EEMDL
Energy Emissions Modeling and Data Lab

- Welcome to the EEMDL webinar on FEAST modeling. We will start in a few minutes.
- Please use the Q&A feature in the Teams App to ask questions throughout the webinar. We will pause at two points in the webinar to answer questions.
- There may be versions of Teams that do not support Q&A – in that case, please send your questions to eemdl@utexas.edu.
- Webinar will be recorded and made available. Q&A at the end of the webinar will not be recorded.

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MINES

EEMDL
Energy Emissions Modeling and Data Lab

Energy Emissions Modeling & Data Lab

An Initiative of the University of Texas at Austin, Colorado State University, and Colorado School of Mines

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Agenda

- Part 1: Introduction to EEMDL
- Part 2: Use of FEAST in the EPA Methane Supplemental Proposal
- Part 3: Introduction to FEAST Modeling
- Part 4: FEAST 3.1. and the EPA Supplemental Rule
- Q&A
- Part 5: FEAST Modeling: Next Steps
  - Role of intermittent emission events
  - Basin-specific FEAST modeling
  - CEMS: Use of the FEAST modeling framework for continuous monitoring systems
- Part 6: Next Steps

Part 1: Introduction to EEMDL

What is EEMDL *(pronounced 'em-del')*?

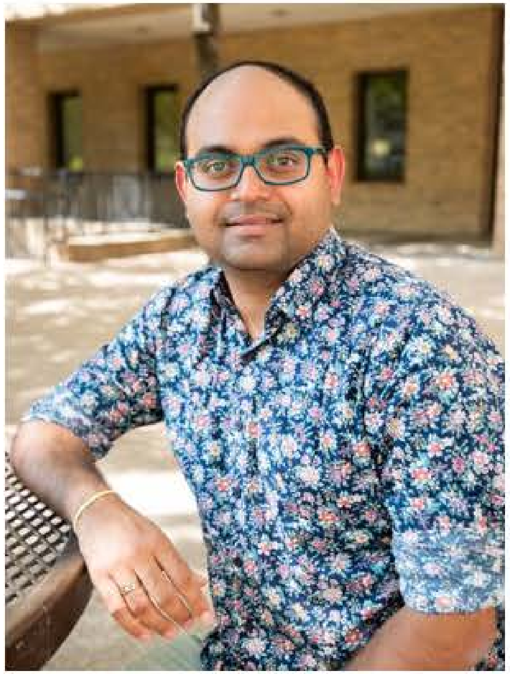
- The **Energy Emissions Modeling and Data Lab or EEMDL** at the University of Texas at Austin is a multi-disciplinary research and education center with a mission to be a global data and analytics hub to support improved greenhouse gas emissions accounting across energy supply chains

- EEMDL is a 5-year effort funded by a consortium of organizations in the private sector

- Three founding partners:
  - The University of Texas at Austin
  - Colorado State University
  - Colorado School of Mines

- EEMDL will be led be experts in greenhouse gas emissions measurements and analysis across energy supply chains

Who is leading EEMDL?



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EEMDL leadership has led multiple national and international field campaigns measuring methane emissions from oil and gas supply chains, evaluated new emission detection technologies and methods, developed new tools for greenhouse gas emissions assessments, served on national and international advisory committees, and published 100+ peer-reviewed publications on methane emissions from oil and gas operations

What will EEMDL do?

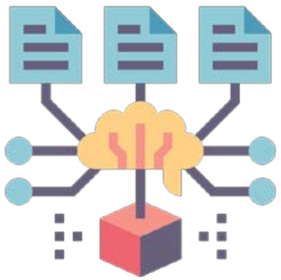
- **Data analytics hub**
  - Develop and make available peer-reviewed models and tools for reliable, transparent, and measurement-based greenhouse gas emissions assessments

- **Standardized emissions datasets**
  - Provide timely, standardized, and comprehensive measurement-based GHG emissions inventory estimates across global energy supply chains

- **Train user community**
  - Train stakeholders in industry, government, and other institutions to use EEMDL models and tools, and develop a global community of practitioners

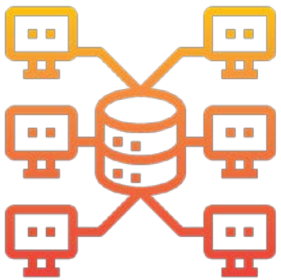
- **Collaborate**
  - Work with stakeholders in industry, academia, government agencies, and non-profit organizations to advance reliable GHG emissions assessments, provide clarity to users, and support technology vendors

What will EEMDL do?



Protocols, Models and Tools

- Create reliable, transparent models and methods to support interpretation of methane emissions measurements
- Develop tools to improve regional, national, and global emission inventories using measurement-informed approaches



Datasets

- Provide high-resolution, timely, reliable, and measurement-based datasets on methane emissions across oil and gas supply chains
- Integrate public and private data, and develop finely resolved emission datasets

Training/Education

- Provide short courses, workshops, and other public educational materials
- Conduct training sessions on EEMDL models and tools for government, NGOs, industry
- Develop methodologies, user guides, and visualization tools

What opportunities are available with EEMDL?

- EEMDL will collaborate with the community – government, industry, NGOs, and academics – to develop relevant and timely datasets and analytical tools

- If you are an operator or researcher, please reach out to discuss EEMDL data sharing and analysis framework and potential benefits to working with EEMDL

- Other modes of engagement:
  - Joint research projects between industry, NGOs, and universities
  - Federal or state-agency funded research projects
  - EEMDL strategic advisory committee membership
  - EEMDL technical advisory committee membership
  - EEMDL sponsorship

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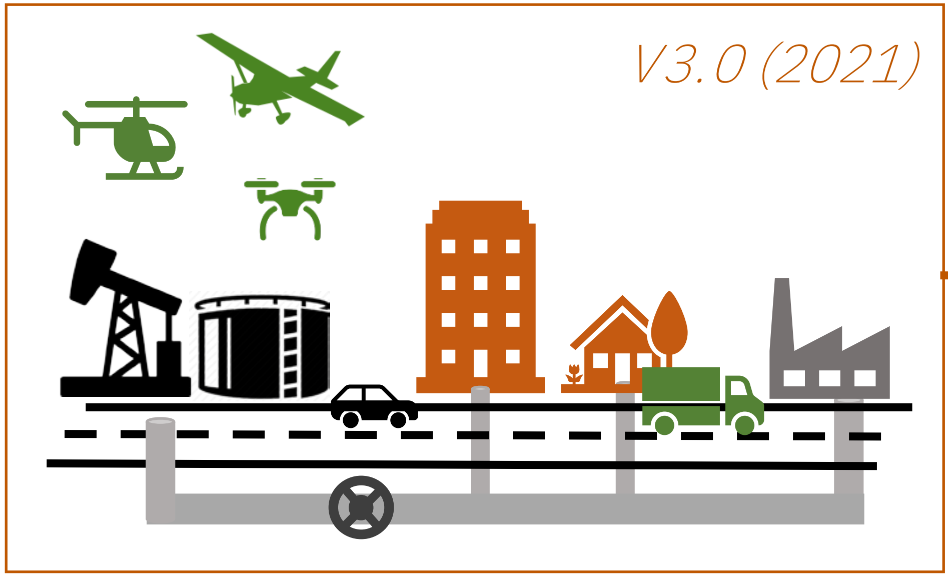
How can EEMDL's tools be used in methane regulatory processes?

Case Study: EPA Methane Rule

FEAST model

(developed by EEMDL researchers)



- ✓ *Peer-reviewed*
- ✓ *Transparent*
- ✓ *Widely used in industry, government*
- ✓ *Reliable and Timely*

EPA methane supplemental proposal (Nov. 2022)

EPA Issues Supplemental Proposal to Reduce Methane and Other Harmful Pollution from Oil and Natural Gas Operations

Proposed Survey Matrix for Alternative Periodic Screening Approach for Affected Facilities Subject To Quarterly OGI Monitoring for Methane

(proposed requirements for the NSPS and the Emissions Guidelines are the same)

Minimum Screening Frequency	Minimum Detection Threshold of Screening Technology
Quarterly + Annual OGI	≤1 kilograms per hour (kg/hr)
Bimonthly	≤2 kg/hr
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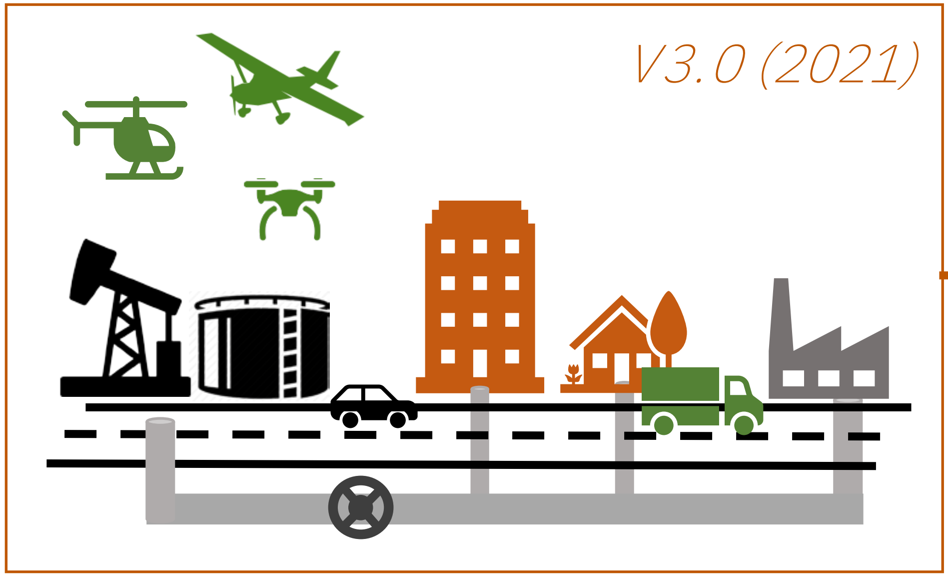
Bimonthly + Annual OGI	≤10 kg/hr
Monthly + Annual OGI	≤30 kg/hr

Use of the Fugitive Emission Abatement Simulation Toolkit (FEAST) in the EPA Supplemental Proposal for methane emission regulations

FEAST model

(developed by EEMDL researchers)



EPA developed case studies demonstrating how new measurement technologies could be evaluated for equivalence with quarterly Optical Gas Imaging screening

- Define model facilities that have leaks and large emission events
- Determine detection efficiencies for emissions as a function of the detection limit of the measurement and the frequency of sampling
- Estimate emission reductions

Framework applied to periodic aircraft overflights – conceptually similar periodic OGI screening

Proposed Survey Matrix for Alternative Periodic Screening Approach for Affected Facilities Subject To Quarterly OGI Monitoring for Methane

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Part 2: Introduction to FEAST

Fugitive Emissions Abatement Simulation Toolkit (FEAST): Introduction

- FEAST models evolution of methane emissions at oil and gas facilities
- Provides consistent platform to compare technology performance as part of leak detection and repair (LDAR) programs

Technology/Methods

- Detection probability curves
- Controlled test data
- Field performance data

FEAST

1. Technology equivalence
2. Costs and benefits of LDAR program options
3. Long-term emissions reductions

Emissions Scenarios

- Activity data (EPA model plant)
- Emissions data
- Super-emitters

LDAR Program

- Survey frequency
- Repair timelines
- Hybrid technologies

Kemp et al. (2016) *Environ. Sci. Tech.* **50** 4546.
Kemp et al. (2021) *Environ. Sci. Tech.* **55** 9140.
Rutherford et al. (2021) Nat. Commun. **12** 4715.

Technology parametrization in FEAST.

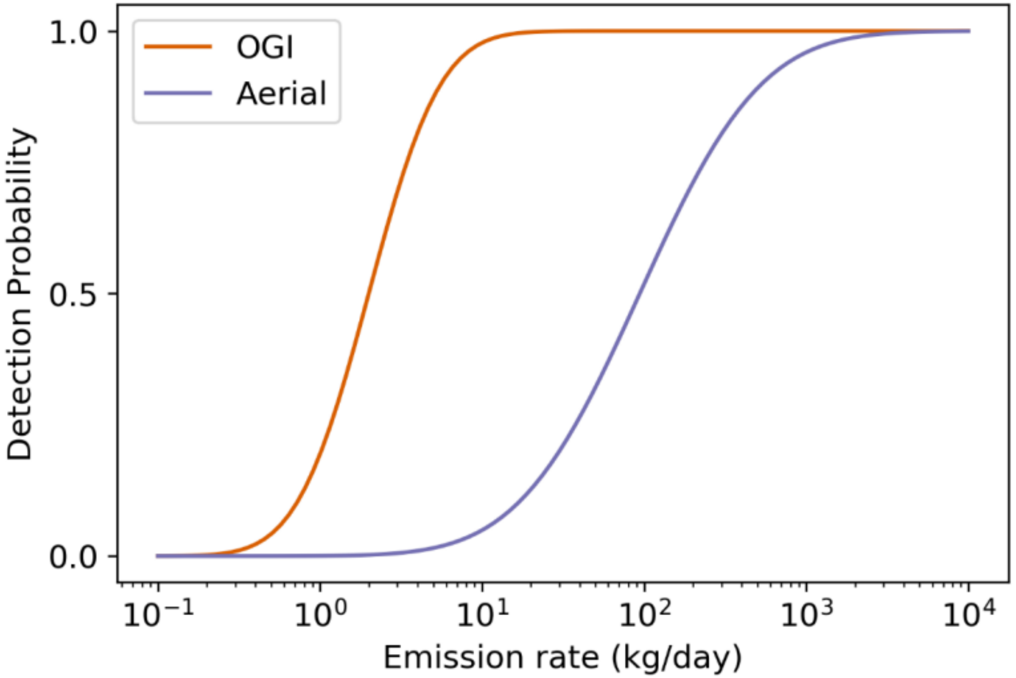
- Detection based on modeling ‘probability of detection’ surface
  - Detection depends on (a) emission rate, and (b) wind speed

- Data from controlled release testing E.g., METEC facility (CSU)

Controlled Release Testing
(METEC)

Ravikumar et al. (2019)

Probability of detection curve
(can also be a surface)



Kemp et al. (2021)

Activity data in FEAST.

- Activity data based on modeling scenarios:
  - Operator-specific, state-specific, or basin-specific

- Upstream facility example: major equipment on site, components/equipment

Facility
- N_{well}
- …
- …

→

Equipment
- Separator
- Dehydrator
- Tank
- Compressor
- VRU
- Flare

→

Component
- Flanges/Connectors
- Valves
- PRVs
- Open-ended lines
- Pneumatics

Facility ← Basin/Operator/State-specific distribution of wells per site

Equipment ← EPA/GRI 1996 data Table 4-7 GHGRP

Component ← TSD to EPA methane rule

FEAST models both fugitive emissions and vents.

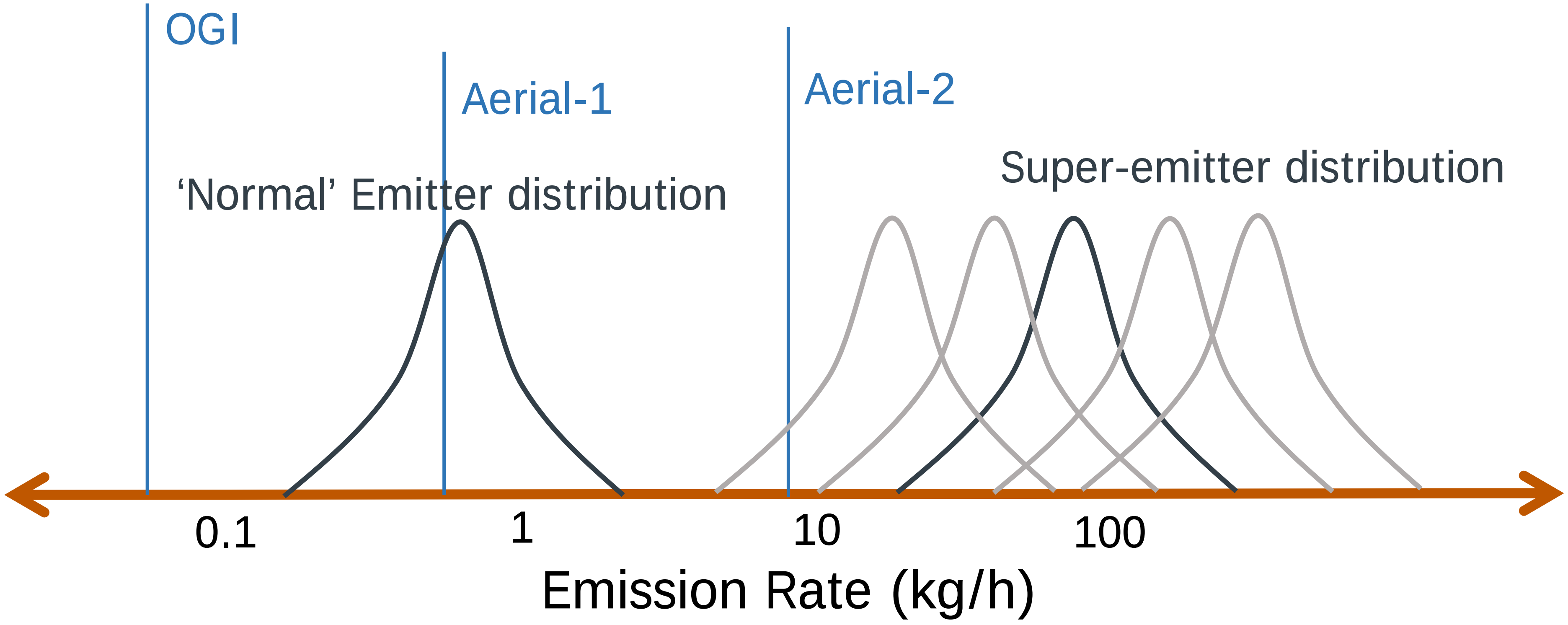
- 100 upstream sites x 100 Monte-Carlo simulations

$$Total\ Emissions = \underbrace{Leaks + Anomalous\ Emissions}_{\text{Fugitive Emissions}} + \underbrace{Routine\ Vents}_{\text{Vents}}$$

Type of Emission	Description	Emitter Distribution	Intermittency	Repairable or Not
Leaks	Wear and tear, malfunction, etc.	Compiled	No	Yes
Anomalous Vents	Thief hatch, unlit flares, etc.	Super-emitter	Yes	Yes
Vents	Pneumatics		Yes	No

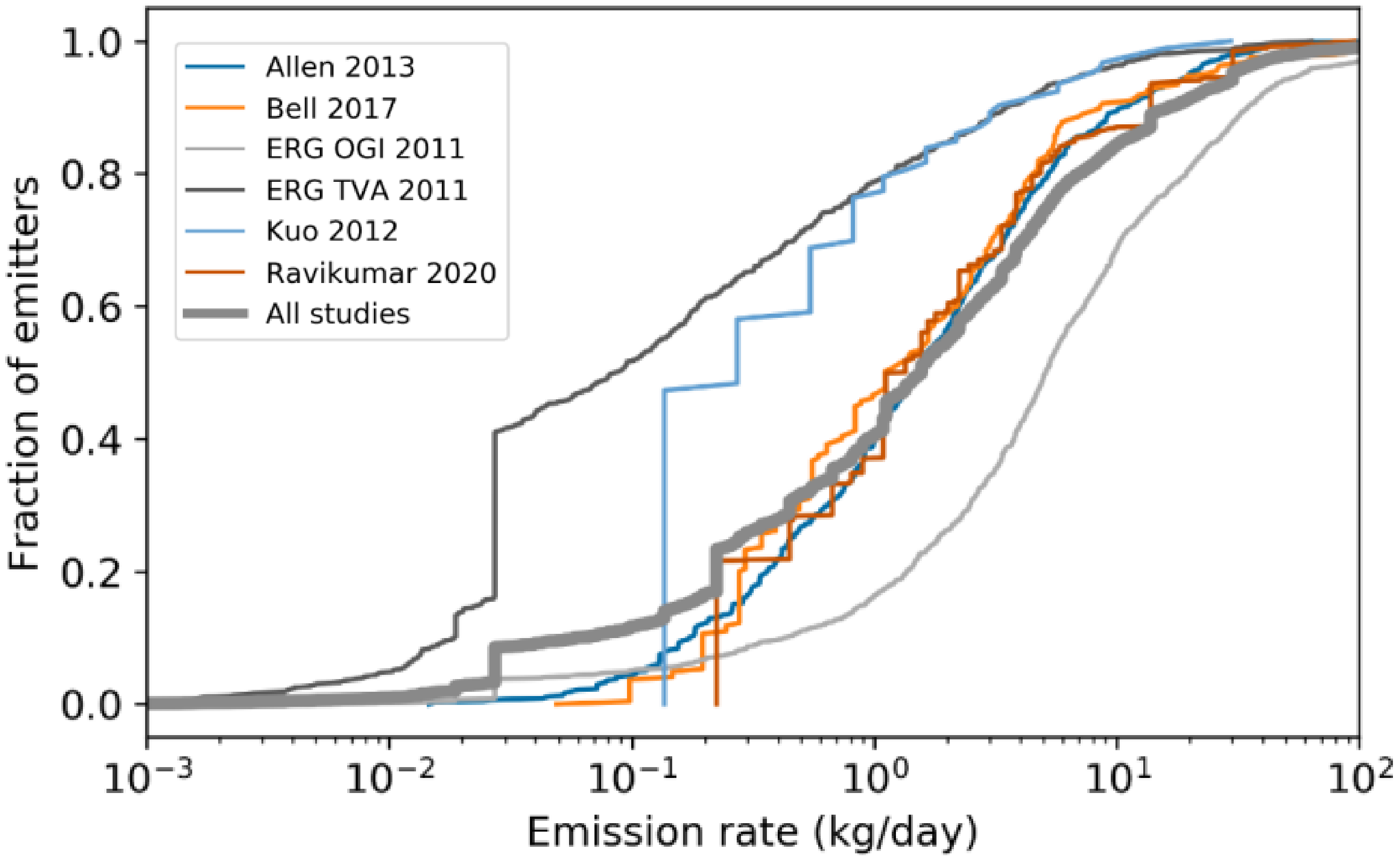
Emissions modeling in FEAST.

- Total emissions = Normal emissions + Super-emitters
  - Normal emission distribution: Emissions compiled from various component-level measurement campaigns
  - Super-emitter distribution: Emissions complied from top-down measurement campaigns, that are basin-specific



Normal emitter distribution

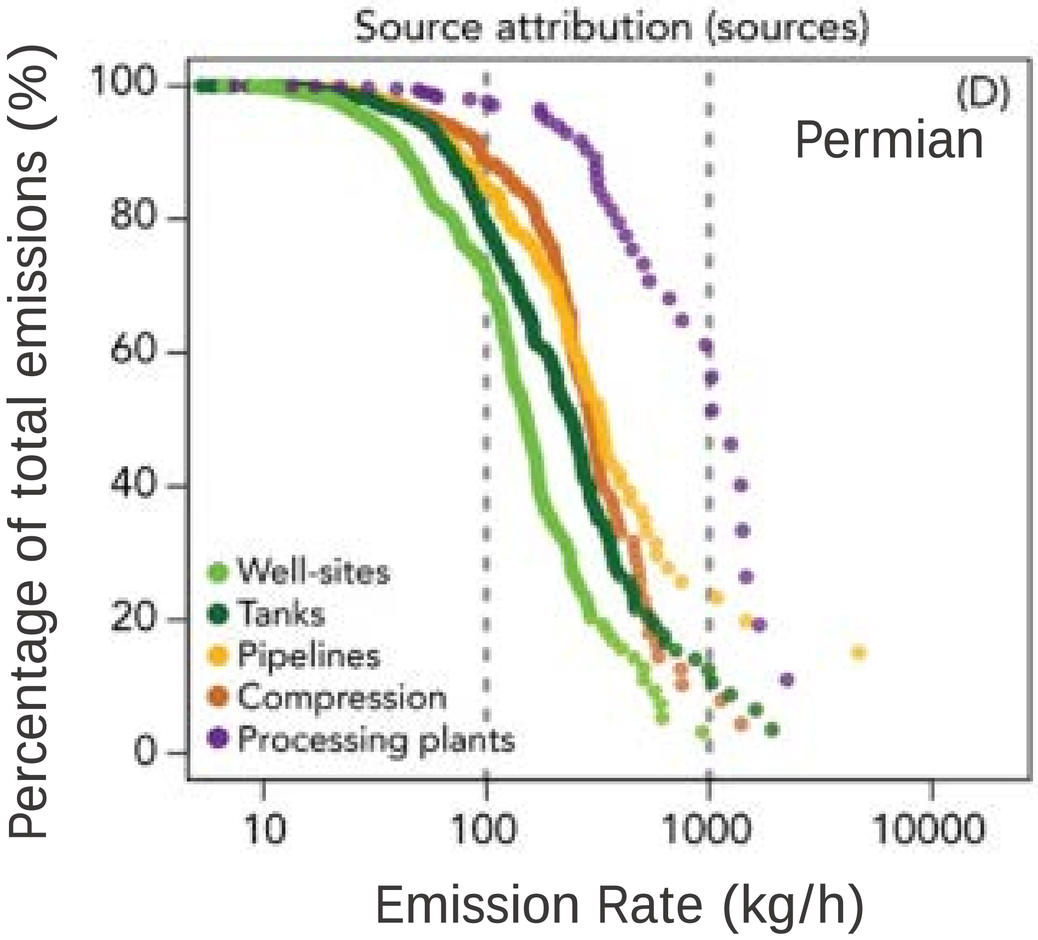
- Emissions compiled from various peer-reviewed studies with component-level data



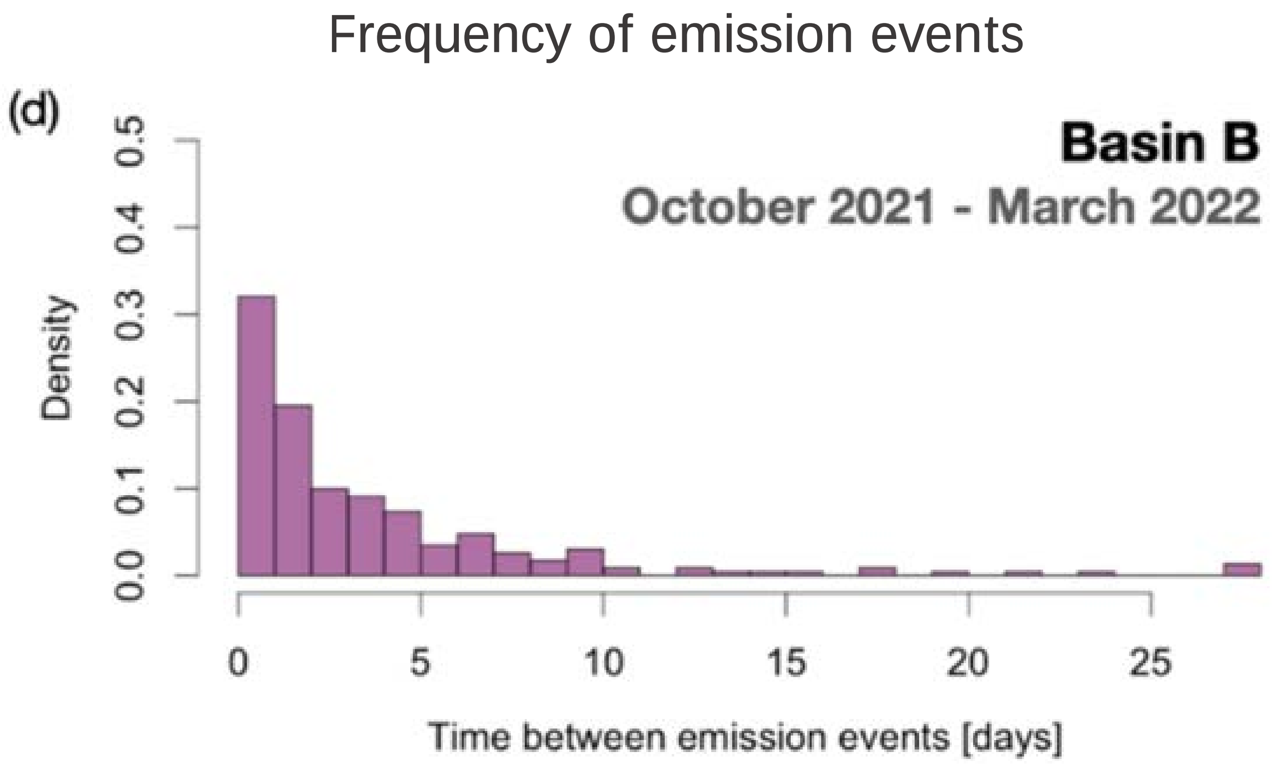
Kemp et al. (2021)

Super-emitter distribution.

- Basin-specific distributions of large emitters → frequency and duration of super-emitters are key parameters

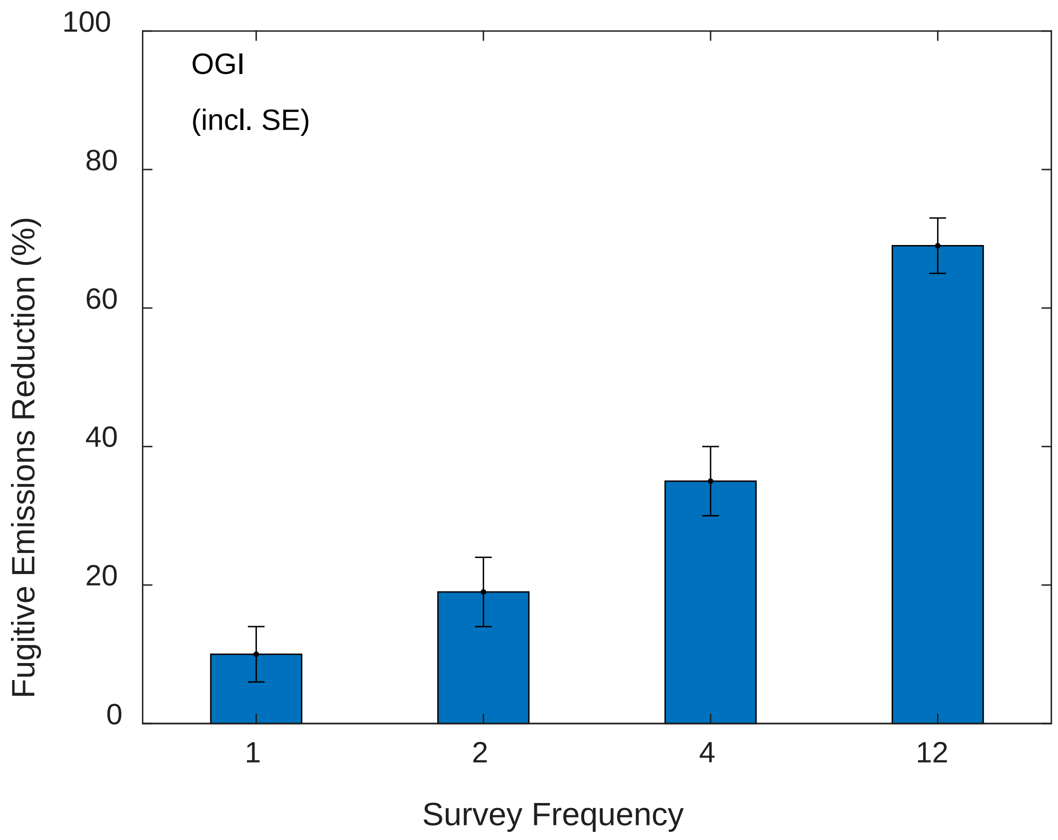


Cusworth et al. (2022)



Wang et al. (2022)

Example FEAST result: Fugitive emissions reduction as a function of survey frequency.

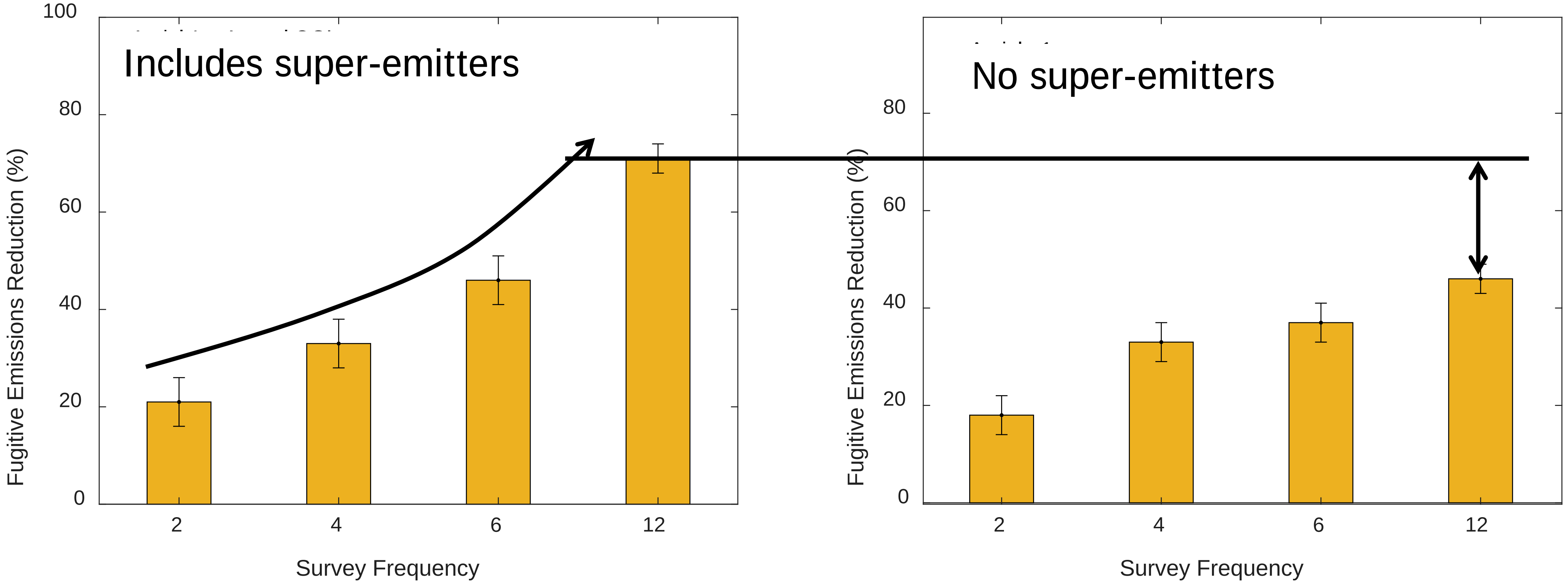


- Emissions reduction increases as survey frequency increases
  - Intermittent, super-emitter emission events are detected and repaired
- Super-emitters detection effective only when duration of intermittent events longer than time between surveys
  - 35% → 70% in fugitive emissions reduction from quarterly to monthly surveys

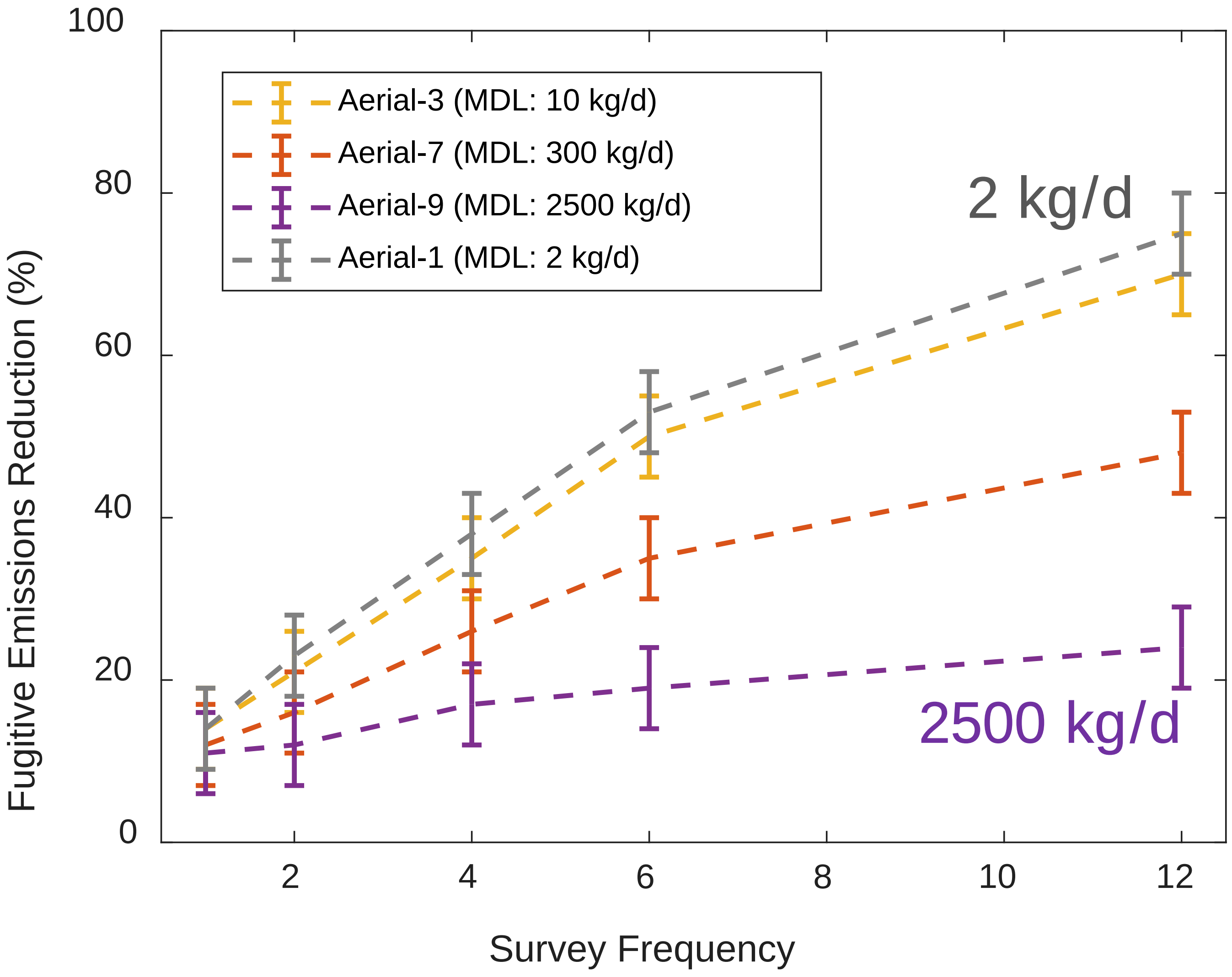
Example FEAST result: New technologies are effective at detecting anomalous, intermittent emission events.

- High frequency (monthly) aerial surveys effective at capturing intermittent emission events (average emission duration = 45 days)

- Time between surveys < average emission event duration



Example FEAST result: Higher survey frequency improves emissions reduction only if detection threshold is “sufficiently” low.



- High detection threshold technology in a basin with low average emissions (or fewer super-emitters) will not be effective in reducing fugitive emissions

Part 3: FEAST 3.0 and EPA Supplemental Proposal

FEAST and the EPA Supplemental Proposal: Summary.

- New technologies as alternatives to OGI-based LDAR: Based on a matrix approach using the FEAST modeling framework

4x OGI monitoring OR

Minimum Survey Frequency	Detection Threshold
Quarterly + Annual OGI	≤ 1 kg/h
Bi-monthly (once in 2 months)	≤ 2 kg/h
Monthly	≤ 4 kg/h
Bi-monthly + Annual OGI	≤ 10 kg/h
Monthly + Annual OGI	≤ 30 kg/h

- Key differences between EPA FEAST modeling vs. alternative modeling scenarios (model assumptions)

- Updated modeling parameters for realistic emissions scenario and environmental conditions

FEAST-EPA: Model assumptions.

Parameter	Supplemental Proposal FEAST Assumption	Alternative Modeling Scenarios in FEAST
Facility type	Four model plants	Operator or Basin-specific activity data
Normal emitter distribution	Compilation of bottom-up measurement campaigns	
Normal emitter frequency	0.5%	0.5%
Normal emitter duration	Persistent	Persistent
Super-emitter distribution	Cusworth et al. (2021) Permian data	
Super-emitter frequency	1%	1% (varies by basin, super-emitter type)
Super-emitter duration	Persistent	Varies (5 – 45 days)
Vents	Not included	Included
Technology parameters	Probability of detection curves	Probability of detection surfaces
Weather dependency	No	Yes

FEAST-EPA: Equivalency modeling conducted independently for different model plants.

Model Site Name	Description	Number of Fugitive Components	Number of Tanks	Number of Large-Emitters
Model Plant 1	Single wellhead only	112	0	1
Model Plant 2	Small well sites	157	0	1
Model Plant 3	Wellhead only sites (2+ wellheads)	220	0	2
Model Plant 4	Well sites with centralized production facilities	612	2	4

- Baseline emissions at each model plant calibrated based on number of fugitive components and calibrated against recent meta study on site-level emissions (Rutherford et al. 2022)

Example EPA-FEAST equivalence modeling.

- Estimate emissions reduction from different combinations of survey frequency, detection limit, and technology

Table 12. Results of Emission Simulations Results for Model Plant 4 Including Large-Emitters

Sitewide Monitoring Program		No. of Runs	Average Emissions (tons CH_4/year) per Site for Leak Generation Rate Levels		
Frequency (Days Between Surveys)	Detection Limit (kg/hr)		Quarterly OGI	Sitewide Survey	Sitewide Survey with Annual OGI
Quarterly (91)	1	2000	16.50	17.53	16.54
Bimonthly (60)	2	1000	16.60	15.69	13.92
Bimonthly (60)	4	2387	16.00	19.12	15.83
Bimonthly (60)	5	2000	15.60	19.90	15.85
Bimonthly (60)	10	1000	16.05	26.62	16.57
Monthly (30)	4	1000	16.02	15.54	13.26
Monthly (30)	5	1392	15.60	15.87	12.71
Monthly (30)	15	1000	16.82	30.05	15.78
Monthly (30)	30	1000	15.09	49.79	15.05

Key modeling questions going forward.

- **Impact of intermittent super-emitters on performance of both OGI and alternative technologies**
  - Performance of monthly aerial surveys significantly better than quarterly OGI surveys (prior FEAST modeling)

- **Modeling CEMS in realistic field configurations**
  - Deployments are rarely single sensors but a ‘network’ of 3 or more sensors
  - Translating matrix approach to be applicable to CEMS

- **State or basin-specific FEAST modeling for state implementation plans**
  - Emissions distributions, and therefore technology equivalence, vary by basin

- **Environmental impacts of technology performance**
  - Monthly surveys using some technologies may be challenging in regions with significant winter weather

Part 5a: Role of intermittency in determining equivalence.

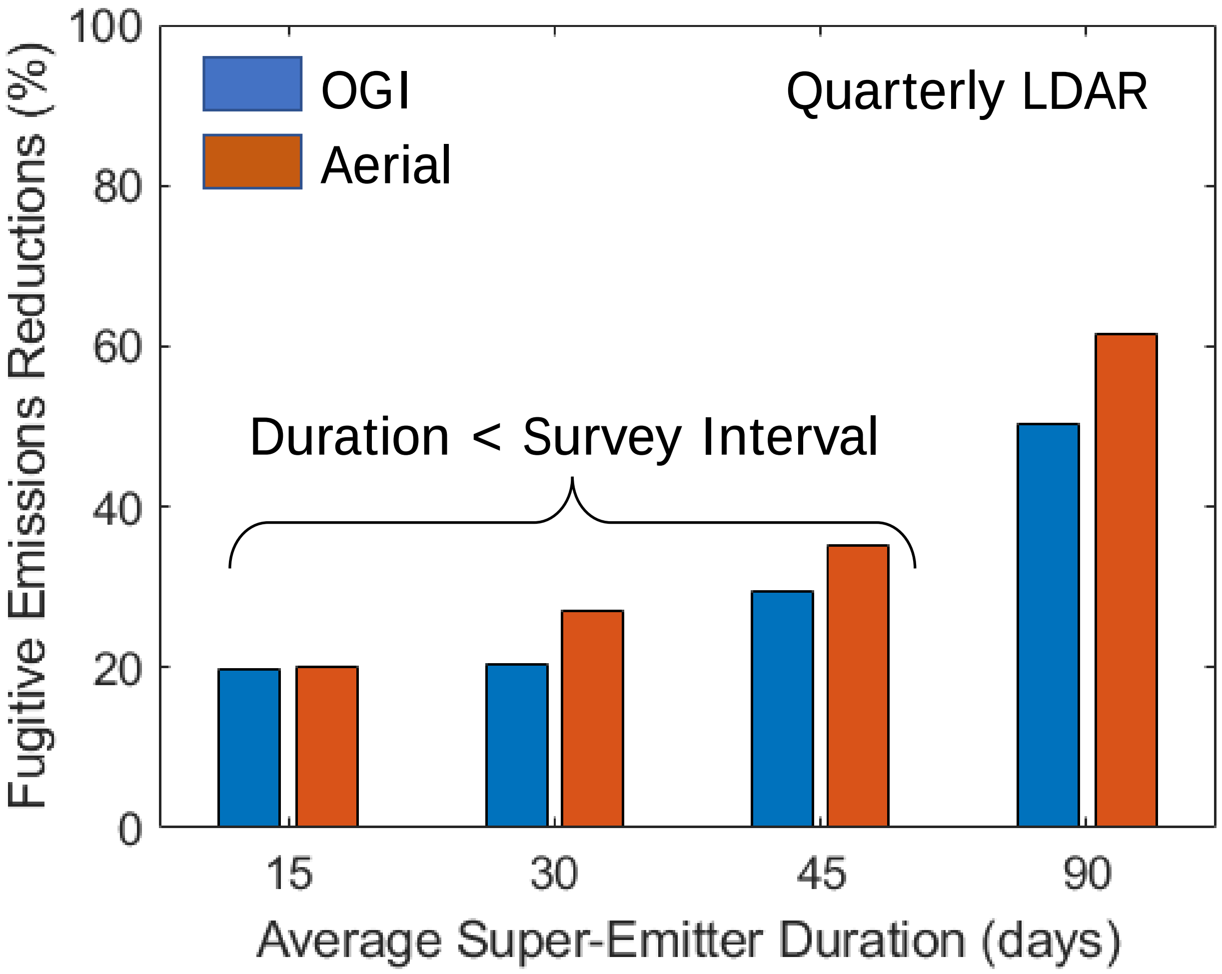
How do emissions intermittency affect detection effectiveness?

- Identical assumptions for activity data and emissions distribution, except duration of super-emitter events
- Survey frequency: quarterly

Scenarios	Duration of super-emitter events	Average repair delay
#1 (baseline)	Persistent	7 days
#A	90 days	
#B	45 days	
#C	30 days	
#D	15 days	

- If event durations is less than time between surveys, many super-emitters will not be detected
  - Survey frequency becomes more critical in the presence of intermittent emissions

New technologies are more effective at detecting short-duration, high-volume emission events.

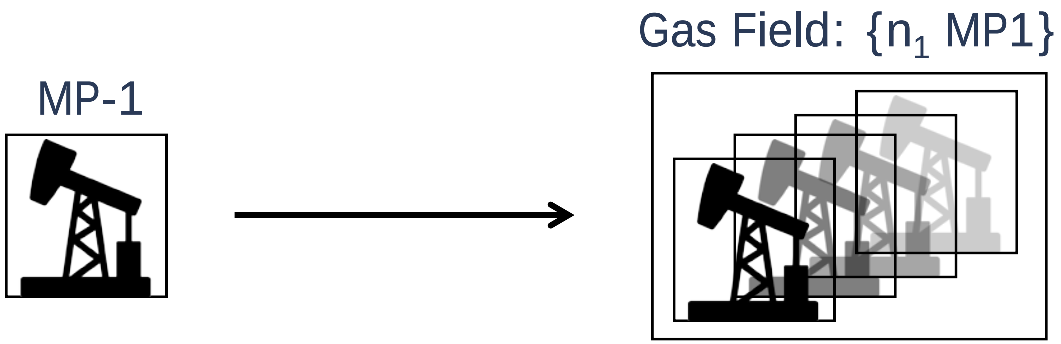


- If $\frac{1}{Survey\ Freq.} > Emitter\ Duration$, most super-emitters are not detected, and emissions reductions remain low
- For quarterly surveys, emissions reductions for aerial surveys high when average duration of super-emitter events is 90 days
- When super-emitter duration << 90 d, effectiveness of aerial system <30%
  - Survey frequency should a function of duration of super-emitters

Part 5b: Basin-specific FEAST modeling

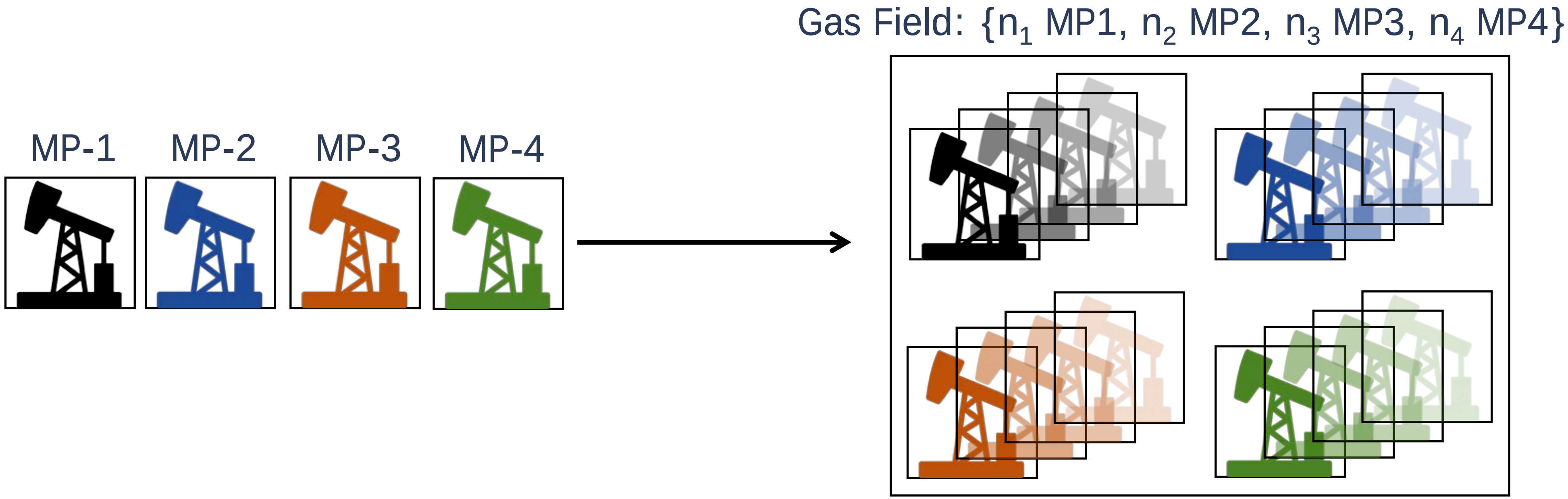
Ensemble modeling at the basin- or operator-level.

- EPA-FEAST modeling focused on equivalence for individual model plants



Monte-Carlo modeling of each model plant conducted independently

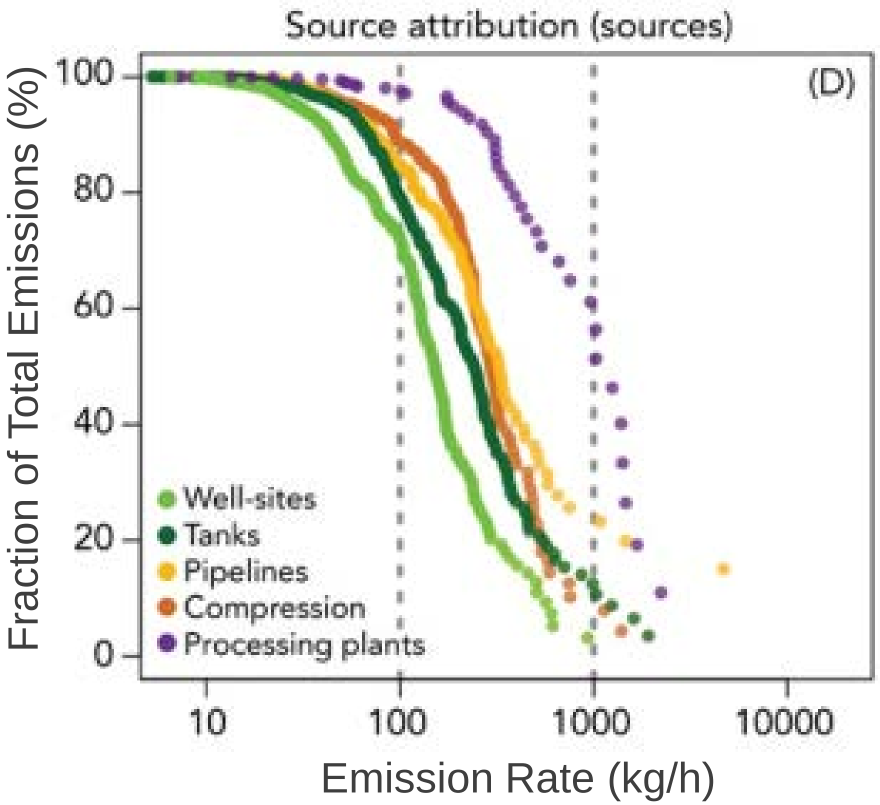
- Ensemble modeling is also available in FEAST: assets of an operator/basin



Basin-specific modeling in FEAST: Permian vs. Marcellus basin.

- Activity and emissions data vary significantly across basins
  - Technology that is effective in basin A may not necessarily be effective (or result in similar emissions reductions) in basin B

- Weather conditions vary significantly across basins
  - Extensive snow or cloud cover reduce technology effectiveness
  - Weather-dependent technology performance modeling



Cusworth et al. (2022)

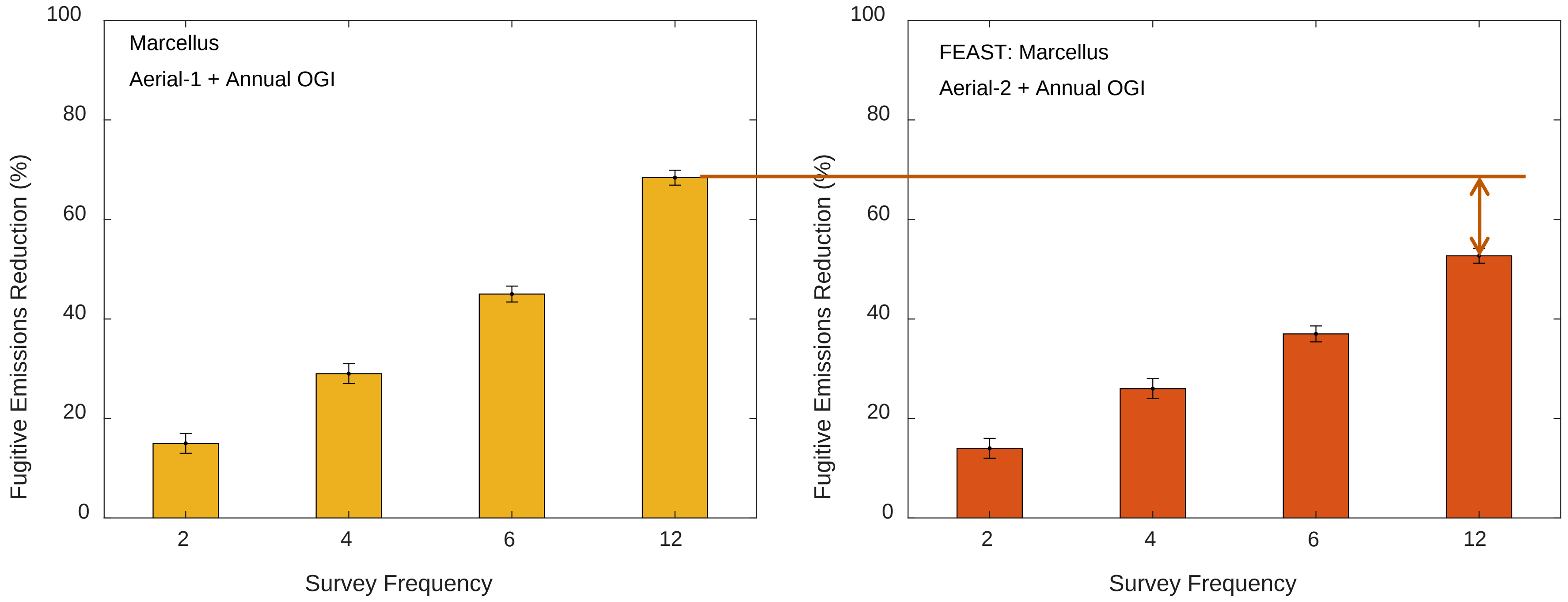
Basin-specific modeling in FEAST: Permian vs. Marcellus basin.

- Compare performance of three technologies: OGI, aerial survey with low detection threshold (aerial-1), and aerial survey with high detection threshold (aerial-2)
- Optionality: Annual OGI survey at all sites, in addition to aerial survey at different survey frequency

Parameter	OGI	Aerial-1	Aerial-2
Median Detection Threshold (kg/h)	0.1	1	10
Follow-up Survey	N/A	OGI	OGI
Wind dependence	No	Yes	Yes
Survey frequency	Semi-annual, quarterly, bi-monthly, monthly		

Marcellus basin results: new technology + annual OGI

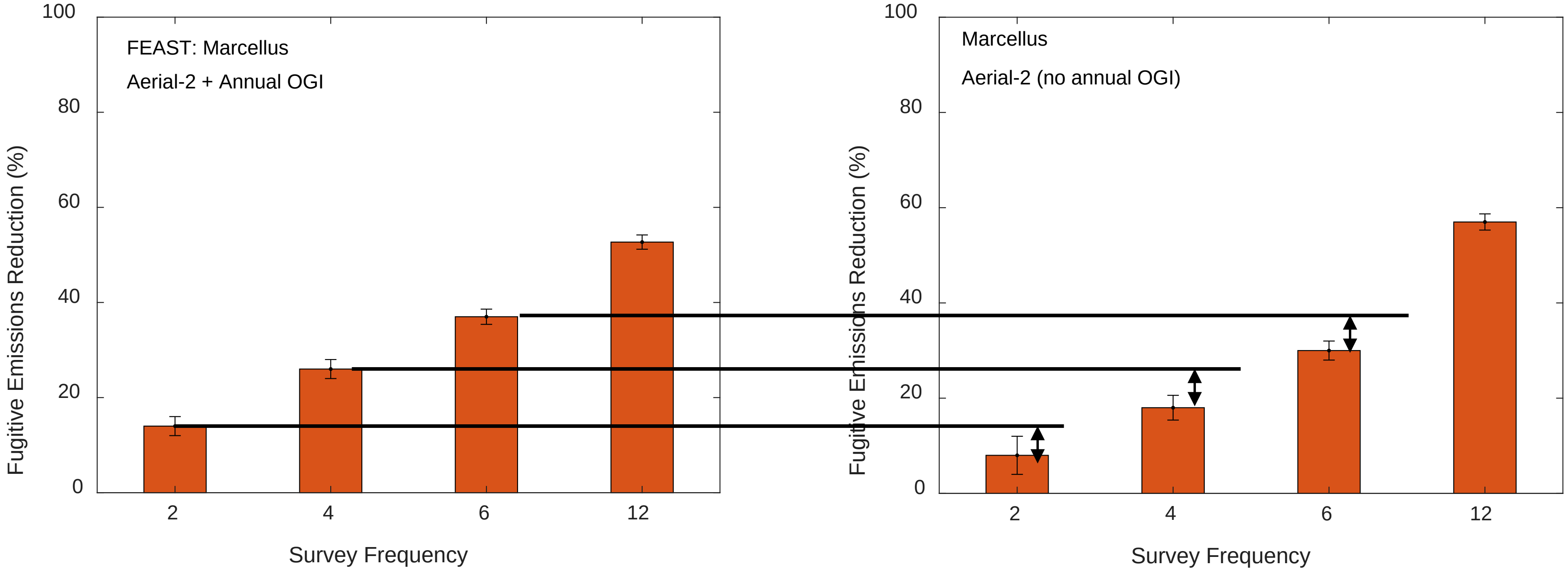
- Marcellus: fewer super-emitters, higher fraction of emissions from typical leaks
  - Lower detection threshold required for effective emissions reduction



- Aerial-2 with high detection threshold exhibits less effective performance compared to Aerial-1 → large proportion of emissions below detection threshold

Marcellus basin results: impact of annual OGI surveys, in addition site-wide aerial surveys.

- No qualitative difference with additional of annual OGI survey, when site-wide survey technology has low detection threshold



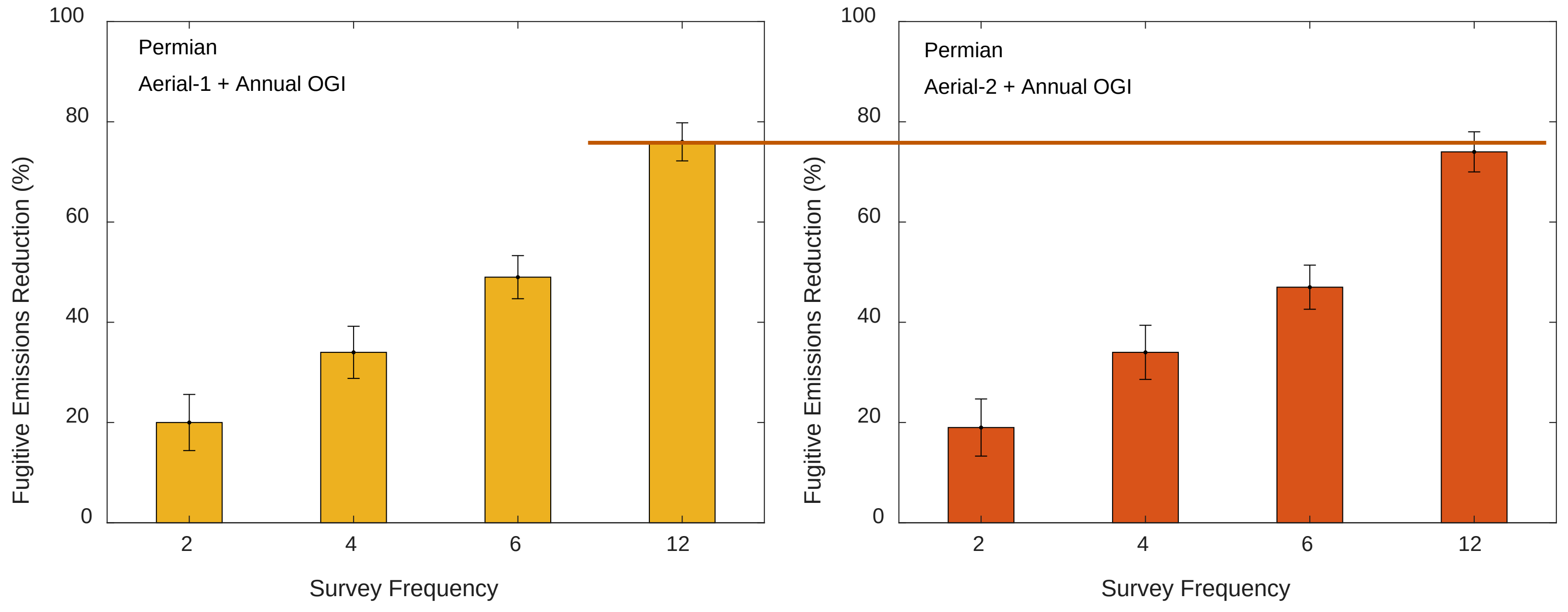
5-10 percentage points increase in emissions reduction with annual OGI

- Higher emissions reduction with addition of annual OGI survey, when site-wide survey technology has high detection threshold
  - Higher fraction of total emission below detection threshold of site-wide survey

Permian basin results: technologies with higher detection threshold perform as well as technologies with lower detection threshold

- Performance of Aerial-2 (10 kg/h) comparable to that of Aerial-1 (1 kg/h) even if detection threshold is an order of magnitude worse.

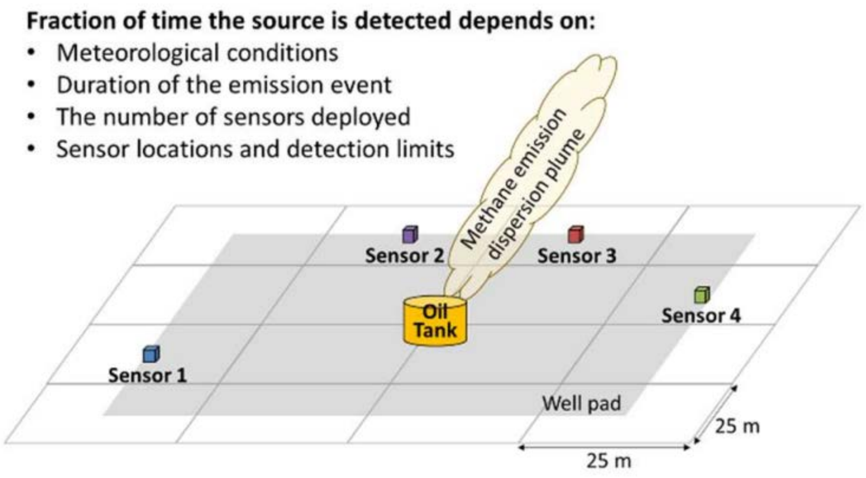
- Super-emitters dominate total emissions in Permian basin → missing emissions below detection threshold has limited effect on overall emission reductions, as long as super-emitters are detected



Part 5c: Continuous Emissions Monitoring Systems

Determining emission equivalencies for Continuous Emissions Monitoring Systems (CEMS) using the FEAST conceptual framework

Continuously operating fixed point methane emission monitoring systems



Recently published analysis framework for determining CEMS detection efficiencies for intermittent and continuous emissions
(Chen, et al, ES&T, 2023 doi: 10.1021/acs.est.2c06990)

- Define model facilities that have leaks and large emission events
- Determine detection efficiencies for emissions as a function of the detection limit of the measurement and the frequency of sampling
- Estimate emission reductions

This same framework can be applied to continuous emission monitoring systems

Proposed Survey Matrix for Alternative Periodic Screening Approach for Affected Facilities Subject To Quarterly OGI Monitoring for Methane

(proposed requirements for the NSPS and the Emissions Guidelines are the same)

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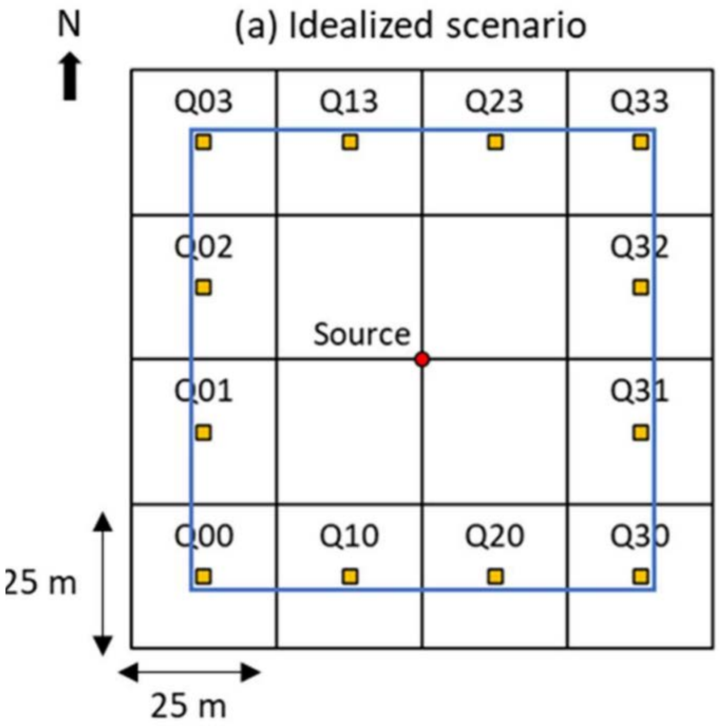
Monthly + Annual OGI	≤30 kg/hr

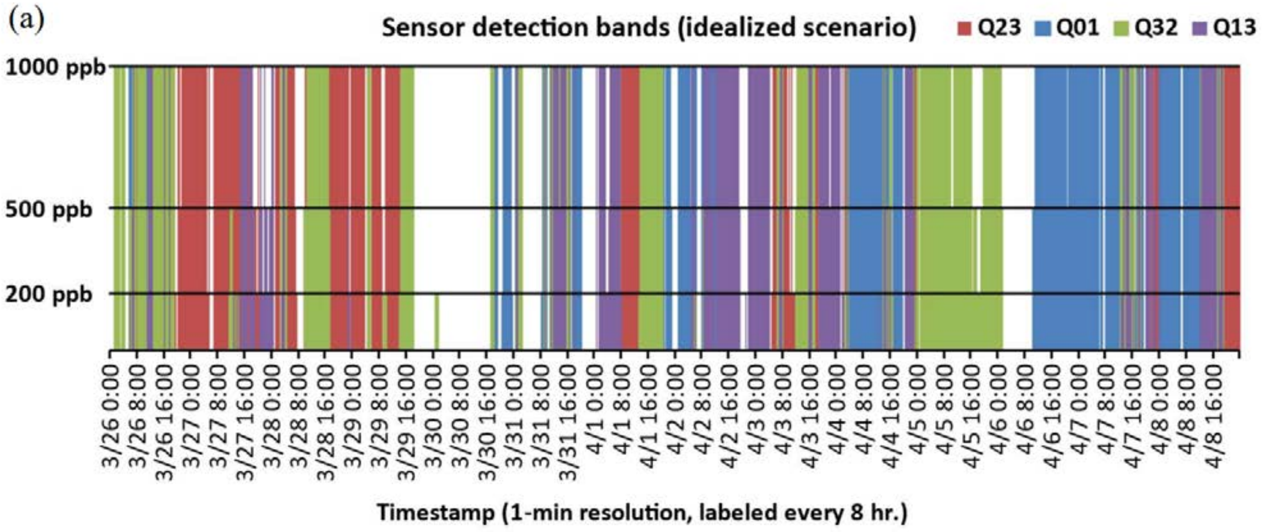
Detection probabilities for an idealized site.

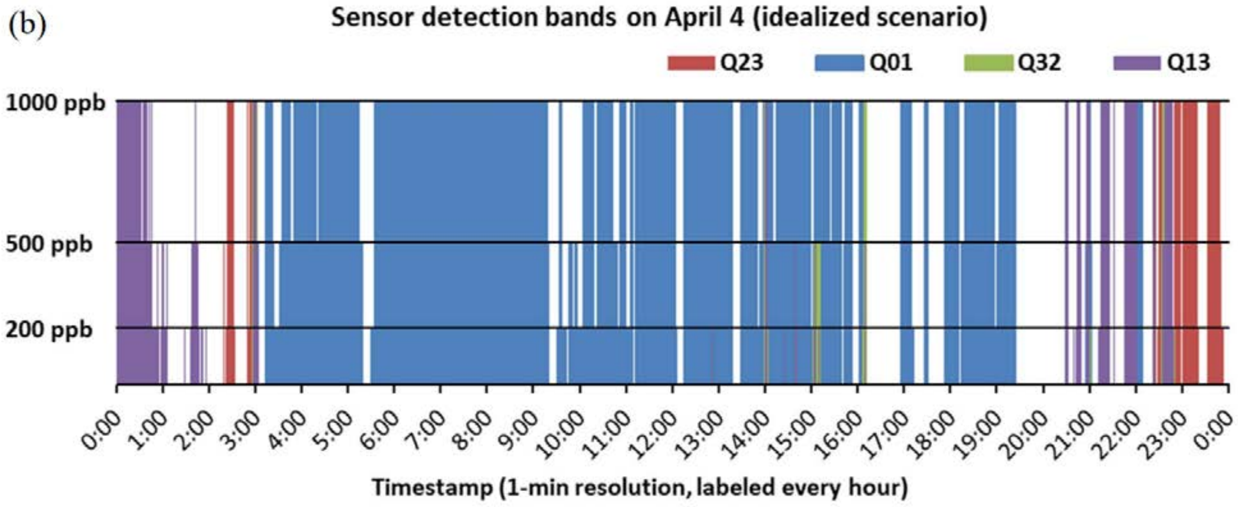
Idealized site layout



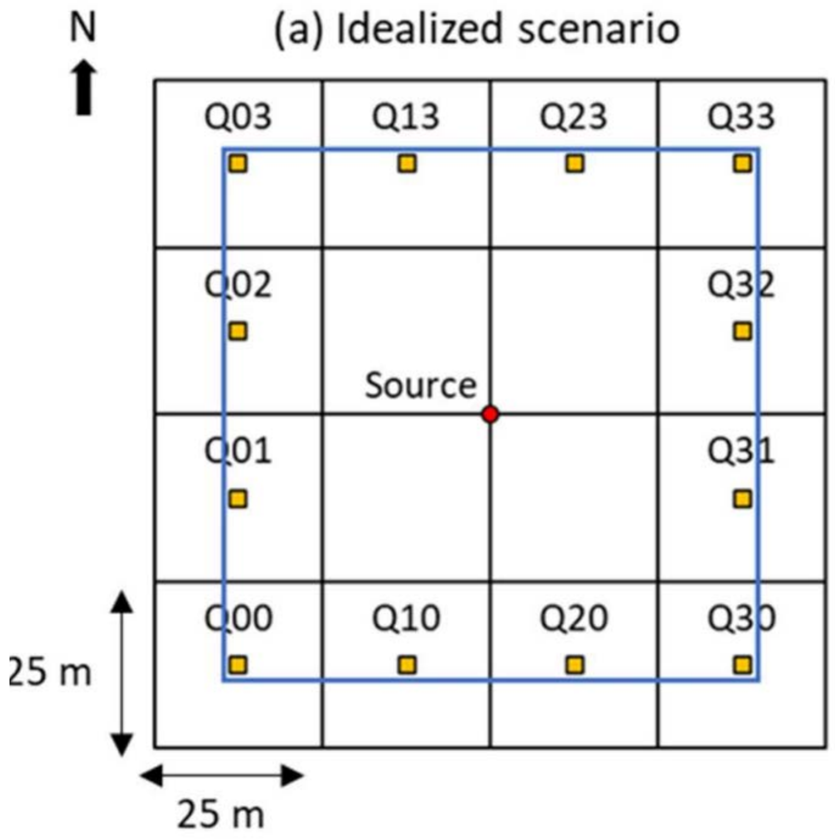
Idealized site.

Detect and non-detect times for two-week period representative of annual meteorology

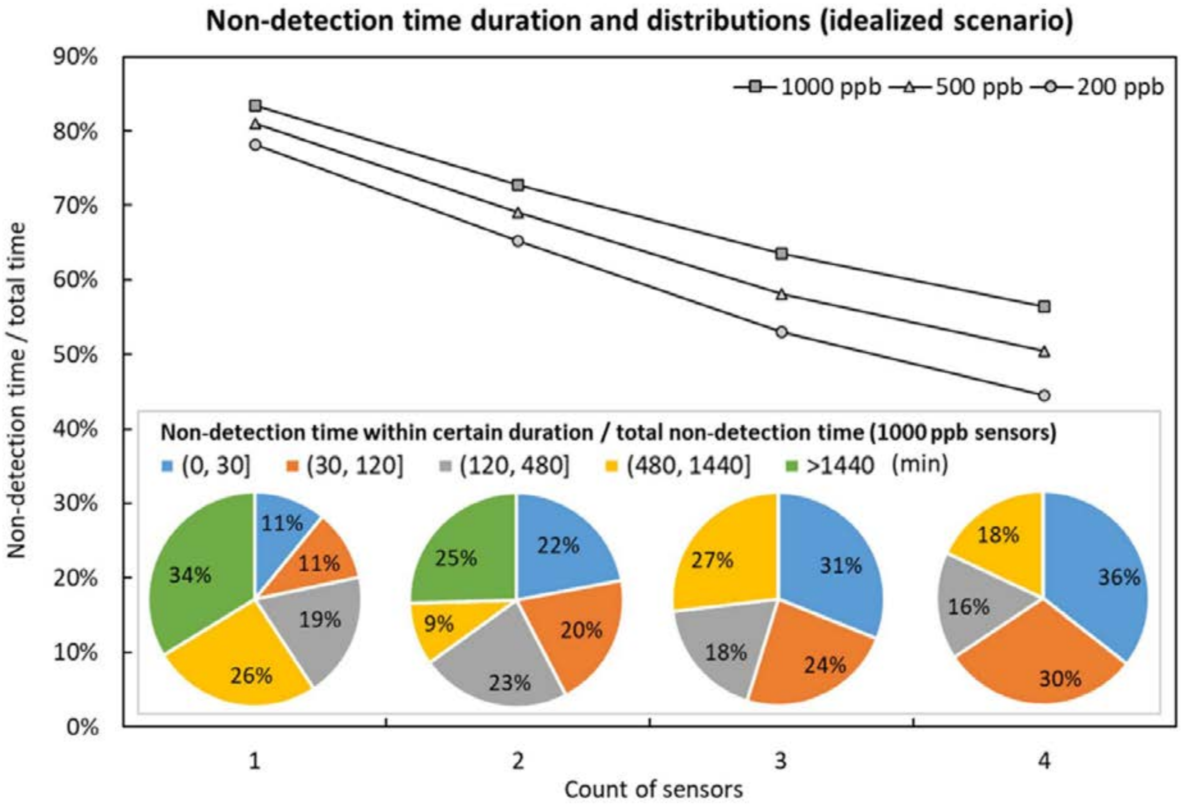




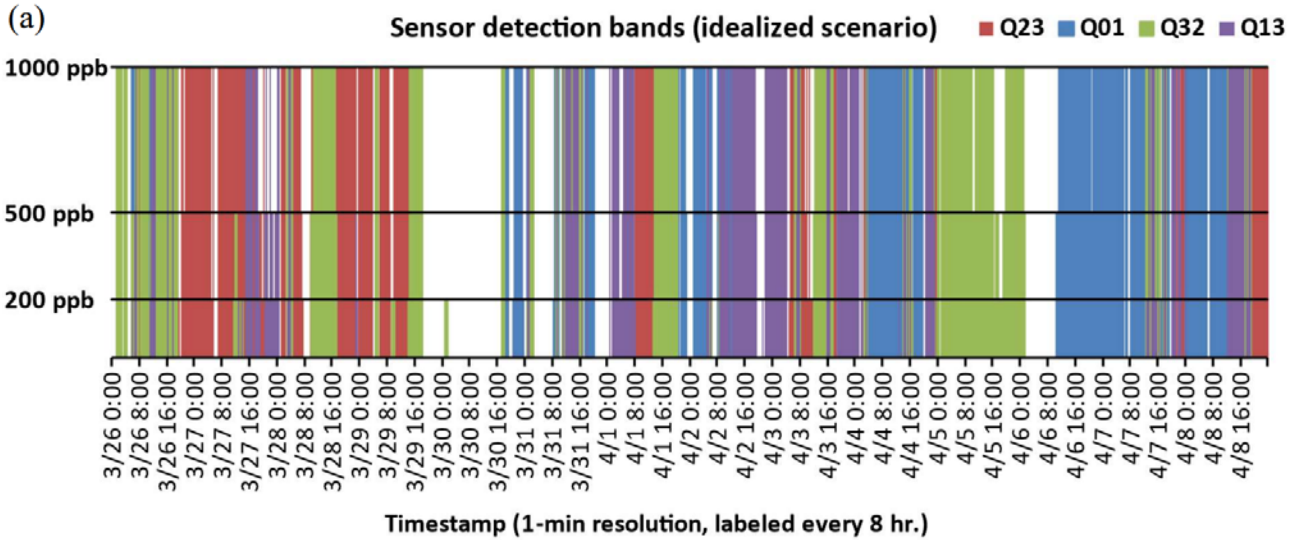
Idealized site layout



Idealized site temporal coverage and time to detect for infinite duration events.

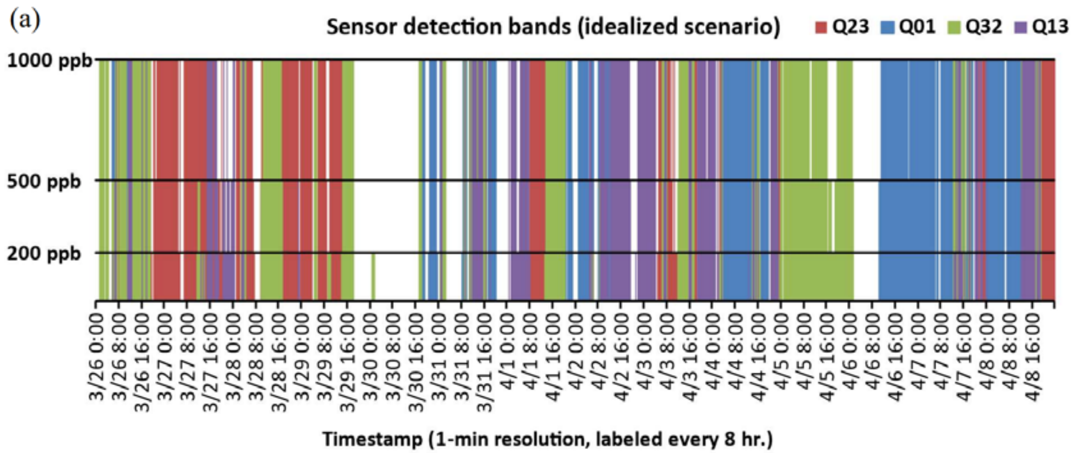


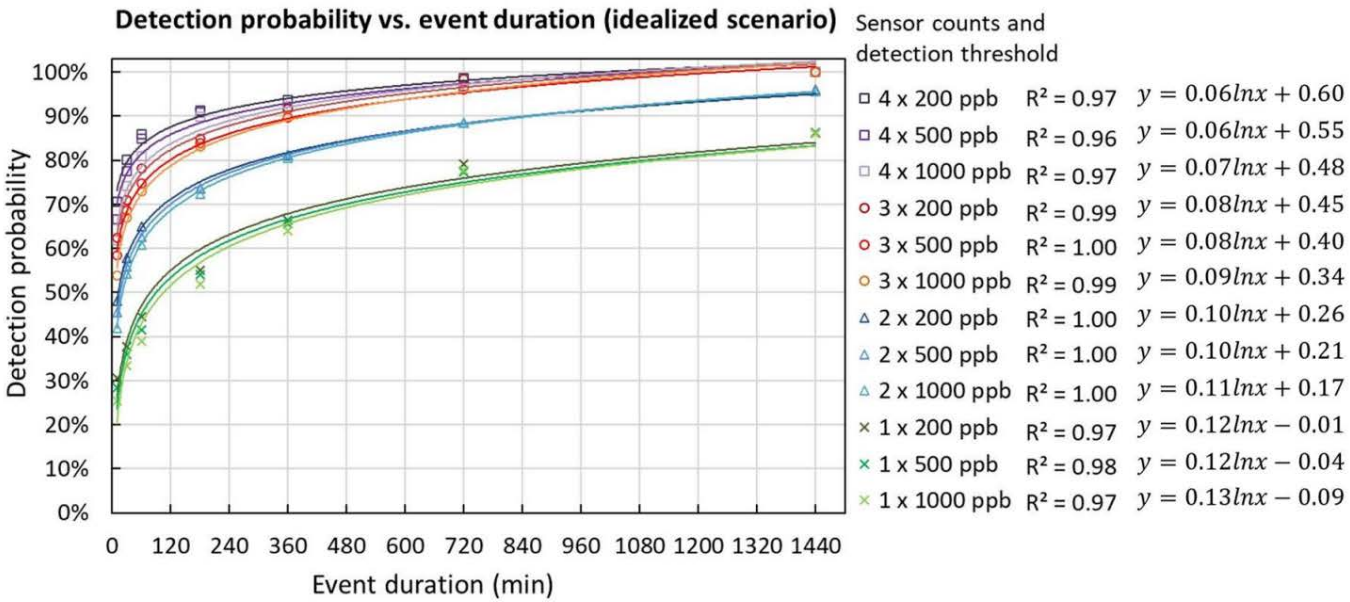
Times to detection for a continuous emission is a few hours to a day



Idealized site detection efficiency for short duration events.

Detection efficiency



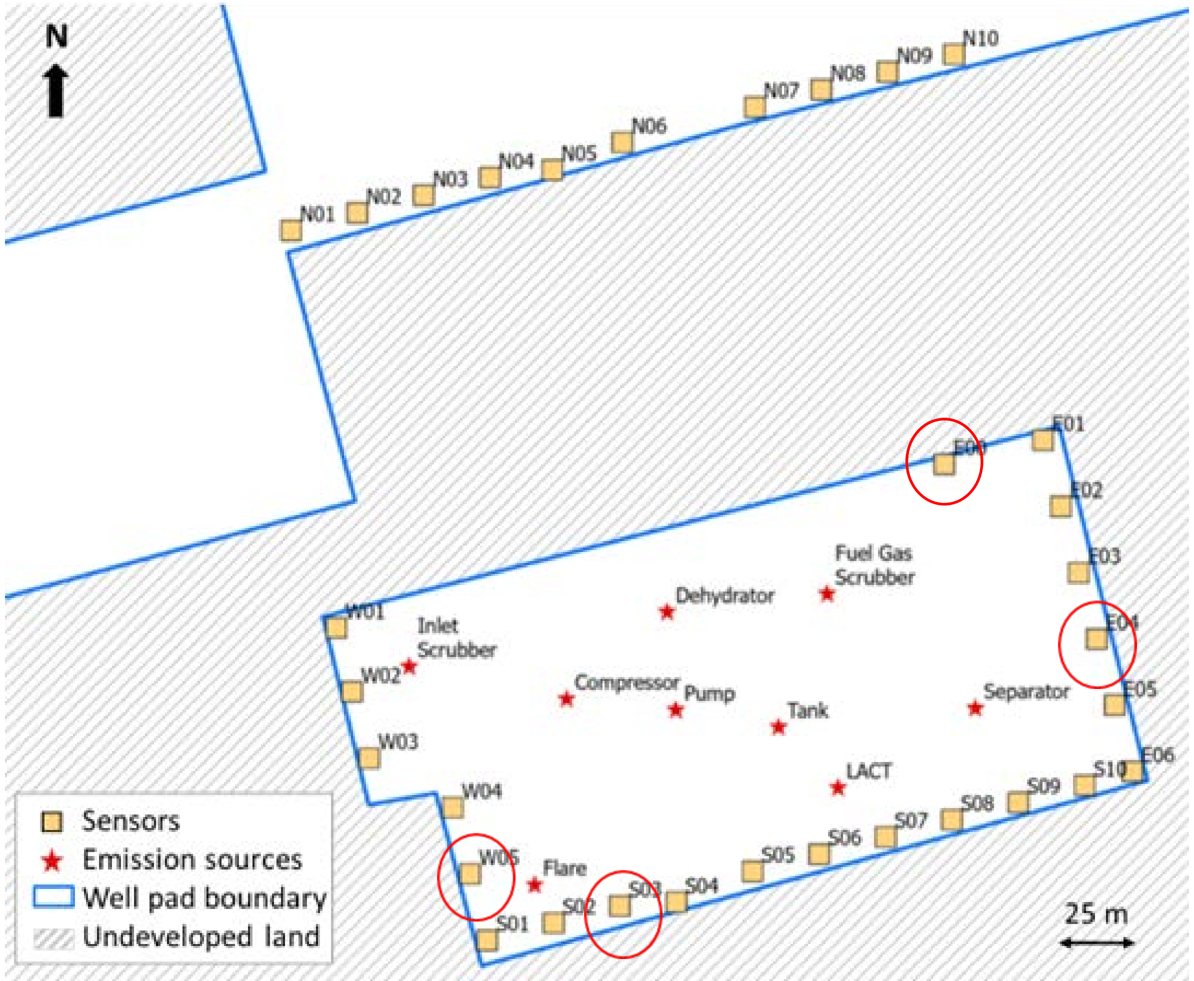


Detection of emission event mass, on average is higher than detection of events, but depends on distribution of event duration

More complex site.

Stack height of the equipment and plume rise parameters applied in dispersion modeling; temporal coverage of detection by source, with the optimized sensor network by maximizing averaged temporal coverage of detection among the nine simulated sources.

Equipment type	Stack height (m)	Plume rise (m)	Fraction of time with detection over 1000 ppb with the optimized sensor network
Compressor	6.9	5.0	5.0%
Dehydrator	2.0	0	21.6%
Flare	6.1	5.0	4.1%
Fuel gas scrubber	2.0	0	27.5%
Inlet Scrubber	2.0	0	10.7%
Lease Automatic Custody Transfer unit (LACT)	2.0	0	30.4%
Pump	2.0	0	22.0%
Separator	2.0	0	32.1%
Tank	5.5	0	21.9%

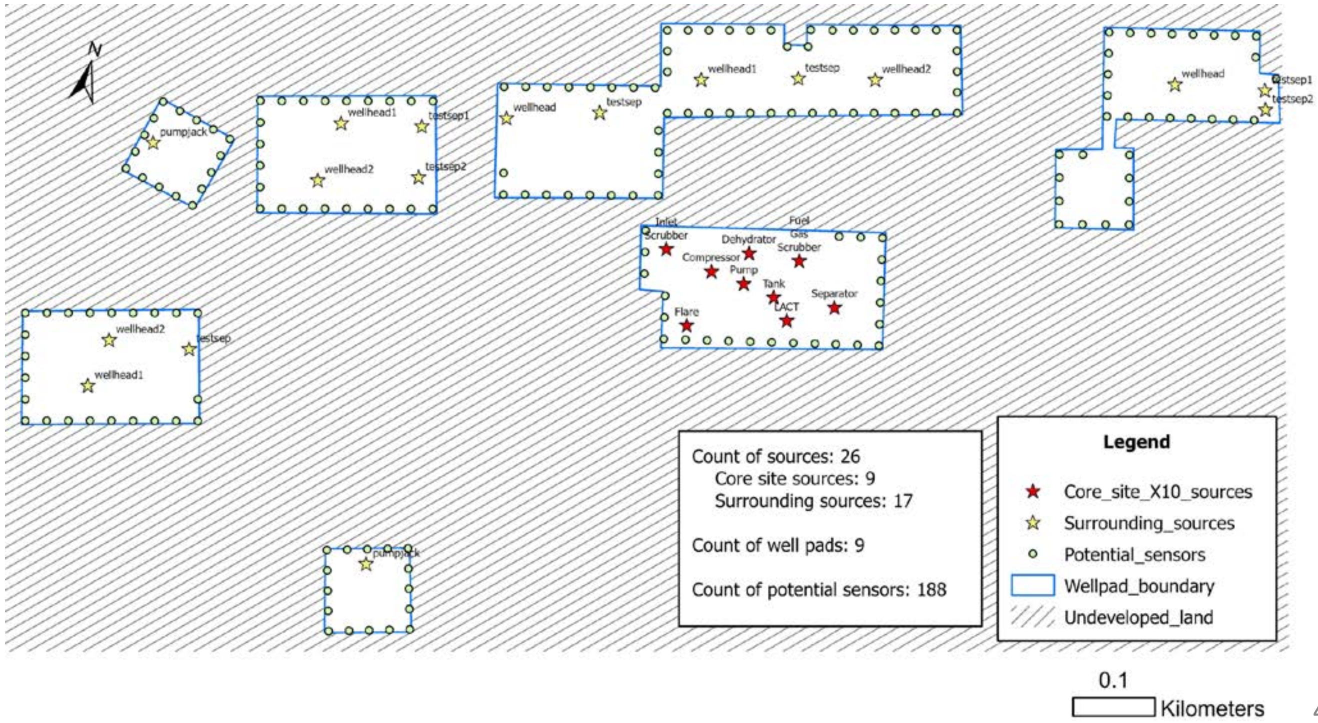


Determining emission equivalencies for Continuous Emissions Monitoring Systems (CEMS) using the FEAST conceptual framework

- Key question for single sites becomes how many sensors with a specified detection limit will be required to achieve the same level of emission detection as quarterly OGI inspections
  - Will depend on assumptions made about large events
  - Will vary by region

- Key question for groups of pads becomes whether sensors can effectively monitor nearby pads

- Define model facilities that have leaks and large emission events
- Determine detection efficiencies for emissions as a function of the detection limit of the measurement and the frequency of sampling
- Estimate emission reductions



Part 6: Next Steps

Keeping up with future FEAST developments.

- FEAST is publicly available for internal research use
  - Downloadable on Github (FEAST 3.1): GitHub Link
  - Partnering with the Texas Advanced Computing Center (TACC) to make a more user-friendly version available by Summer 2023

- FEAST Service Center provides services to external organization on FEAST modeling. Rates and details here: https://www.feast.ceer.utexas.edu/

- EEMDL will provide continued support for the FEAST model
  - New features, new FEAST versions, basin-specific FEAST models, etc.

- Launch **FEAST user groups**:
  - Keep track of latest version of software and get regular model updates
  - Share best practices in use of software
  - Introduce new users to software
  - Crowdsource and troubleshoot bugs

FEAST user groups.

- To be part of the FEAST user group, sign up via email at feast@utexas.edu with subject "FEAST user group"

- Additional benefits of being part of FEAST User Groups
  - Periodic training classes for new features and new users

  - On-going FEAST-based coursework leading to a formal certificate program in modeling methane mitigation programs

- First meeting of FEAST user group in Feb. 2023 – date TBD

- In-person workshops during EEMDL Annual Meeting in September

Resources and links.

- For all EEMDL-related events/updates: https://www.eemdl.utexas.edu
  - Keep track of EEMDL events/products (~monthly) and job opportunities

- EEMDL general inquiries: eemdl@utexas.edu

- Contact EEMDL co-directors for collaboration, data sharing, data analysis:
  - arvind.ravikumar@austin.utexas.edu
  - allen@che.utexas.edu

- FEAST 3.1 version used in EPA supplemental proposal: GitHub Link

- FEAST Service Center: https://www.feast.ceer.utexas.edu/

- FEAST user groups: Email feast@utexas.edu with subject ‘FEAST User Group’

Upcoming events.

- Thank you for attending this EEMDL and FEAST webinar

- **Upcoming events: All events will be posted on EEMDL website** (https://www.eemdl.utexas.edu)

  - Feb 2023 (date TBD): FEAST user group meeting (sign up to receive updates)

  - March 22 & 24, 2023: Methane short course