US EPA WCC Partners Meeting

Natural Gas for Goods Movement: Current and Future Emissions Performance

Timothy O'Connor
Senior Attorney / Director, California Climate
September 4, 2014

EDF
ENVIRONMENTAL DEFENSE FUND
Finding the ways that work

Reasons for natural gas as a transportation fuel

1. Compressed natural gas (CNG) is a cleaner burning fuel that can emit 70-90% less PM than diesel when coupled with oxidation catalysts.

2. Natural gas is currently less expensive than diesel and will remain so for the foreseeable future.

3. Natural gas is a domestic, abundant fuel source that benefits national energy security.

4. Combustion of natural gas emits less CO_2 than combustion of diesel.

Problem with natural gas as a transportation fuel

The environmental benefits of natural gas as a fuel are not always clear.

NGVs have the potential to benefit the climate, but only if methane is addressed in a comprehensive manner, including emissions upstream of the vehicle/fueling station (must view this from a full life-cycle analysis perspective, not just the vehicle emissions)

Solution for natural gas as a transportation fuel

Minimizing methane leakage rates across the supply chain, including from natural gas trucks and fueling infrastructure, is essential to helping natural gas achieve its maximum environmental potential.

NATURAL GAS PRODUCTION

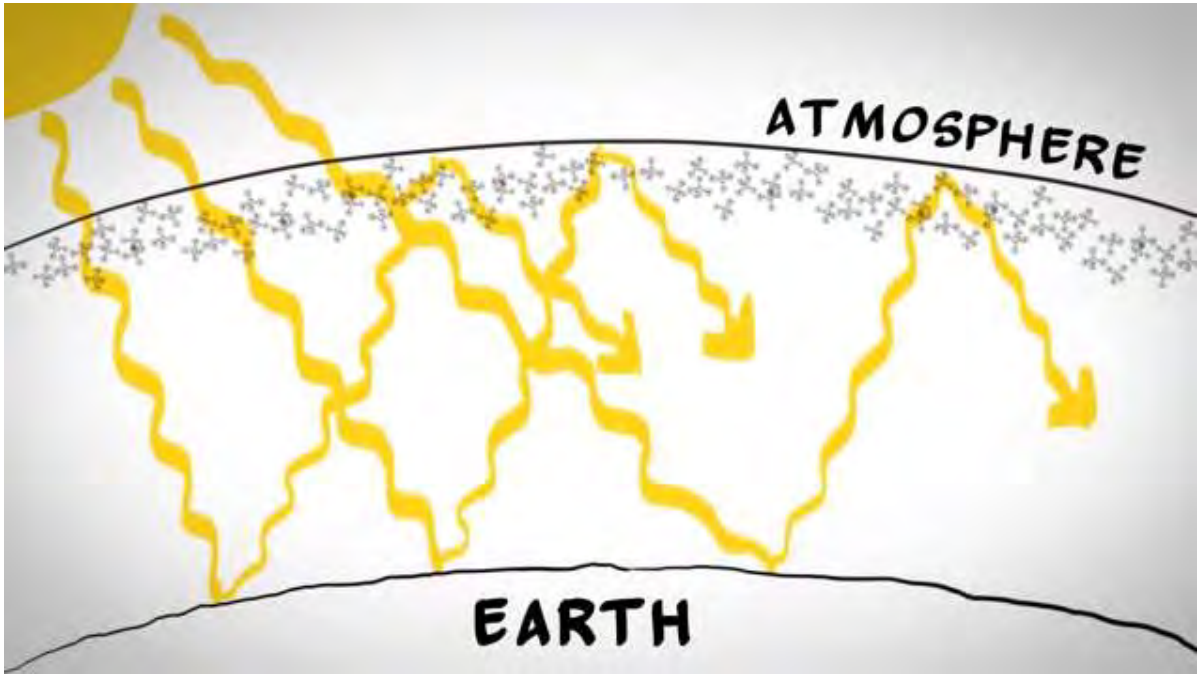
PROCESSING

TRANSMISSION & STORAGE

LOCAL DISTRIBUTION TO OTHER END USERS

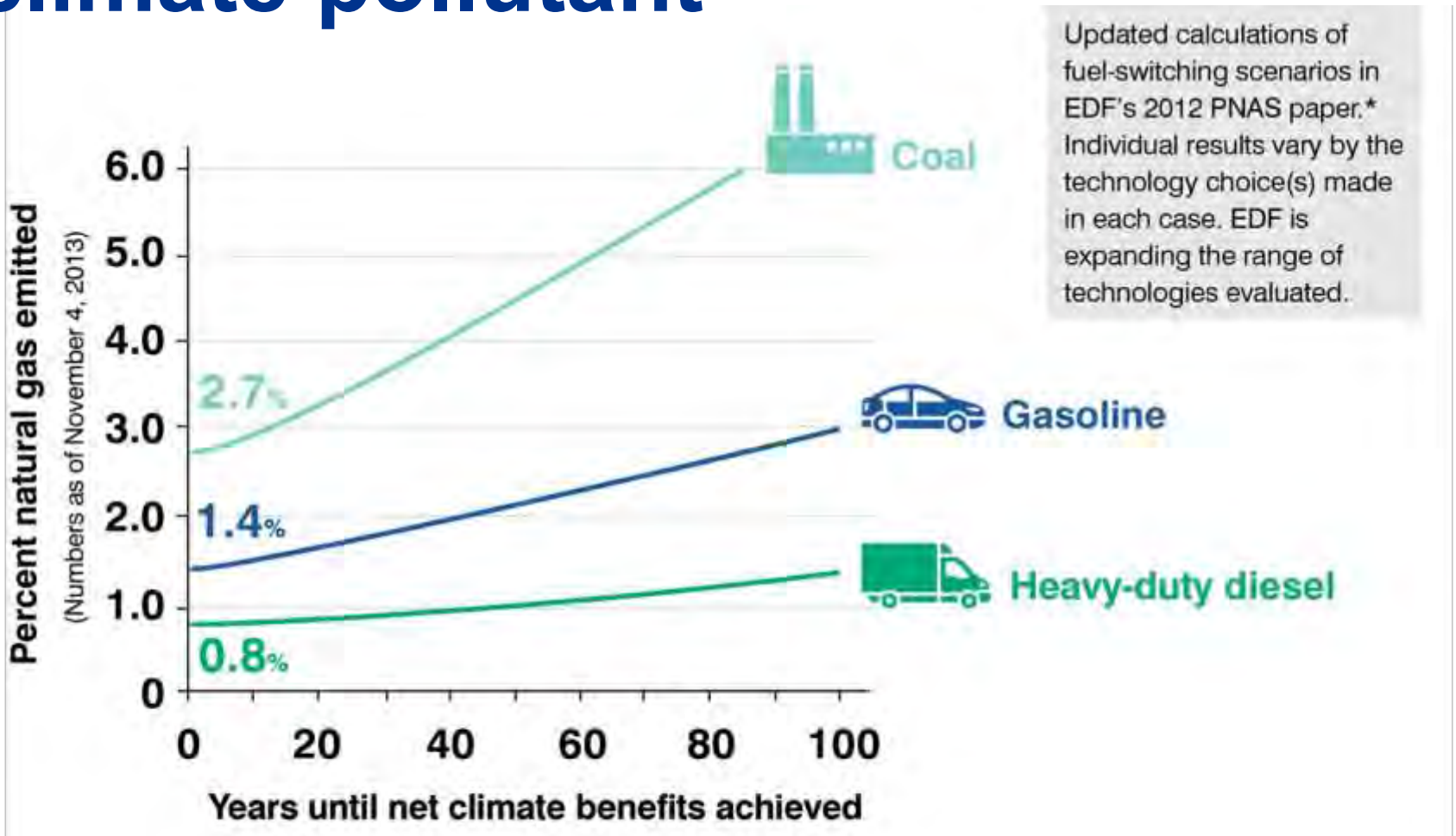
Climate implications of methane

POUND FOR POUND METHANE TRAPS
84x MORE HEAT OVER 20 YEARS



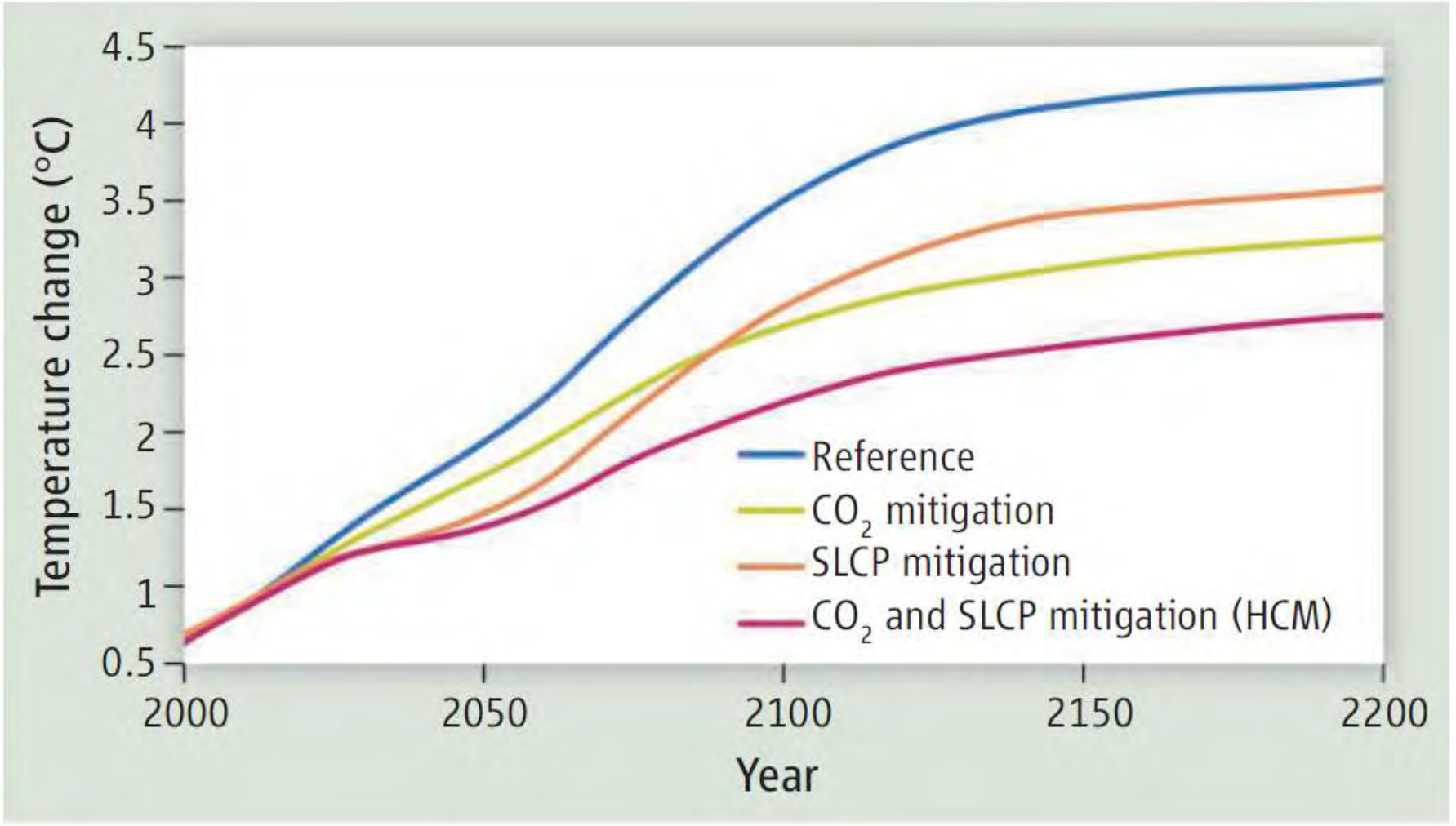
www.edf.org/climate/methane

Significance of methane as a climate pollutant



*Adapted from Alvarez et al. (2012) PNAS, 109: 6435–6440, reflecting new IPCC AR5 & 2013 EPA GHG data. IPCC updates: (1) direct/indirect radiative forcing of CH_4 and CO_2, (2) CH_4 lifetime, (3) CO_2 impulse response function. Additional effects due to climate-carbon feedbacks and CO_2 from the oxidation of CH_4 not included (AR5 lacks data to support time-dependent analysis but EDF believes these effects to be small). Emissions updates include factors in Table 1 and corresponding LREF values in Table S1 of PNAS paper; an LREF value specific to heavy-duty CNG vehicles is now used.

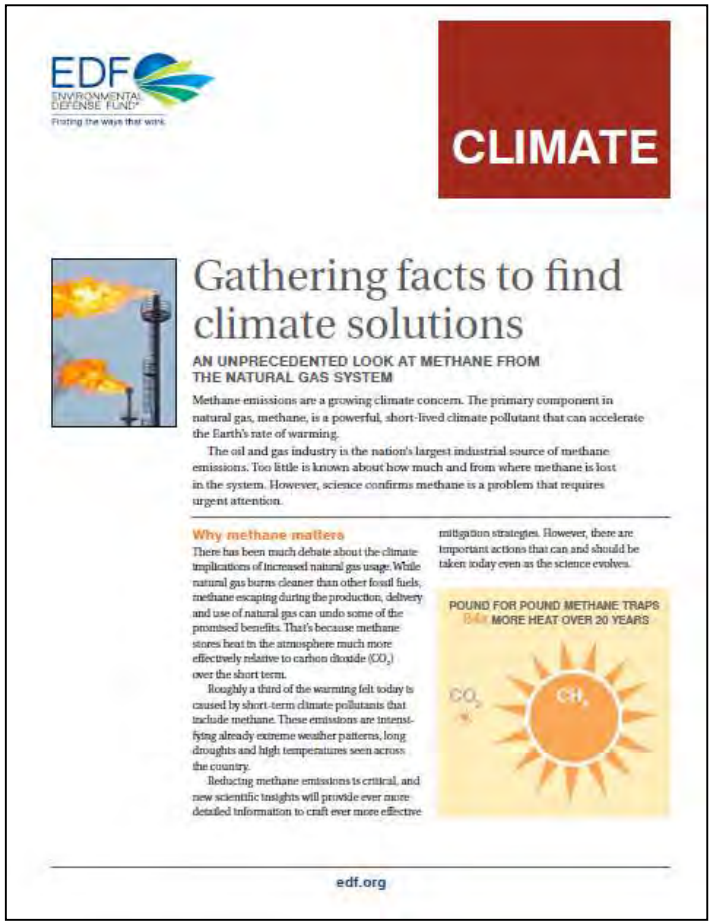
Methane *and* CO_2, not CH_4 *or* CO_2



Shoemaker, et. al., **What Role for Short-Lived Climate Pollutants in Mitigation Policy?,** Science, December 19, 2013

EDF Methane Studies

- 16 studies w/roughly 90 collaborators in 5 research modules
- All studies to be submitted or published by the end of 2014



EDF
ENVIRONMENTAL DEFENSE FUND
Finding the ways that work

CLIMATE

Gathering facts to find climate solutions

AN UNPRECEDENTED LOOK AT METHANE FROM THE NATURAL GAS SYSTEM

Methane emissions are a growing climate concern. The primary component in natural gas, methane, is a powerful, short-lived climate pollutant that can accelerate the Earth's rate of warming.

The oil and gas industry is the nation's largest industrial source of methane emissions. Too little is known about how much and from where methane is lost in the system. However, science confirms methane is a problem that requires urgent attention.

Why methane matters

There has been much debate about the climate implications of increased natural gas usage. While natural gas burns cleaner than other fossil fuels, methane escaping during the production, delivery and use of natural gas can undo some of the promised benefits. That's because methane stores heat in the atmosphere much more effectively relative to carbon dioxide (CO_2) over the short term.

Roughly a third of the warming felt today is caused by short-term climate pollutants that include methane. These emissions are intensifying already extreme weather patterns, long droughts and high temperatures seen across the country.

Reducing methane emissions is critical, and new scientific insights will provide ever more detailed information to craft ever more effective mitigation strategies. However, there are important actions that can and should be taken today even as the science evolves.

POUND FOR POUND METHANE TRAPS 84x MORE HEAT OVER 20 YEARS

CO_2 CH_4

edf.org

www.edf.org/methaneleakage

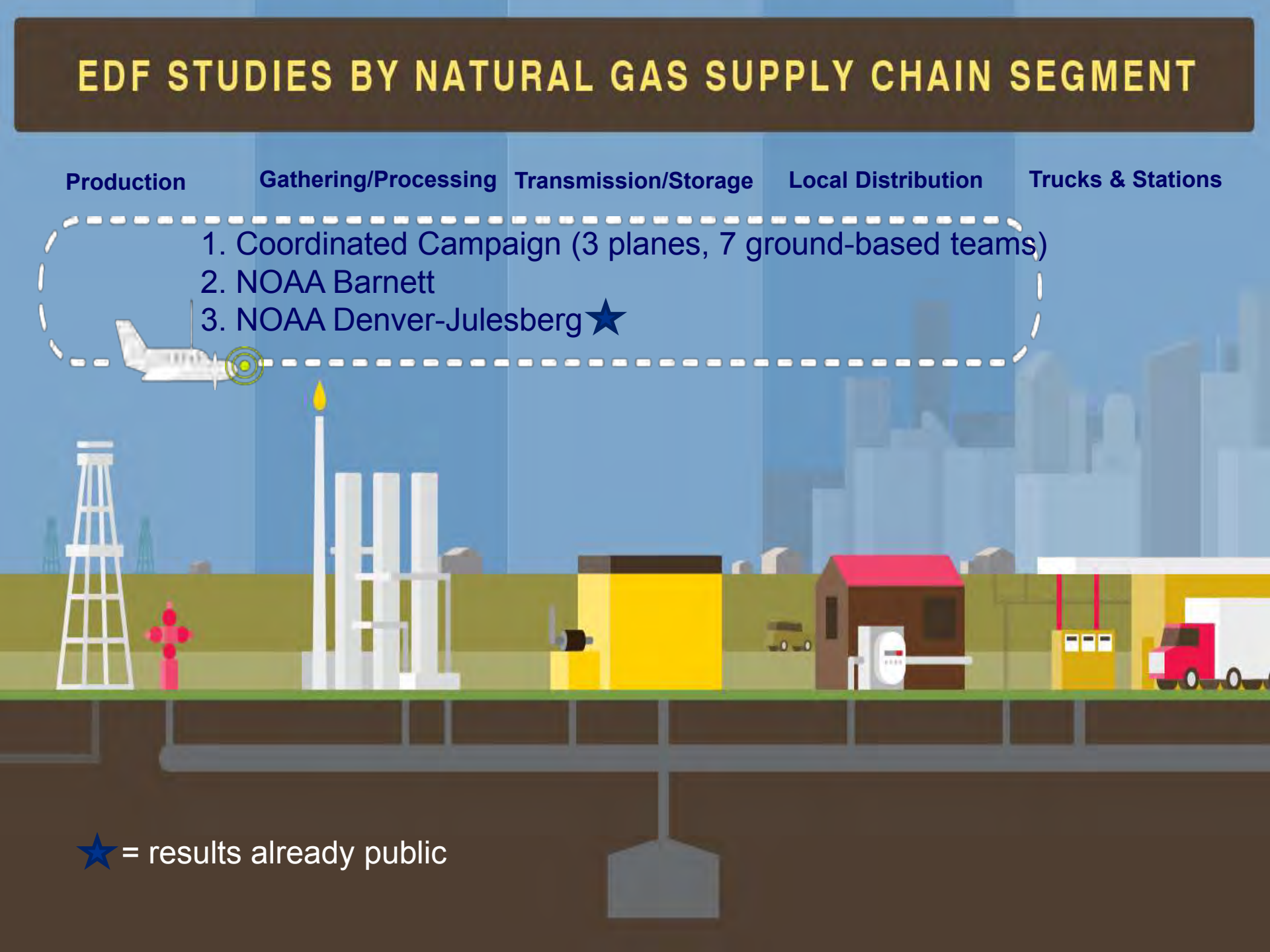
Methane leakage research modules

1. Production
2. Gathering / Processing
3. Transmission / Storage
4. Local Distribution
5. Trucks & Stations

EDF STUDIES BY NATURAL GAS SUPPLY CHAIN SEGMENT

Production | **Gathering/Processing** | **Transmission/Storage** | **Local Distribution** | **Trucks & Stations**

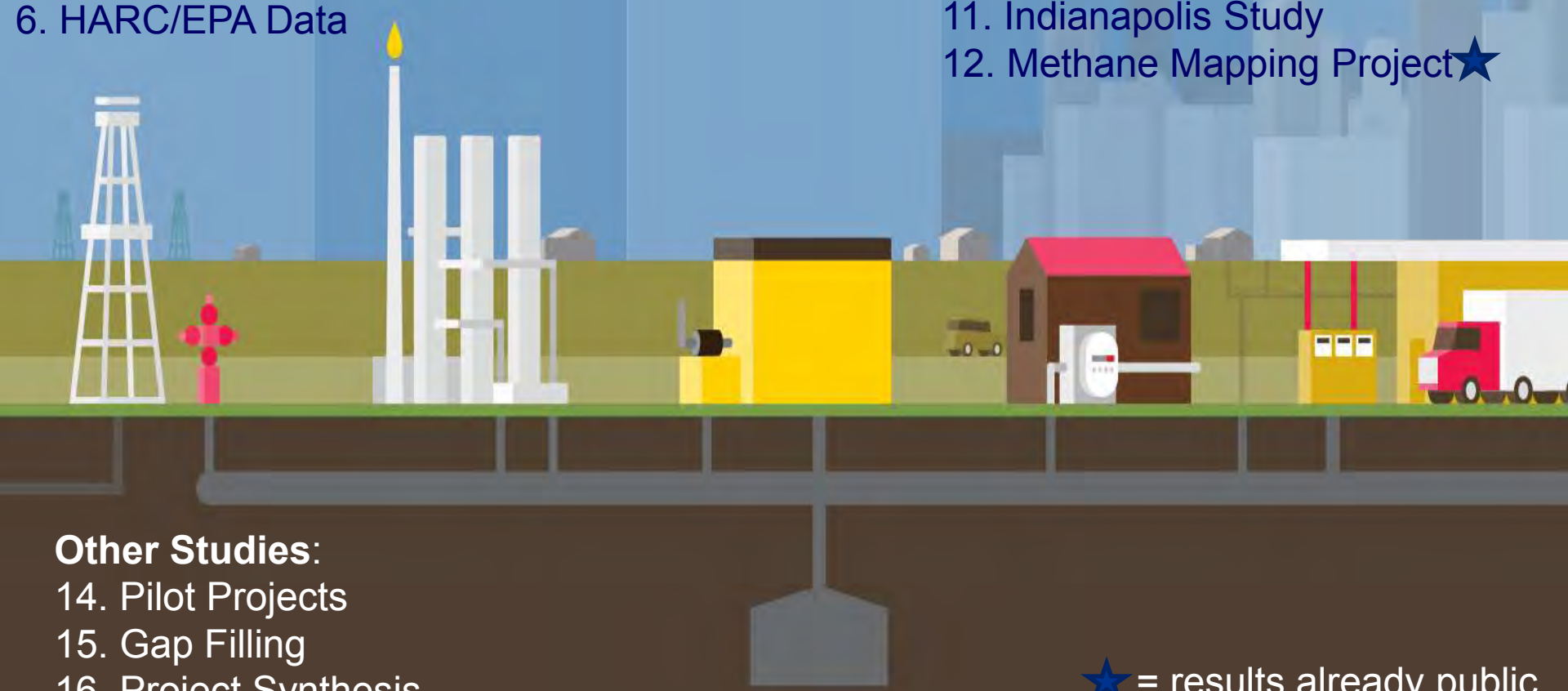
1. Coordinated Campaign (3 planes, 7 ground-based teams)
2. NOAA Barnett
3. NOAA Denver-Julesberg ★



★ = results already public

EDF STUDIES BY NATURAL GAS SUPPLY CHAIN SEGMENT

Production	Gathering/Processing	Transmission/Storage	Local Distribution	Trucks & Stations
4. UT Phase 1★ 5. UT Phase 2 6. HARC/EPA Data	7. CSU Study	8. CSU Study	9. WSU Multi-City 10. Boston Study 11. Indianapolis Study 12. Methane Mapping Project★	13. WVU Study



Other Studies:
14. Pilot Projects
15. Gap Filling
16. Project Synthesis

★ = results already public

Even 1.3% is Too Much

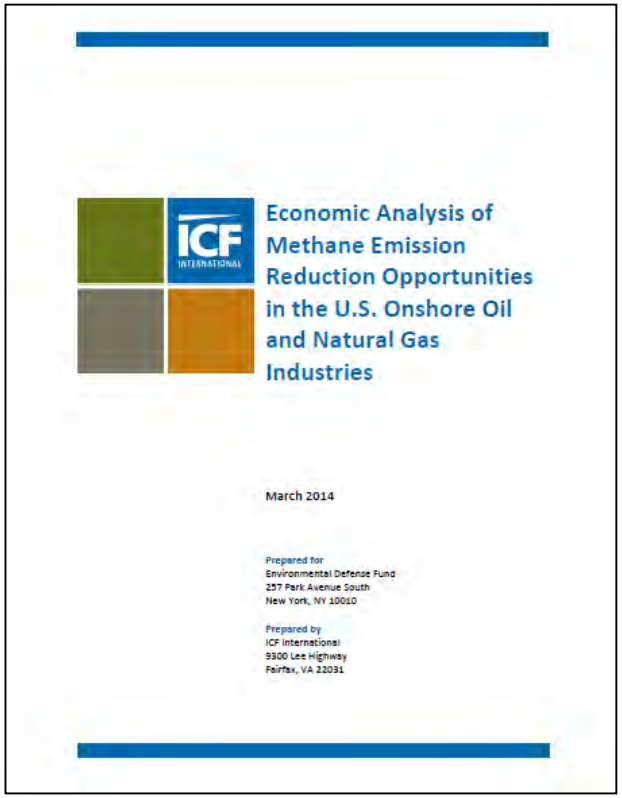
1.3% Leak Rate =

- **$1.7- $6.2 Billion** of lost revenue
- Annual GHG emissions of:
  - **117 million cars or**
  - **146 coal power plants**
- Gas carried by **127 LNG tankers.**

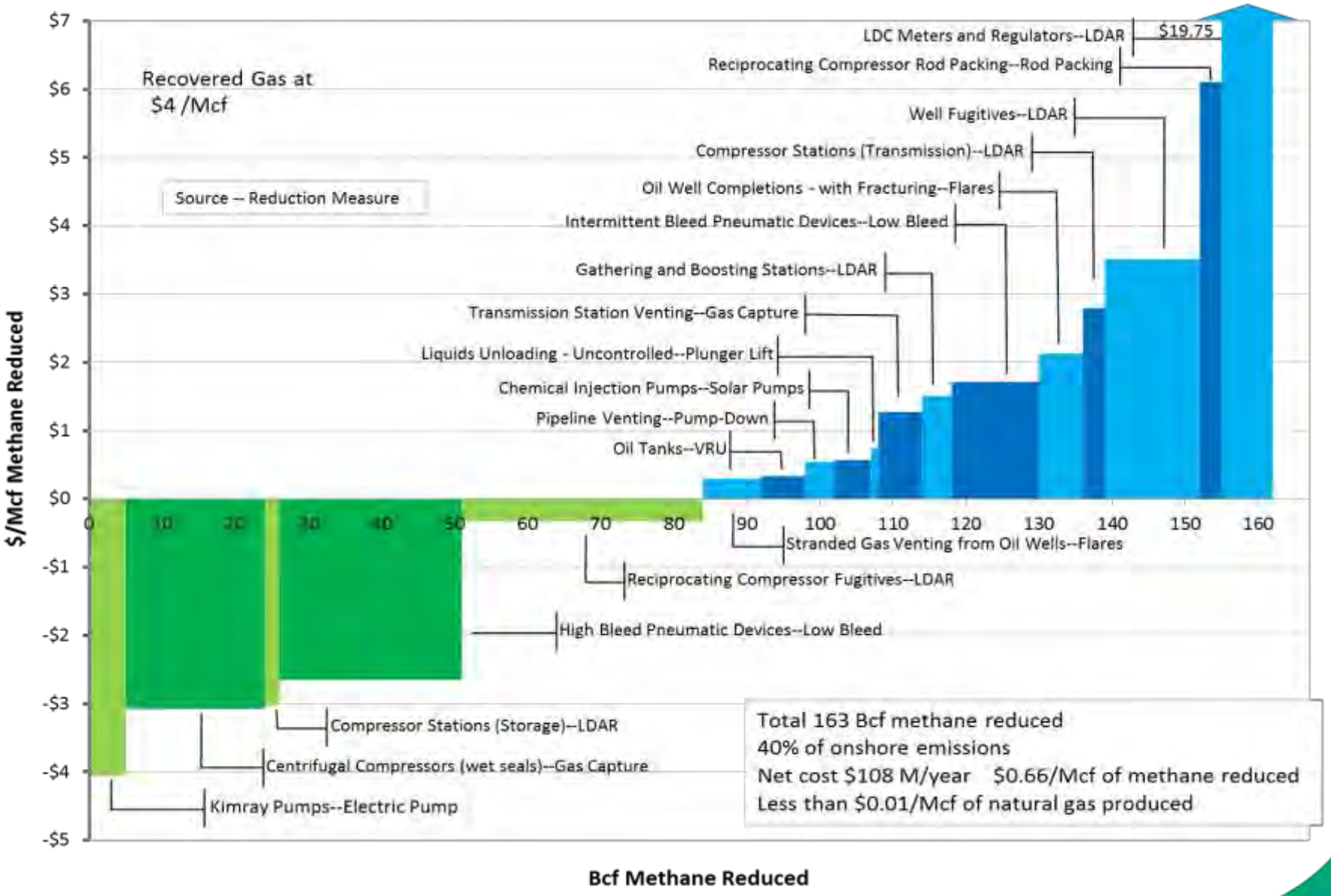
Sources: 1.3 % Leak Rate comes from US GHG inventory for Natural Gas Systems, including Associated Gas of 6,592 Gg CH4. *http://epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2014-Chapter-Executive-Summary.pdf*
$1.7 billion comes from June 2013-June 2014 avg. henry hub price ($4.31/Mmbtu) $6.2 is Japanese avg import price June 2013-June 2014.
117 and 146 comes from EPA GHG calculator http://www.epa.gov/cleanenergy/energy-resources/calculator.html#results and multiplying 6592 by 86/25 to get the 20 year GWP.
127 LNG tankers comes from http://www.eia.gov/oiaf/servicerpt/natgas/chapter3.html where 1 tanker holds 3 bcf, using 6592 Gg.

ICF Consulting Methane Cost Curve Report (March 2014)

Cost-effective solutions exist for oil and gas industry to reduce methane emissions



Methane Reductions are Cost-Effective



Key Take-Aways from ICF

- **CH_4 emissions will grow 4.5%** (now → 2018)
- In 2018, **90% of emissions will come from existing infrastructure**.
- Using today's technologies, **CH_4 can be cut 40%** from onshore oil and gas sources.
- Reductions are achievable at **a net cost of less than a $0.01 / Mcf of gas produced**.
- Some **CH_4 controls pay for themselves**.

Tim O'Connor
toconnor@edf.org
415-293-6132

EDF
ENVIRONMENTAL DEFENSE FUND®
Finding the ways that work

Additional Information on 16 Methane Studies

1. University of Texas-Austin production study

This study measured methane emissions during production of natural gas—some of the first measurements ever collected from hydraulically fractured wells. Diverse methods were used to directly measure methane emissions at well pads operated by nine cooperating U.S. natural gas companies.

Results were published in the Proceedings of National Academy of Sciences in September 2013.

2. NOAA, CU-Boulder Denver flyover study

A cooperative effort, led by NOAA and the Cooperative Institute for Research in Environmental Sciences (CIRES) at Univ. Colorado-Boulder, measures methane emissions in Colorado's most active oil and gas field. Using data gathered by aircrafts flying over the basin, the team compares the differences in atmospheric concentrations of hydrocarbons upwind and downwind of production areas.

Results were published in the
Journal of Geophysical Research: Atmospheres
June 2014

3. Washington State University multi-city local distribution study

WSU's Laboratory for Atmospheric Research is leading a nationwide field study to better understand methane emissions associated with the delivery of natural gas to end users. Researchers will quantify methane emissions from facilities and pipes operated by 13 utilities in various regions around the country. Emission factors derived from these data will be used to estimate methane emissions from U.S. natural gas distribution systems.

4. Boston local distribution study

Recognizing that detailed estimates of methane emissions from specific urban natural gas systems will provide important insights, Boston University, Duke University and Harvard University scientists developed an innovative tower-based quantitative technique for use in the urban environment. They conducted this work in the Greater Boston area where an old gas distribution infrastructure is believed to cause higher emissions rates than cities with newer infrastructure.

5. Houston Advanced Research Center-U.S. Environmental Protection Agency study

EPA's Office of Research and Development has collected data on methane emissions at well production sites over several years.
EDF contracted with HARC, in partnership with EPA, to undertake additional analysis of these data and to publish the results.

6. University of Texas production study—phase 2

This study expands on results from the first UT study by collecting additional data from two important emission sources associated with natural gas production: 1) liquid unloadings, when producing wells are cleared of water and other liquids inhibiting the flow of gas, and 2) pneumatics, valves operating routine functions at well sites. UT is coordinating with 10 natural gas companies on this effort.

7. Methane mapping

EDF is engaged in a project to detect methane emissions on the streets of urban America using mobile sensing systems. Led by researchers at Colorado State University, the goal is to develop a method to map and quantify methane leaks from local distribution systems that utilities could use to identify and prioritize repair or replacement of leaky pipelines, not otherwise addressed as an immediate public safety risk.

8. West Virginia University pump-to-wheels study

WVU's Center for Alternative Fuels, Engines and Emissions is leading a study in cooperation with 10 companies and a research organization to directly measure methane emissions from the operation of natural gas fueled medium- and heavy duty vehicles, as well as CNG and LNG refueling and maintenance facilities. The study includes modeling emissions from this sector under differing growth scenarios.

9. NOAA, CU-Boulder Barnett flyover study

As part of a broader project (No. 10), scientists with the National Oceanic and Atmospheric Administration and the Cooperative Institute for Research in Environmental Sciences at the University of Colorado-Boulder are measuring atmospheric concentrations of hydrocarbons in order to quantify regional methane emissions in an active oil-and gas basin that includes infrastructure from production through distribution.

10. Barnett coordinated campaign

EDF convened 12 diverse research teams in October 2013 to measure methane emissions in the Barnett Shale in Texas. This campaign used a variety of aircraft, vehicle and ground-based measurements to quantify methane emitted across the natural gas supply chain. Gathering this data with a variety of techniques allows us to compare methodologies and gain new insights, including better understanding the differences between top-down and bottom-up techniques.

11. Colorado State University transmission and storage study

This study uses a downwind tracer gas method to estimate the amount of methane lost during long-distance transportation and storage of natural gas as it moves across the country, in cooperation with seven industry companies and an industry association. CSU's researchers are also taking direct measurements and incorporating data companies provided for EPA's Greenhouse Gas Reporting Program to develop a national emissions estimate for this industry segment.

12. Indianapolis local distribution study

To gain further regional insights of local distribution methane leaks, Washington State University is coordinating with the National Institute of Standards and Technology to measure methane lost from the gas utility infrastructure in Indianapolis, which is part of a broader NIST project.

13. Colorado State University gathering and processing study

CSU's Engines and Energy Conversion Laboratory is leading an effort to quantify national methane emissions associated with the natural gas industry's gathering infrastructure and processing plants. Researchers are working with six industry companies and using tracer gas releases to quantify methane emissions from this sector.

14. Filling gaps, including super emitters

The main objective of this effort is to address knowledge gaps not being addressed by the other studies, including whether “superemitting” sites or sources produce a large share of emissions.

15. Project synthesis

After the series of EDF-initiated studies are completed, EDF will engage stakeholders from across the projects to develop an integrated understanding of what was learned, including the development of an overall methane emissions rate across the natural gas supply chain.

16. Pilot projects

Three initial projects helped build the foundation for this research series. University of Texas- Arlington collected methane data using mobile methane-sensing technology that helped inform the first UT study (No.1), as well as the Coordinated Campaign (No. 9 & No. 10). Harvard, Duke and Boston University researchers experimented with tower-based sensing systems for making methane emissions estimates in an urban environment. This work led to the larger Boston study (No. 4). University of Colorado-Boulder scientists conducted research to identify elevated levels of methane and hydrogen sulfide that provided insights for subsequent overflight work.