2
Explores the role of top-down measurement
Explore →

Open-source code
LDAR-Sim on github
Find the code base for LDAR-Sim V2
Explore →

Documentation
User manual
Learn LDAR-Sim function and parameters
Explore →

Education
LDAR-S
A brief intro
Explore →

Section 1: Lighting a Fire
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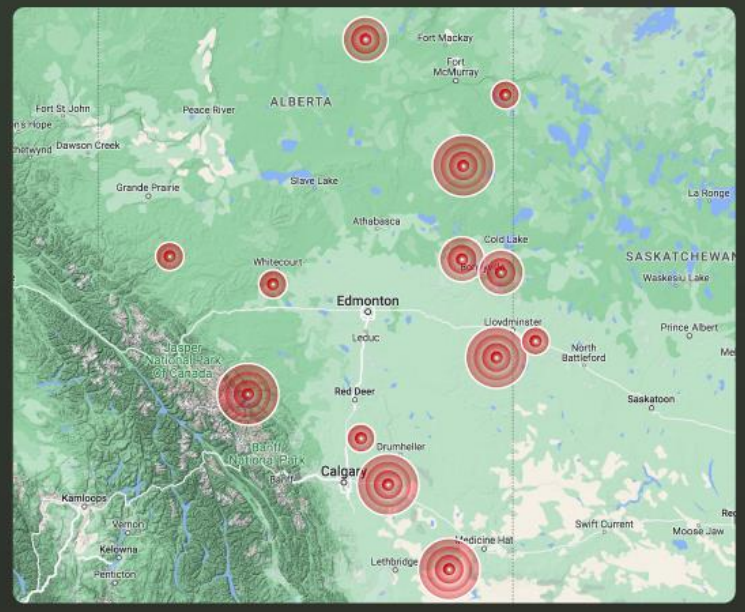
Highwood Emissions Management

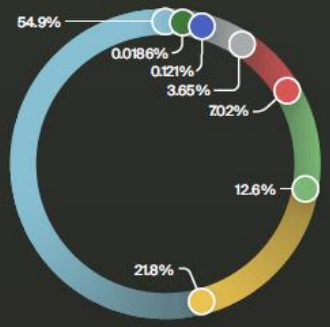
Highwood Emissions Management

Measurement-Informed Roadmapping

1 Understand your emissions

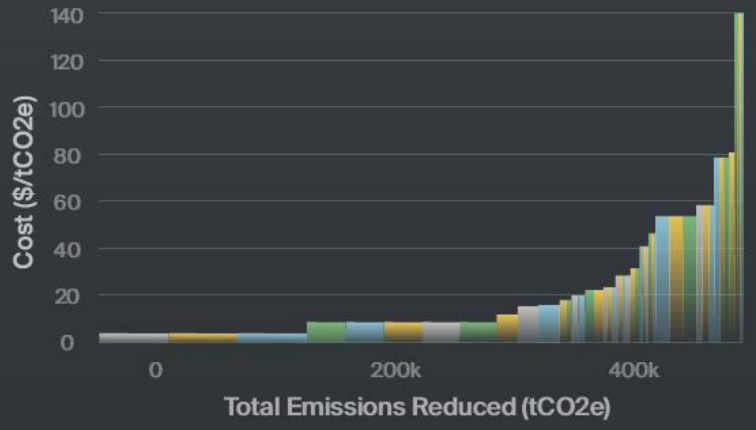


- Compressor Station 54.9%
- Gas Well 21.8%
- Pad 12.6%
- Multi Well Battery 7.02%
- Group Point 3.65%
- Single Well Battery 0.121%
- Other 0.0186%

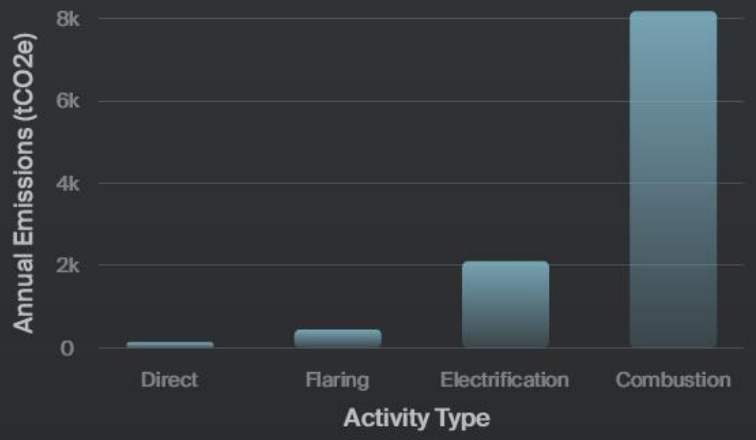


2 Evaluate opportunities

Emissions by Activity

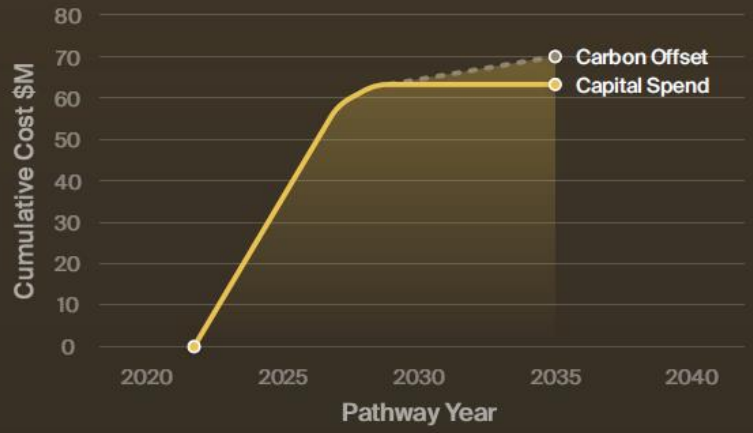


Total Annual Emissions vs Activity Type



3 Optimize your pathway

Net Zero Pathway Cost



Emissions

Highwood Analysis 1: Feasibility of Canada's Targets

Canada-wide study

31,750 Sites Simulated

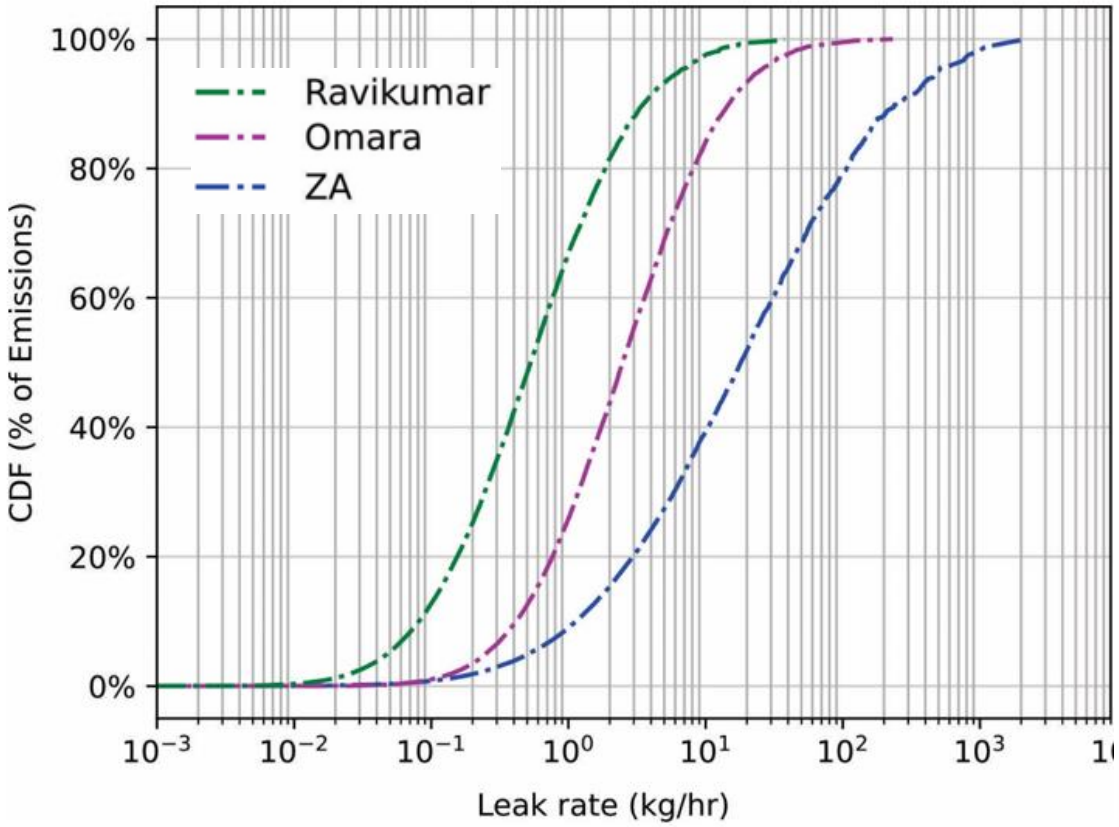
31Mt CO_2e
Vented Emissions Annually
Western Canadian Oil and Gas

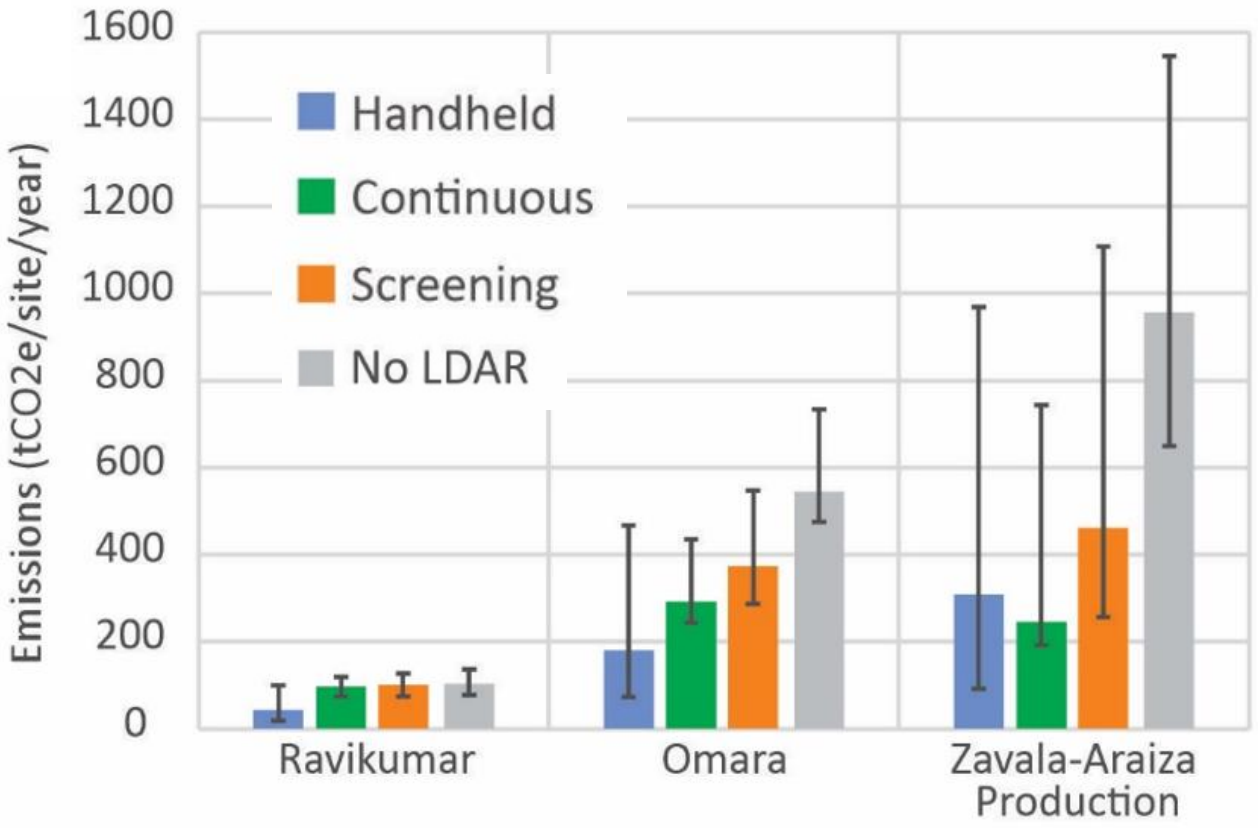
32%
Lower emissions if AB grid moves to 50/50 natural gas/low carbon energy

$2.2B
Capital Expenditure
to achieve 75% reduction in routine vented emissions

$10B
Cost estimate to electrify all compressor stations in AB and SK

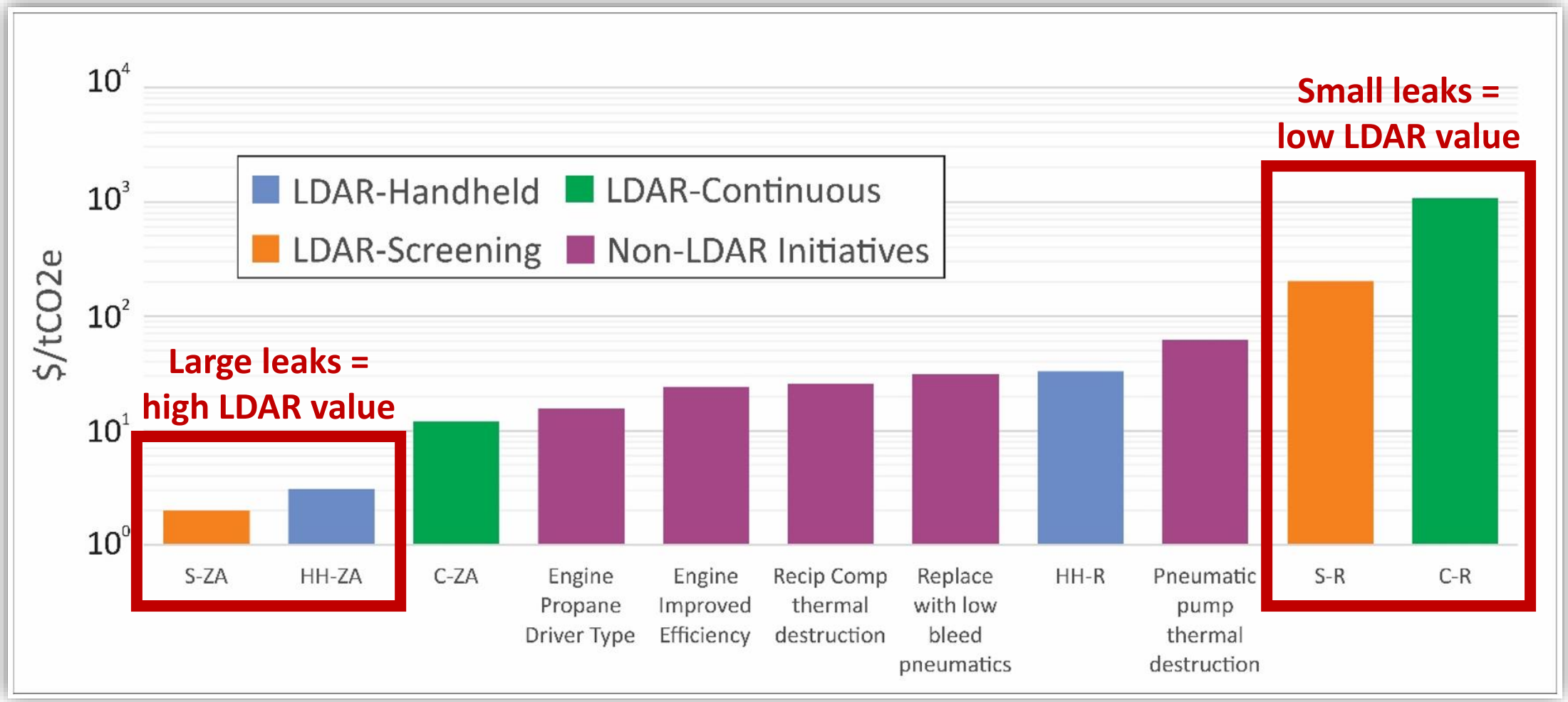
Highwood Analysis 2: World Petroleum Congress





24TH WORLD PETROLEUM CONGRESS 2023
CALGARY | CANADA
17 - 21 SEPTEMBER

Highwood Analysis 2: World Petroleum Congress



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Highwood Emissions Management

How can O&G companies take credit for strong performance?

Highwood Emissions Management

Highwood Emissions Management

The variety of voluntary initiatives

An Overview of

Voluntary Emissions Reduction Initiatives

for the Oil and Gas Industry

August 2022

Download free on our website!

Highwood Emissions Management

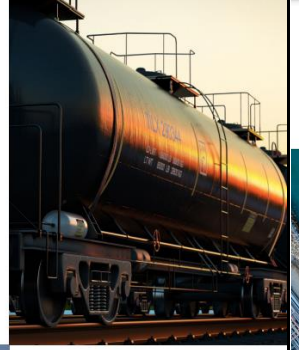
46 Voluntary Initiatives

CERTIFICATIONS

47 EO100™ Standard for Responsible Energy Development
48 The MiQ Standard
49 TrustWell™ Responsible Gas
50 Xpansiv Digital Natural Gas & Methane Performance Certificates

COMMITMENTS

52 Oil and Gas Climate Initiative
53 Oil and Gas Methane Partnership 2.0 (OGMP)
54 ONE Future Methane Intensity Protocol
55 EPA Methane Challenge Program
56 The Environmental Partnership
57 Science-Based Targets Initiative



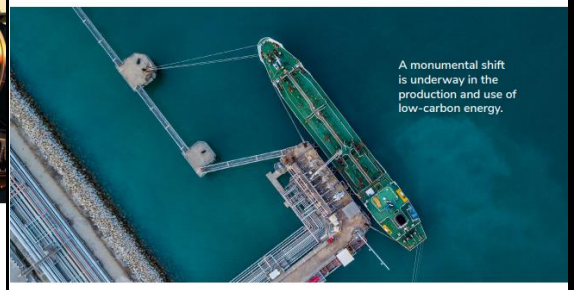
GUIDELINES

59 Veritas Protocols
60 EPA Natural Gas STAR Program
61 NGSI Methane Emissions Intensity Protocol
60 CDP Scores
63 GRI 11: Sector Standards for Oil and Gas
64 Task Force for Climate-Related Financial Disclosures (TCFD) Framework
65 Sustainability Accounting Standards Board (SASB) Oil and Gas Standard
66 IPIECA Sustainability Reporting Guidance
67 SGE Methodology
68 Cheniere QMRV Protocol
69 GIIGNL MRV & GHG Neutral Framework

OTHER INITIATIVES

71 Methane Guiding Principles
72 Global Methane Challenge
73 Global Methane Alliance

Executive Summary



The critical importance of mitigating the impacts of climate change is now widely acknowledged. Regulators and markets are driving action to lower industrial greenhouse gas (GHG) emissions and align with the 2015 Paris Agreement. The oil and natural gas (O&G) industry is no exception. Indeed, O&G emissions – especially methane – are seen as 'low hanging fruit' relative to more challenging sources of carbon from transportation, steel, cement, and agriculture.

New pressures on the O&G industry present operators with exciting opportunities and daunting risks. One of these opportunities is for operators to go 'above and beyond' regulatory decarbonization requirements by participating in a Voluntary Emissions Reduction Initiative. A voluntary initiative is a coordinated effort managed by an administering organization that enables participants to take standardized voluntary steps towards targeting, achieving, and/or taking credit for emissions reductions. By participating, proactive energy companies can demonstrate their environmental leadership, appeal to investors, and in some cases command a premium for certified low-carbon products.

Early in 2021, our team at Highwood Emissions Management observed a rapidly growing ecosystem of voluntary initiatives available to the O&G industry. Our clients expressed increasing confusion as they attempted to navigate a new and expanding network of programs, asking questions like "Which one is best?" and "What is the benefit to my organization?"

In May 2021, we published our first report, bringing structure and guidance to the rapidly emerging voluntary initiatives landscape. We identified 20 distinct voluntary initiatives and defined them as certifications, guidelines, commitments, or ESG ratings. We also introduced disclosure levels and offered recommendations for how administering organizations might improve their programs.

The first edition of this report was disseminated internationally and read by industry executives, regulators, investors, innovators, and diverse organizations participating in – or impacted by – voluntary initiatives. However, much has changed over the past year. In 2021 we predicted consolidation of those 20 initiatives – but we were wrong. Instead, many new certifications, methodologies, and even registries have arisen for differentiated gas. Meanwhile, existing initiatives have changed, often by incorporating more nuance and complexity in their requirements.

We conclude with a set of recommendations from Highwood to guide stakeholders as we collaboratively move to address existing knowledge gaps, strengthen credibility, increase uptake, and realize clearer benefits to participation.

1. The oil and gas industry should continue to work collaboratively towards an industry where rigorous, measurement-based independent certification is the norm.
2. Administering organizations should articulate their value proposition in terms of expected benefits from participation.
3. More collaboration is needed among administering organizations. A good example is the recent partnership between Equitable Origin and MiQ, who have teamed up to offer full ESG certification (EO100) combined with a rigorous focus on methane (MiQ).
4. Administering organizations and investors should collaborate to ensure that assessments provide value for current and future financial and investor reporting.
5. Participants in certification and measurement efforts should commit to increasing accuracy, consistency, and transparency, acknowledging that the industry will be judged by its worst actors.
6. Onlookers should be wary of 'new initiative' syndrome. It may be tempting to create new initiatives to remedy perceived issues with existing programs. It may sometimes be better to work together to strengthen and consolidate existing initiatives.
7. The adoption of direct methane measurement is a positive trend, but more needs to be learned about technology detection performance, emission rate estimation uncertainty, and sampling strategies.

Jessica Shumlich
Chief Executive Officer
Highwood Emissions Management

Key knowledge gaps

1. How can consolidation and harmonization of initiatives improve?
2. How can emissions measurement technologies be used to collect meaningful data?
3. What is the level of effort required for a rigorous measurement program?
4. How should reconciliation of measurements and bottom-up inventories be performed?
5. Is there a meta-initiative that can collect, aggregate, and disseminate reported data?
6. How can more robust and transparent differentiated gas markets be established?

Emerging standards are providing a clearer lens to help organizations identify risks and opportunities within their processes. However, we have yet to witness widespread participation by industry. Understandably, reporting to these initiatives requires an investment of time and money. Until the benefits of these initiatives are clearly articulated, industry will remain hesitant, wondering whether to believe in the hype or pursue more compelling opportunities.

In our 2021 report, we gave structure to the complex world of voluntary emissions reduction initiatives. We will be expanding on that structure in this report, adding more initiatives, performing new analyses, and delivering fresh insights. Our aim is to encourage the adoption of these initiatives by revealing their benefits and making it easier for readers to map out their emissions management journeys.

We believe that the O&G industry can be a robust, self-monitoring, and self-regulating ecosystem built on transparent methodologies and routine public disclosure of emissions data. Each voluntary initiative is a compass that guides the industry towards a shared vision of responsible energy.

Please reach out with your feedback, thoughts, or suggestions – we will listen earnestly as we continue to build and evaluate the systems that reward industry for strong emissions performance.

Thomas Fox
President
Highwood Emissions Management

What's new in the 2022 report?

1. We expanded our analysis to include 8 new initiatives not covered in 2021 including GTI Energy's Veritas, Xpansiv Digital Fuels Program, Cheniere's QMRV Initiative, and others.
2. We broadened the scope of our analysis to cover the entire supply chain, including gathering and boosting, processing, transmission, LNG, and distribution.
3. We devised a new scale to evaluate an initiative based on its reporting and public disclosure requirements. Likewise, an initiative is also assessed on its transparency.
4. We circulated detailed questionnaires and collected a significant amount of data directly from administering organizations to inform results.
5. We evaluated initiatives across new criteria, including Scope 1-3 emissions coverage, geographical coverage, the volume of gas certified, and the engagement value for participating operators.
6. We have included a series of feature articles on current trends and emerging paradigms, including:
   a. The Role of Measurement
   b. Differentiated Gas Across the Supply Chain
   c. Selecting the Right Initiative for You

What is OGMP 2.0?

The Oil and Gas Methane Partnership (OGMP) 2.0 is a voluntary UN initiative to help the O&G industry curb methane.

Global Reporting Framework

With 100+ signatories around the world, OGMP 2.0 is consensus based and promotes continuous improvement.

Measurement & Reconciliation

Grounded in measurement, OGMP 2.0 requires companies to build, validate, and refine source-level inventories.

Five Levels & Gold Standard

Participating companies achieve the Gold Standard when they reach Level 4 (source-level measurement) with a plan to reach Level 5 (site-level measurement and reconciliation).

Highwood Emissions Management

MiQ now certifies > 20% of gas produced in US

1. Calculated **Intensity**

$$= \frac{\text{Methane emitted}}{\text{Natural gas produced}}$$

2. Robust **Monitoring Technology Deployment** at Facility- and Source-levels.

3. **Company Practices** Policies and procedures for methane emissions management.

Accredited third-party Certifying Bodies audit and verify

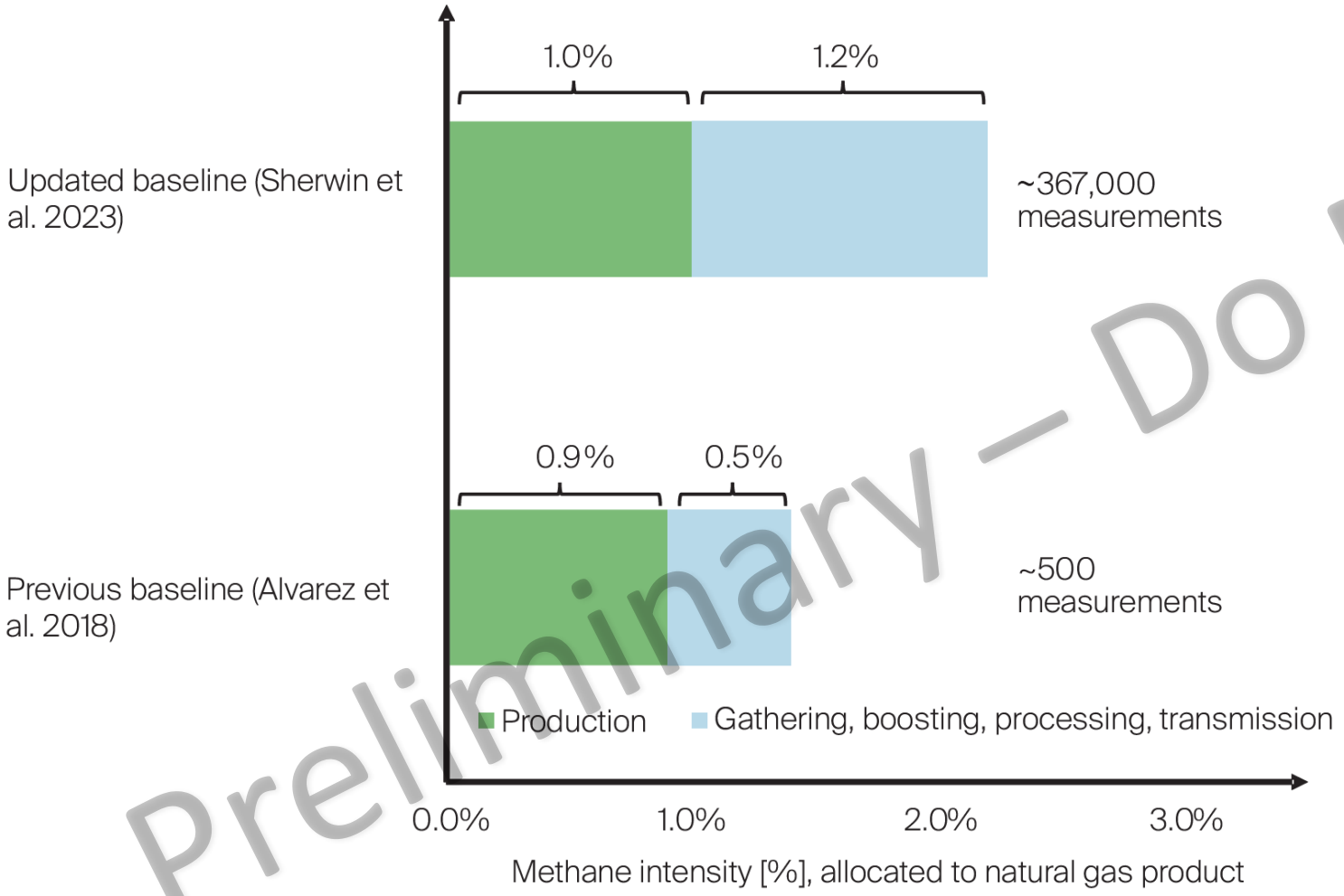
≤ 0.05%	Quarterly	Stringent	A
≤ 0.10%	Semi-annually	High	B
≤ 0.20%	Semi-annually	Medium	C
≤ 0.50%	Annually*	Mandatory minimum	D
≤ 1.00%	Annually*	Mandatory minimum	E
≤ 2.00%	Annually*	Mandatory minimum	F

MiQ

bp CHESAPEAKE ENERGY EQT

ExxonMobil REPSOL COMSTOCK RESOURCES

MiQ-Highwood US Methane Intensity Index



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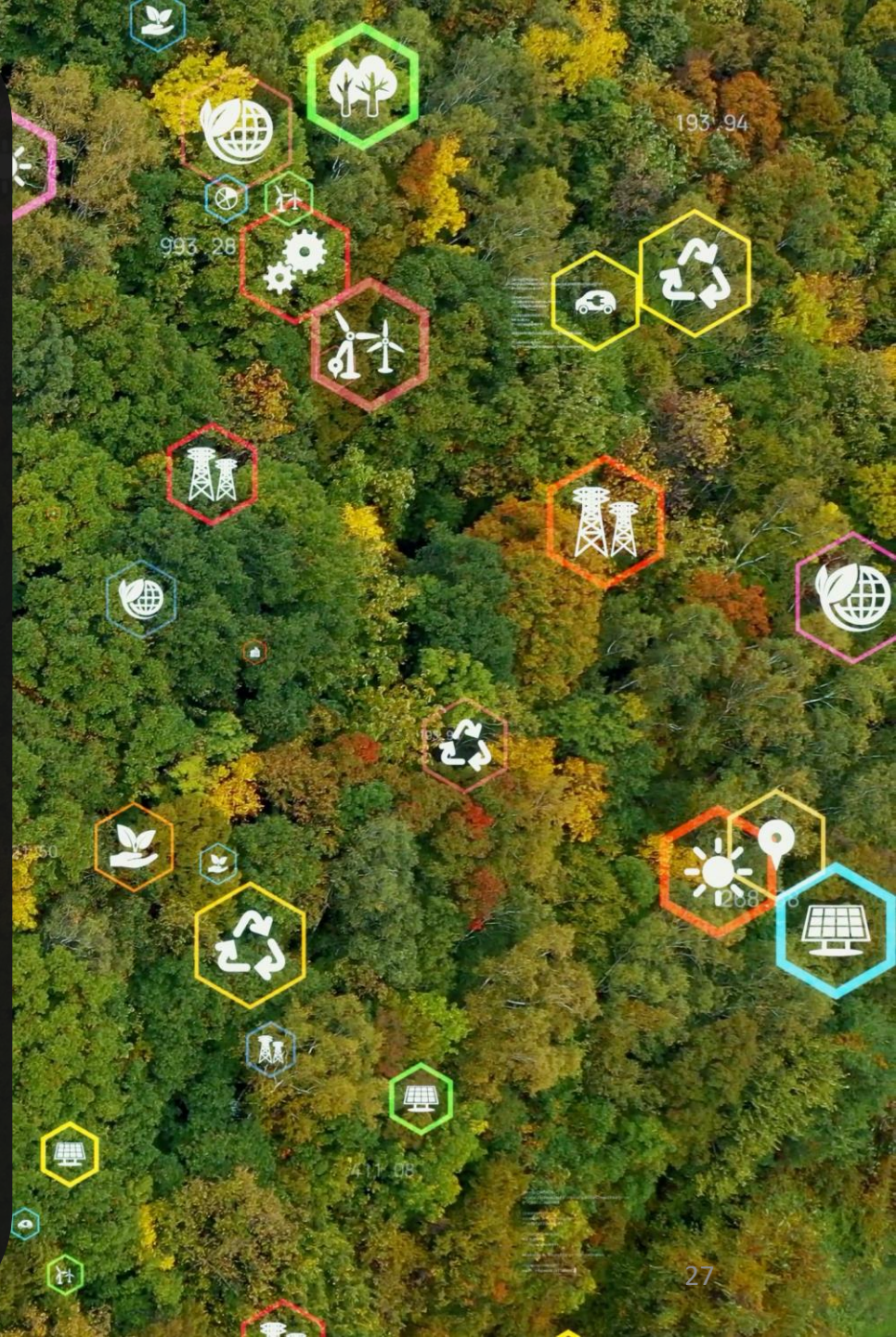


Highwood Emissions Management

Emissions management today…
…looks very different than the past

Then		Now
Simple emissions data	>	Billions of data points
Small focused teams	>	Large, integrated teams
No 3rd party oversight	>	Public satellite data
Minimal LDAR (handheld)	>	200+ alternative methods
No voluntary initiatives	>	27+ initiatives (OGMP 2.0, MiQ)
Minimal reporting/taxation	>	EPA, ECCC, SEC, CSA, and more
No strategic data usage	>	MACCs, AI, simulation, optimization
Investor focus on ROI	>	Carbon liabilities in focus

Highwood Emissions Management

Carbon accounting is here to stay

What to expect

Carbon accounting & supply chain integration

Reconciliation

Measurement-informed inventories

Challenges

Estimation uncertainty

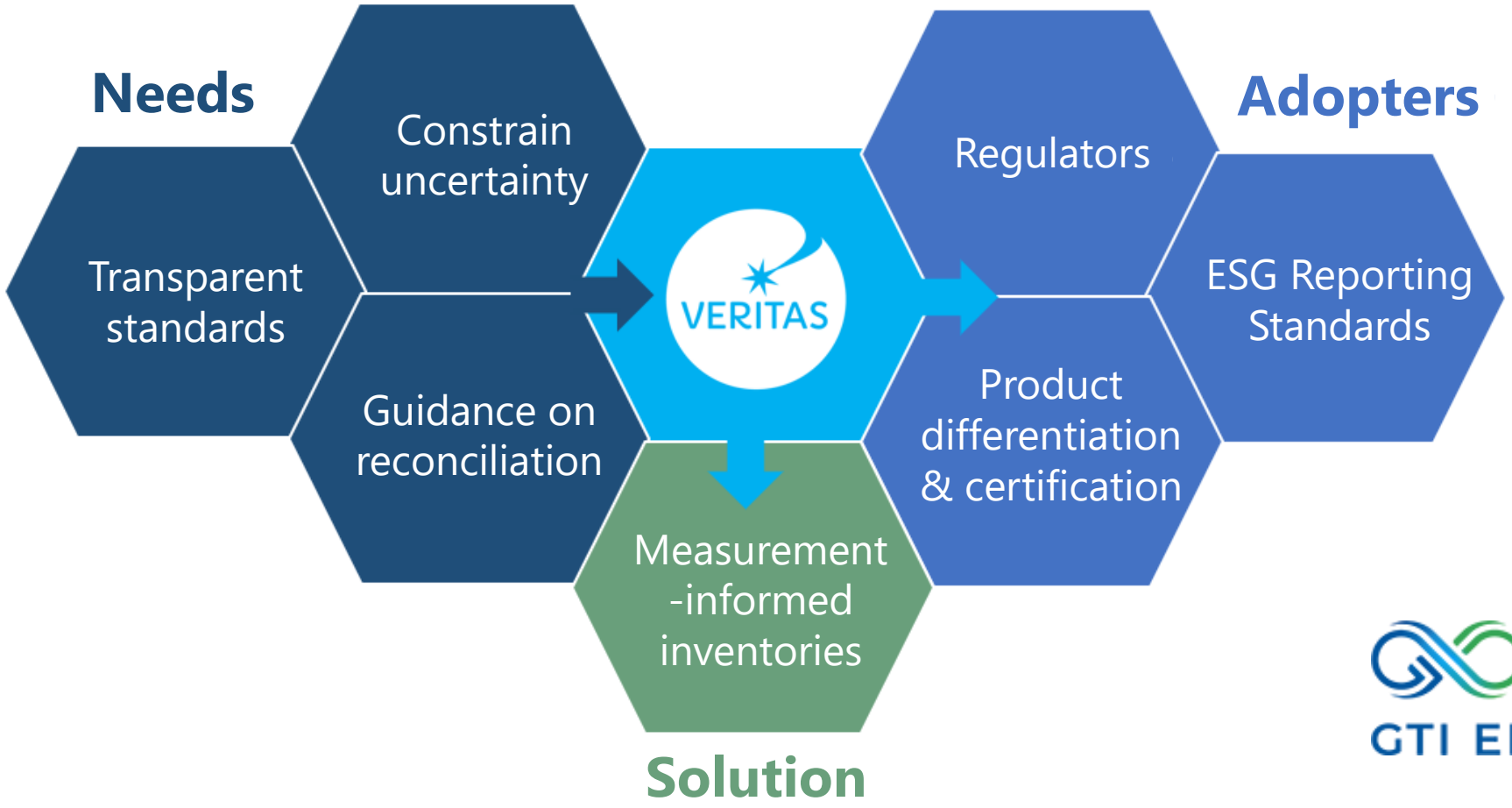
Helping the 99%

Harmonizing standards and regulations

Highwood Emissions Management

GTI Veritas Initiative: Paving the way to measurement

Sponsored by 40+ US companies, Veritas is a standardized measurement-informed approach to calculating methane emissions



VERITAS

GTI ENERGY

Level up.

It’s time to action these key takeaways.

You may think you know

Companies do not know their true emissions, amid rapid change in technology, regulations, and expectations.

The future requires better data

Measurement will soon be table stakes for understanding, “voluntary” and regulatory disclosure, and decision making.

There is opportunity in change

A parallel need for global decarbonization and reliable energy will reward proactive companies.

Highwood’s tools bring efficiency & assurance

Our holistic emissions management solutions can keep you ahead of the curve and aware of risks and rewards.

Highwood Emissions Management

Highwood Emissions Management

Work with the best (and friendliest) in emissions

- Deep O&G expertise
- Independent & agnostic
- Trusted internationally
- On the cutting edge
- Building the future

Reach out to learn more & collaborate

- Learn about Highwood's solutions.
- Sign up to the Highwood Bulletin for regular updates.
- Register for a software demo.
- Download the free 2022 Voluntary Initiatives Report.
- Reach out to chat: thomas@highwoodemissions.com

Highwood Emissions Management