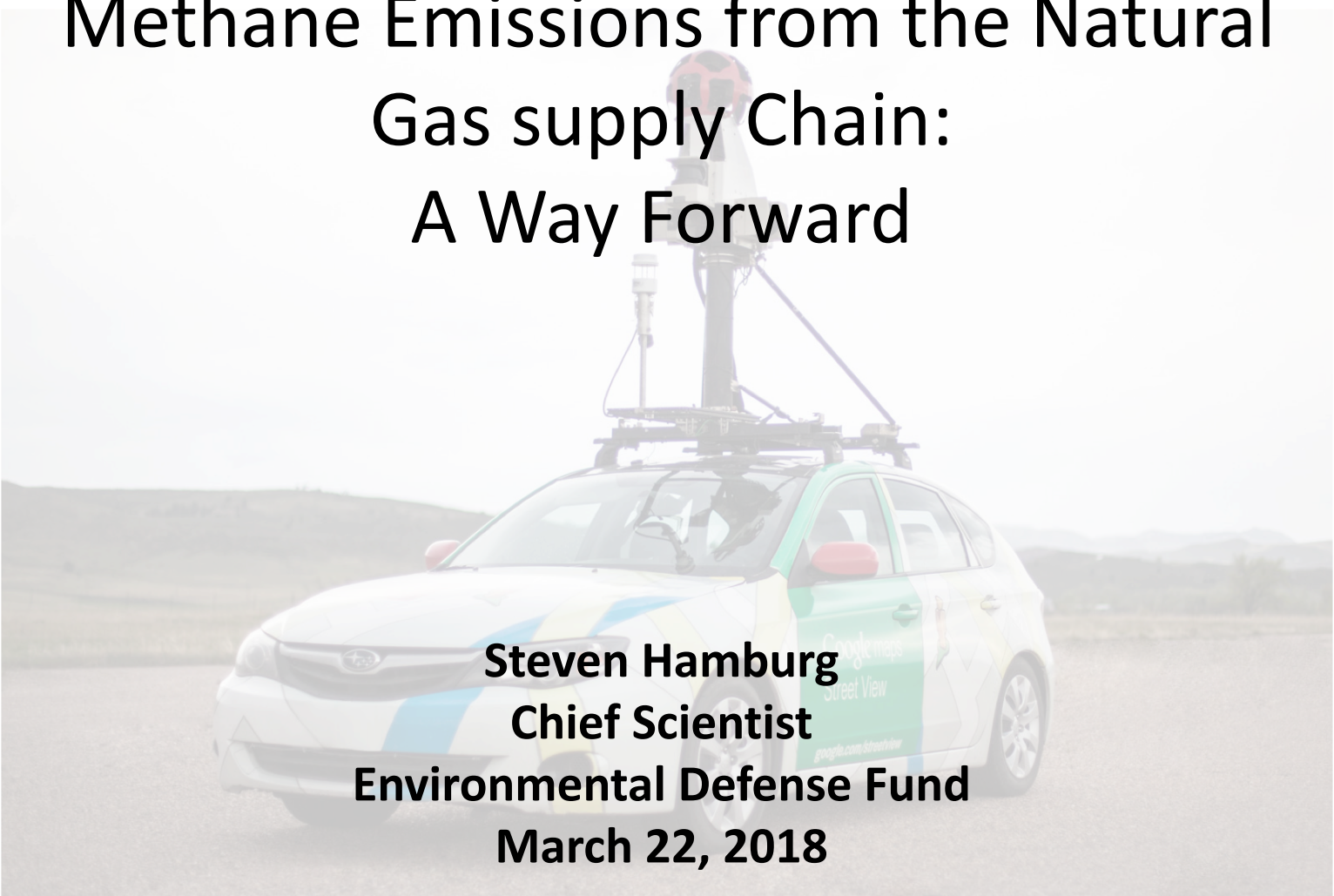


Methane Emissions from the Natural Gas supply Chain: A Way Forward

A white Google Street View car is parked on a dirt road in a hilly, open landscape. The car has a green and yellow stripe on its side and a sensor rig mounted on its roof. The rig includes a camera and various sensors, including a red and black spherical sensor. The background shows rolling hills under a clear sky.

Steven Hamburg
Chief Scientist
Environmental Defense Fund
March 22, 2018



EDF's Methane Research



Science

Studies employ independent experts and use multiple methods to measure methane emissions



Collaboration

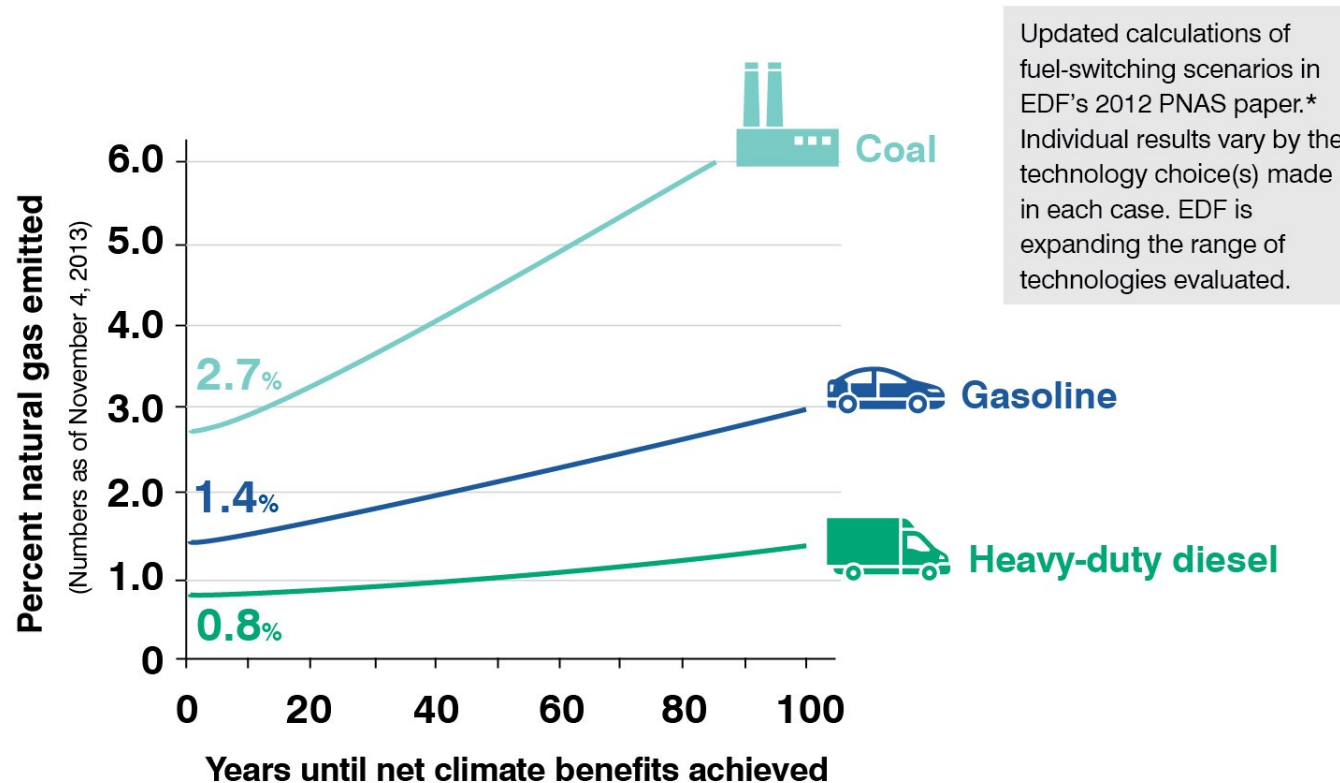
More than 140 partners from 40 academic, industry, and research institutions



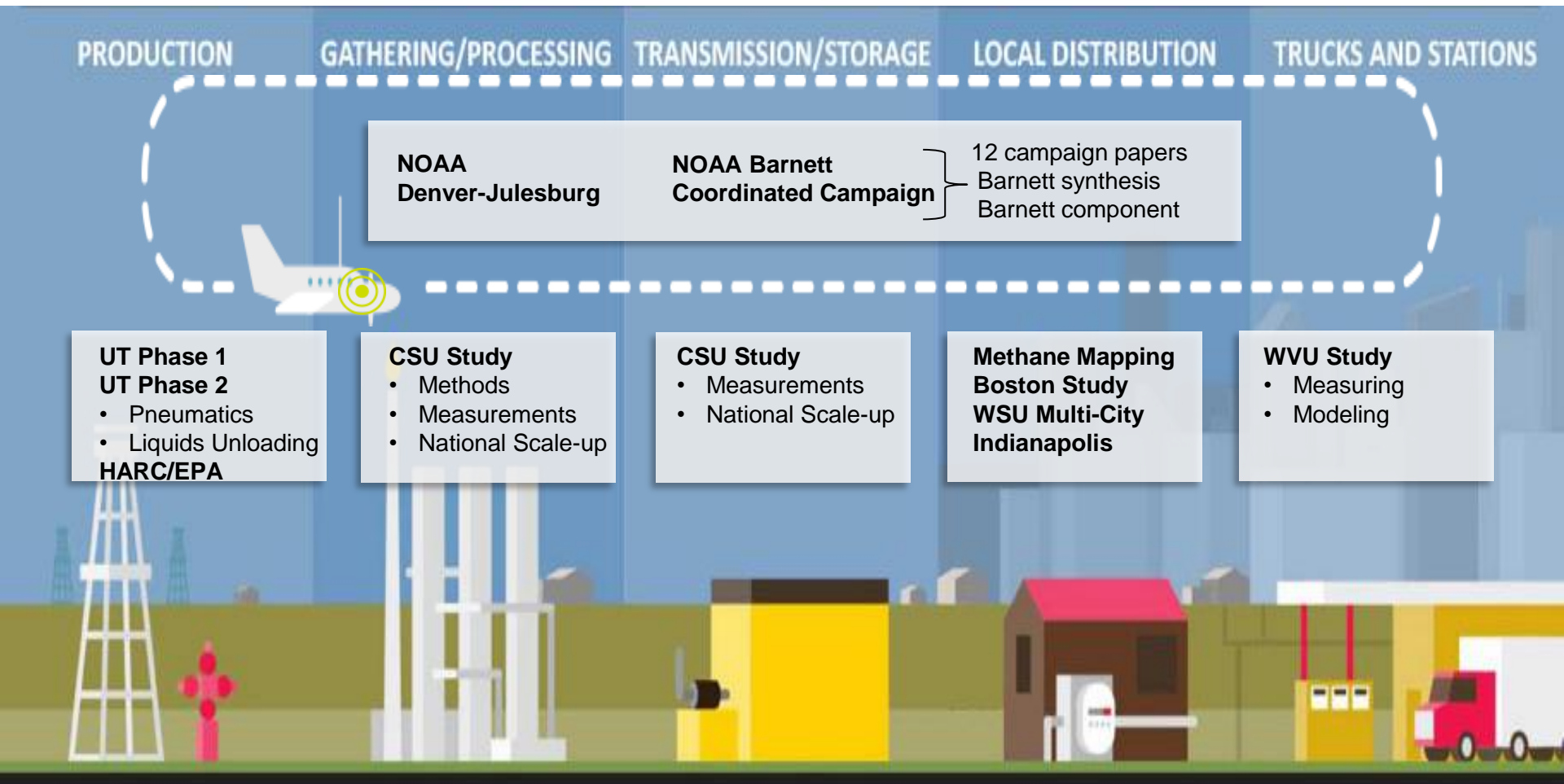
Results

Published in peer-reviewed journals with publically available data

Can Natural Gas Deliver Sustained Climate Benefits?



U.S. studies measured emissions across supply chain.



Pilot Projects

Gap Filling

- Abandoned wells
- Helicopter IR Survey

Synthesis Projects

- NETL LCA
- Synthesis**

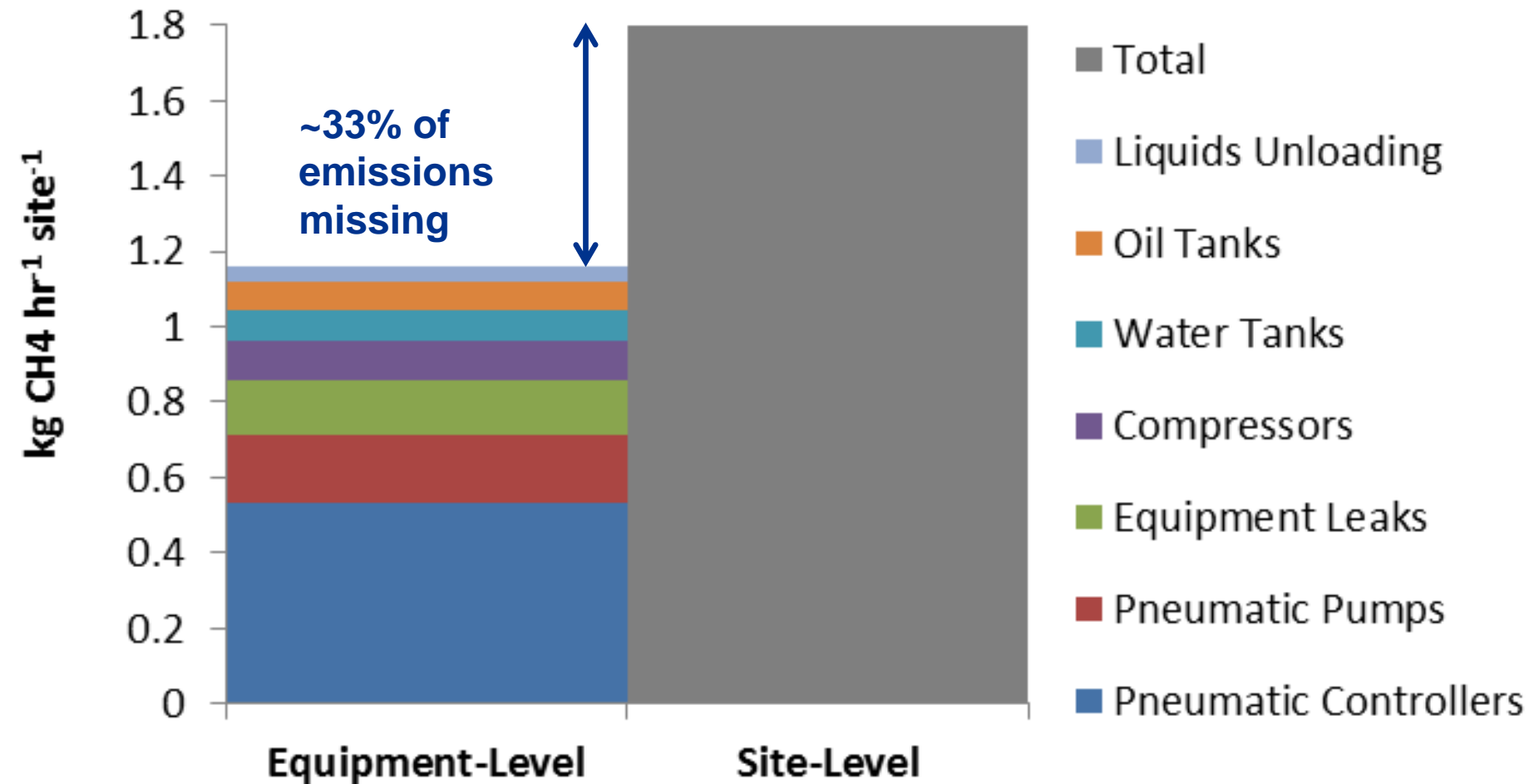


Comprehensive site measurements reveal higher emissions



Emission inventories based on equipment-level measurements often miss emissions found with basin- and site-level methods

Barnett Shale Well Pads



Intentional, Vented Emissions

- **Sources:**

- Pneumatic controllers & pumps account for 1/3 of reported emissions
- Other sources include tanks, compressors, liquids unloading, and blowdowns

- **Solutions:**

- Pneumatics: replace with zero/low-bleed and inspect for malfunctions
- Numerous options for mitigating vented sources
 - <https://www.epa.gov/natural-gas-star-program/recommended-technologies-reduce-methane-emissions>



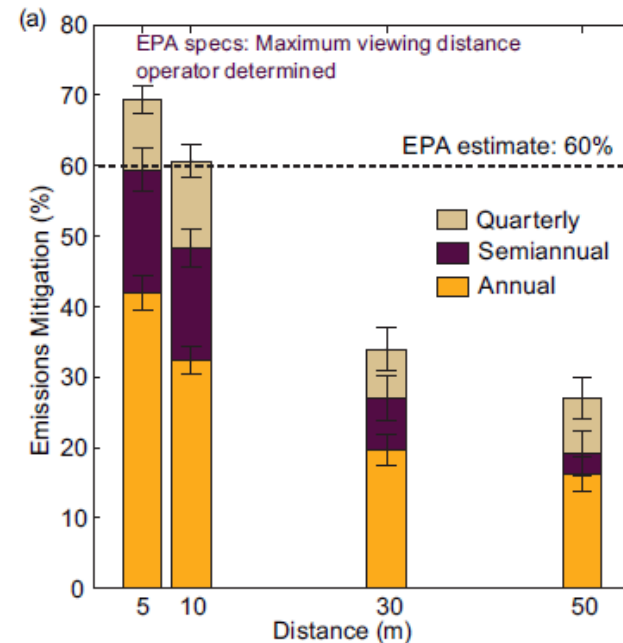
Unintentional, Fugitive Emissions

- **Sources:**

- Equipment leaks account for ~30% of reported emissions

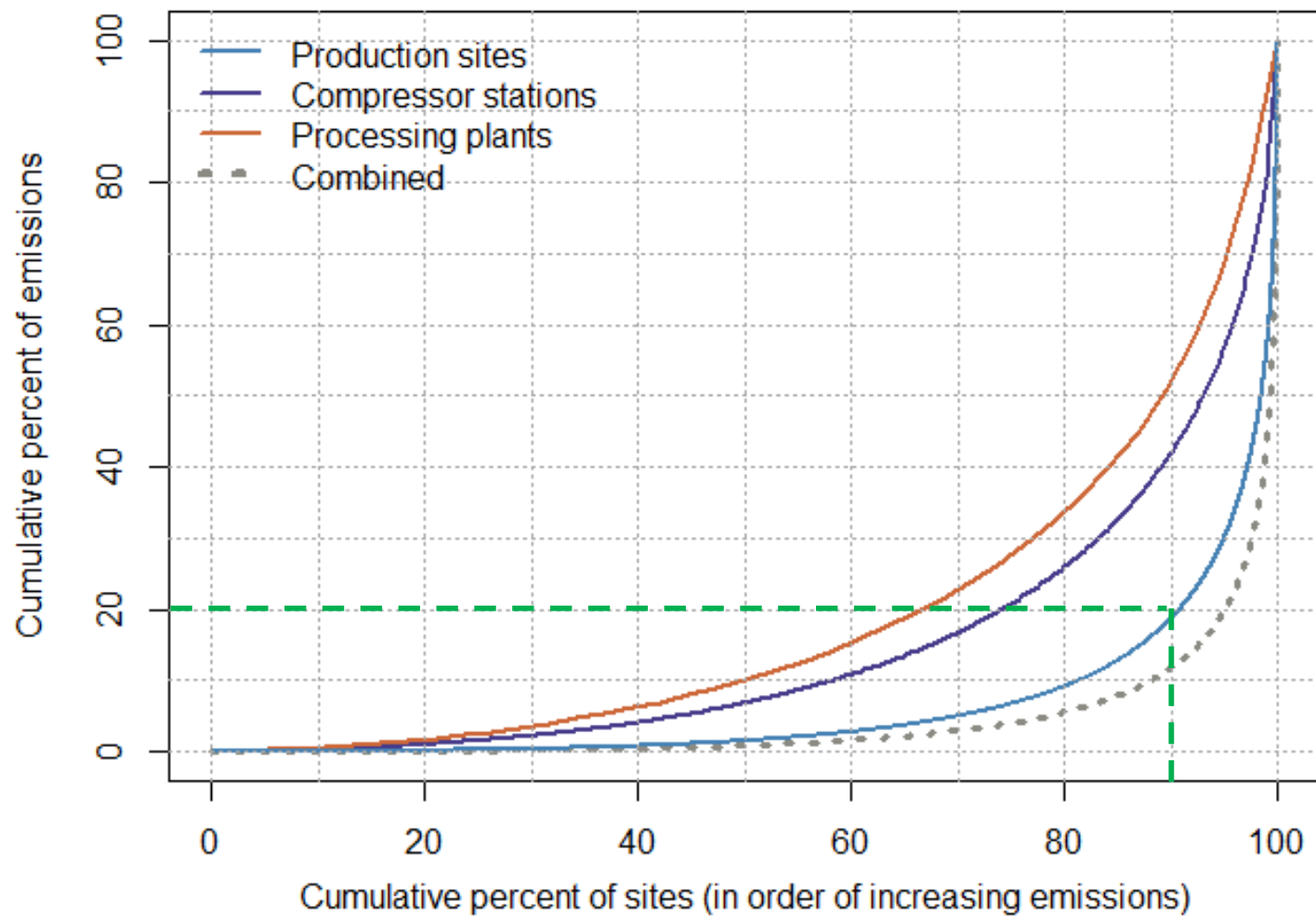
- **Solutions:**

- Optical gas imaging is effective if surveys follow best practices
- Emerging technologies will allow continuous monitoring



Super-emitters are ubiquitous but stochastic





EDF U.S. CH₄ Study Papers

1. **December 2013:** UT Production study: <http://www.pnas.org/lookup/doi/10.1073/pnas.1304880110>
2. **May 2014:** NOAA DJ Basin Flyover: <http://onlinelibrary.wiley.com/doi/10.1002/2013JD021272/pdf>
3. **November 2014:** HARC/EPA Fence-line study: <http://pubs.acs.org/doi/abs/10.1021/es503070q>
4. **December 2014:** UT Production Pneumatics study: <http://pubs.acs.org/doi/abs/10.1021/es5040156>
5. **December 2014:** UT Production Liquids Unloading study: <http://pubs.acs.org/doi/abs/10.1021/es504016r>
6. **January 2015:** Harvard Boston Urban Methane study: <http://www.pnas.org/content/early/2015/01/21/1416261112>
7. **February 2015:** CSU Transmission and Storage study, measurements: <http://pubs.acs.org/doi/abs/10.1021/es5060258>
8. **February 2015:** CSU Gathering and Processing study, measurements: <http://pubs.acs.org/doi/abs/10.1021/es5052809>
9. **March 2015:** WSU Local Distribution study: <http://pubs.acs.org/doi/abs/10.1021/es505116p>
10. **May 2015:** CSU Gathering & Processing study, methods: <http://www.atmos-meas-tech.net/8/2017/2015/amt-8-2017-2015.html>
11. **July 2015:** CSU Transmission & Storage study, national results: <http://pubs.acs.org/doi/abs/10.1021/acs.est.5b01669>
12. **August 2015:** CSU Gathering & Processing study, national results: <http://pubs.acs.org/doi/abs/10.1021/acs.est.5b02275>

Barnett Coordinated Campaign Papers (July 2015) papers 13-24:

13. Overview: <http://pubs.acs.org/doi/abs/10.1021/acs.est.5b02305>
 14. NOAA led Top-down study: <http://pubs.acs.org/doi/abs/10.1021/acs.est.5b00217>
 15. Bottom-up inventory: <http://pubs.acs.org/doi/abs/10.1021/es506359c>
 16. Functional super-emitter study: <http://pubs.acs.org/doi/abs/10.1021/acs.est.5b00133>
 17. Michigan airborne study: <http://pubs.acs.org/doi/abs/10.1021/acs.est.5b00219>
 18. WVU compressor study: <http://pubs.acs.org/doi/abs/10.1021/es506163m>
 19. Princeton near-field study: <http://pubs.acs.org/doi/abs/10.1021/acs.est.5b00705>
 20. Purdue aircraft study: <http://pubs.acs.org/doi/abs/10.1021/acs.est.5b00410>
 21. Aerodyne mobile study: <http://pubs.acs.org/doi/abs/10.1021/es506352j>
 22. U of Houston mobile study: <http://pubs.acs.org/doi/abs/10.1021/es5063055>
 23. Picarro mobile flux study: <http://pubs.acs.org/doi/abs/10.1021/acs.est.5b00099>
 24. Cincinnati tracer apportionment: <http://pubs.acs.org/doi/abs/10.1021/acs.est.5b00057>
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25. **December 2015:** Barnett Synthesis: <http://www.pnas.org/content/112/51/15597.abstract>
 26. **March 2016:** Abandoned & Orphaned Wells: <http://onlinelibrary.wiley.com/doi/10.1002/2015GL067623/full>
 27. **April 2016:** Aerial Infrared Survey: <http://pubs.acs.org/doi/abs/10.1021/acs.est.6b00705>
 28. **August 2016:** Indianapolis Urban Methane study: <http://pubs.acs.org/doi/abs/10.1021/acs.est.6b01198>
 29. **December 2016:** WVU NG vehicles & fueling stations: <http://pubs.acs.org/doi/abs/10.1021/acs.est.5b06059>
 30. **December 2016:** Hi-Flow malfunction paper: <https://www.elementascience.org/articles/10.12952/journal.elementa.000137/>
 31. **January 2017:** Barnett component paper: <https://www.nature.com/articles/ncomms14012>
 32. **April 2017:** Mobile pipeline leak detection: <http://pubs.acs.org/doi/abs/10.1021/acs.est.6b06095>
 33. **July 2017:** Eagle Ford spatiotemporal variability: <http://pubs.acs.org/doi/abs/10.1021/acs.est.7b00814>
 34. **August 2017:** WVU NG vehicles modeling paper: <http://www.tandfonline.com/doi/abs/10.1080/10962247.2017.1368737>

Innovative leak detection technologies have entered a renaissance




<https://www.edf.org/methane-detectors-challenge>

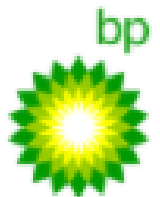
<https://methane.stanford.edu>

<https://arpa-e.energy.gov/?q=arpa-e-programs/monitor>

Recommendations

- **Measurements** should be frequent and robust to increase the accuracy of reported emissions.
 - **Monitoring** for leaks and malfunctions can increase the effectiveness of mitigation.
 - **Root cause analysis** should be used to predict and prevent super-emitters.
 - **Innovation** should be encouraged but new technologies and practices require validation.
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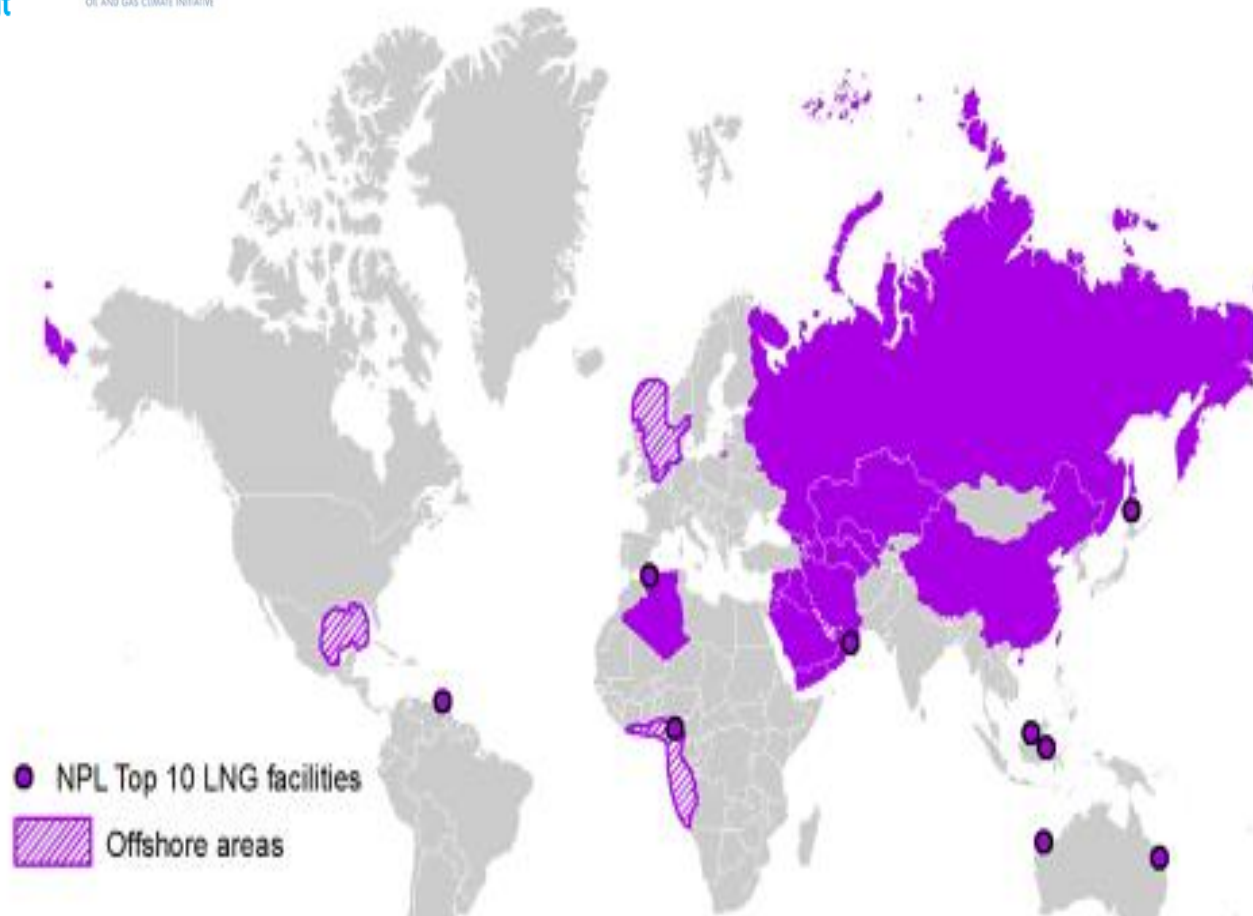
International O&G Methane Research



CCAC International Oil and Gas Methane Science Studies



Cooperating to gather global data



<http://ccacoalition.org/en/content/oil-and-gas-methane>