Emissions from oil and gas operations in the United States and their air quality implications

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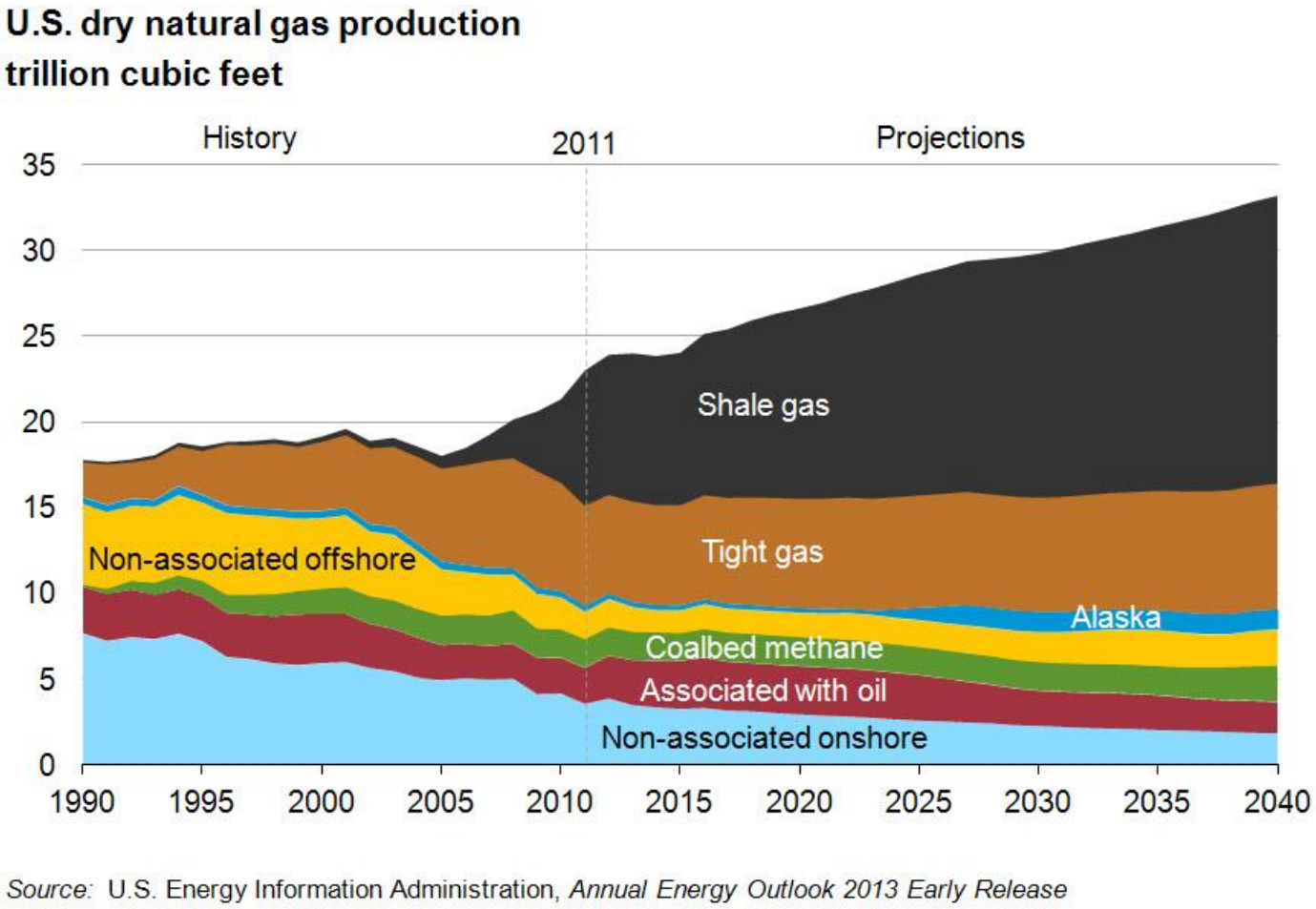
In the U.S., oil and natural gas production are increasing and in 2014, the US became the top global producer of both oil and gas



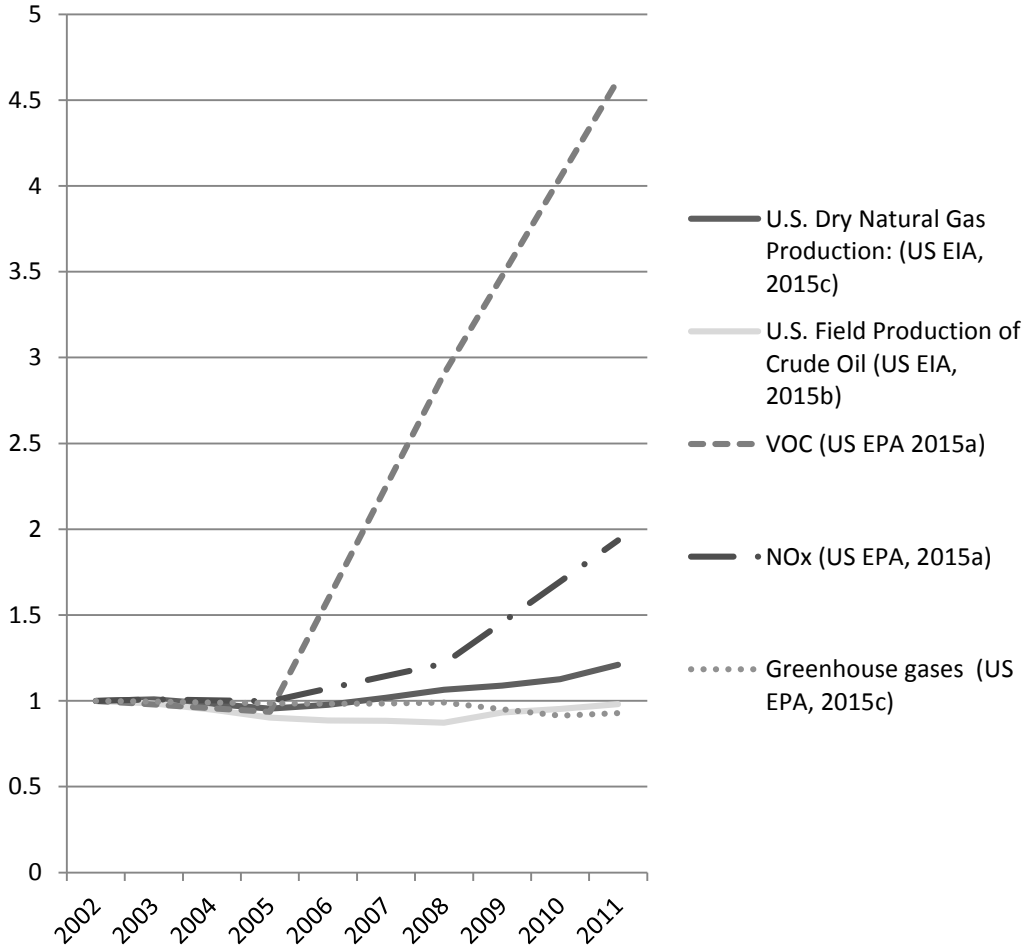
Source: U.S. Energy Information Administration, *Annual Energy Outlook 2013 Early Release*

Air Pollutant Emissions associated with Shale Gas production

- Emissions of ozone (smog) precursors
  - Emissions from trucks and other mobile sources servicing sites; from compressors and other drilling and gas processing equipment; fugitive losses of natural gas and natural gas liquids
- Air toxics
  - Benzene from evaporation of natural gas liquids has been an area of concern; chlorinated organics are an emerging concern
- Greenhouse gases
  - New US federal reporting rules require estimates of greenhouse gas emissions from oil and gas production and new emission controls

Changes in air emissions

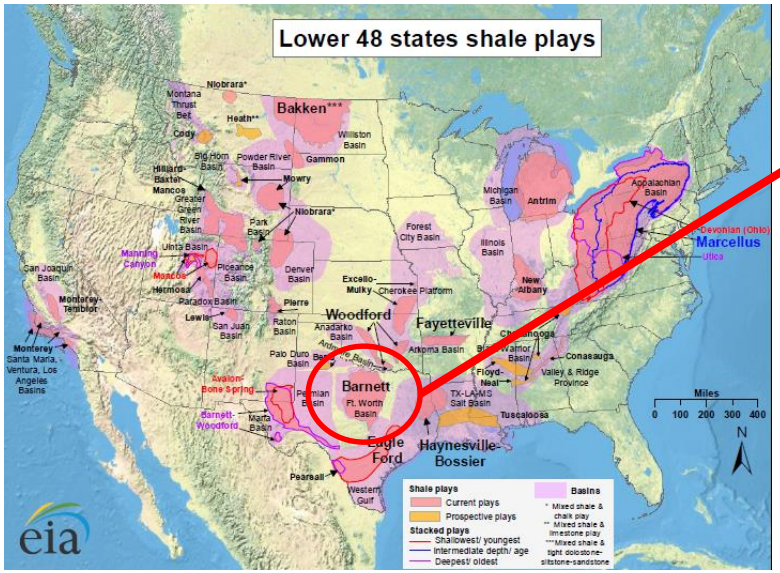
Changes in emissions from oil and gas supply chains



Changes in total US anthropogenic emissions, 2002-2011

- VOC emissions decreased by 11%
- NOx emissions decreased by 40%
- Greenhouse gas emissions decreased by 5%

Challenges in measuring and estimating emissions



Case of Barnett Shale:

>20,000 wells

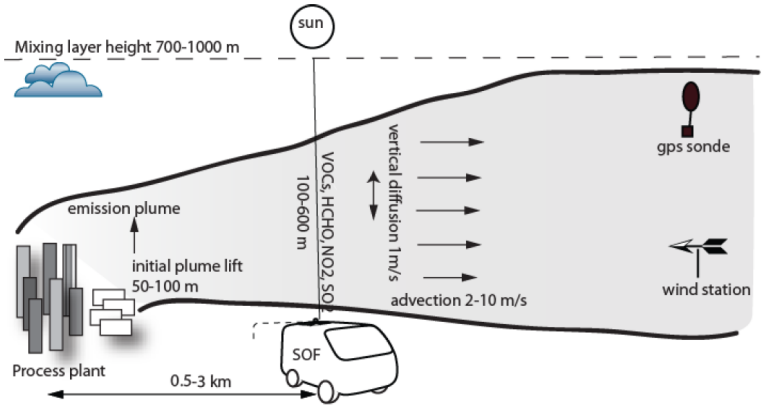
Both dry gas and wet gas

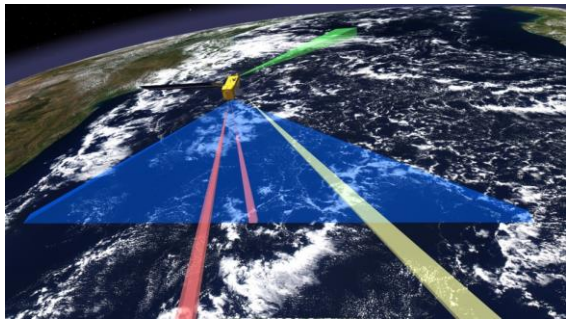
Rapidly evolving

- Many potential sources, geographically distributed, temporal variability
- Emissions can depend strongly on equipment type, operating practices, nature of gas being extracted

Multiple approaches for measurement
(bottom-up and top-down)

- Direct measurements of sources
- Fixed ground measurement network
- Mobile ground monitoring
- Aircraft monitoring
- Satellite measurements
- Different approaches provide complementary information





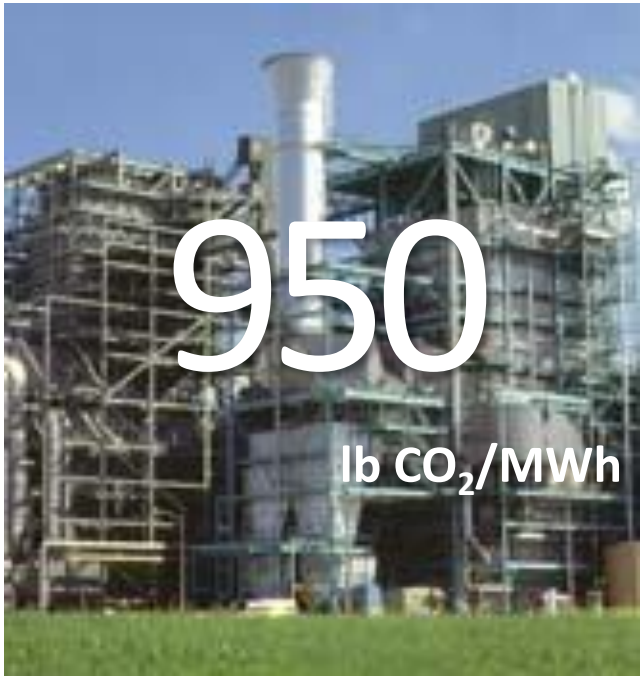
Methane from natural gas production

Why methane?

Will substitution of natural gas for coal or petroleum lead to net climate benefits?

Much of the increased natural gas production in the US is being used in power generation, lowering power plant CO_2 emissions…

Coal



Natural Gas

Power plant emissions…aren't whole story

COAL MINING
& PROCESSING

TRANSPORTATION

COAL
COMBUSTION

NATURAL GAS
PRODUCTION

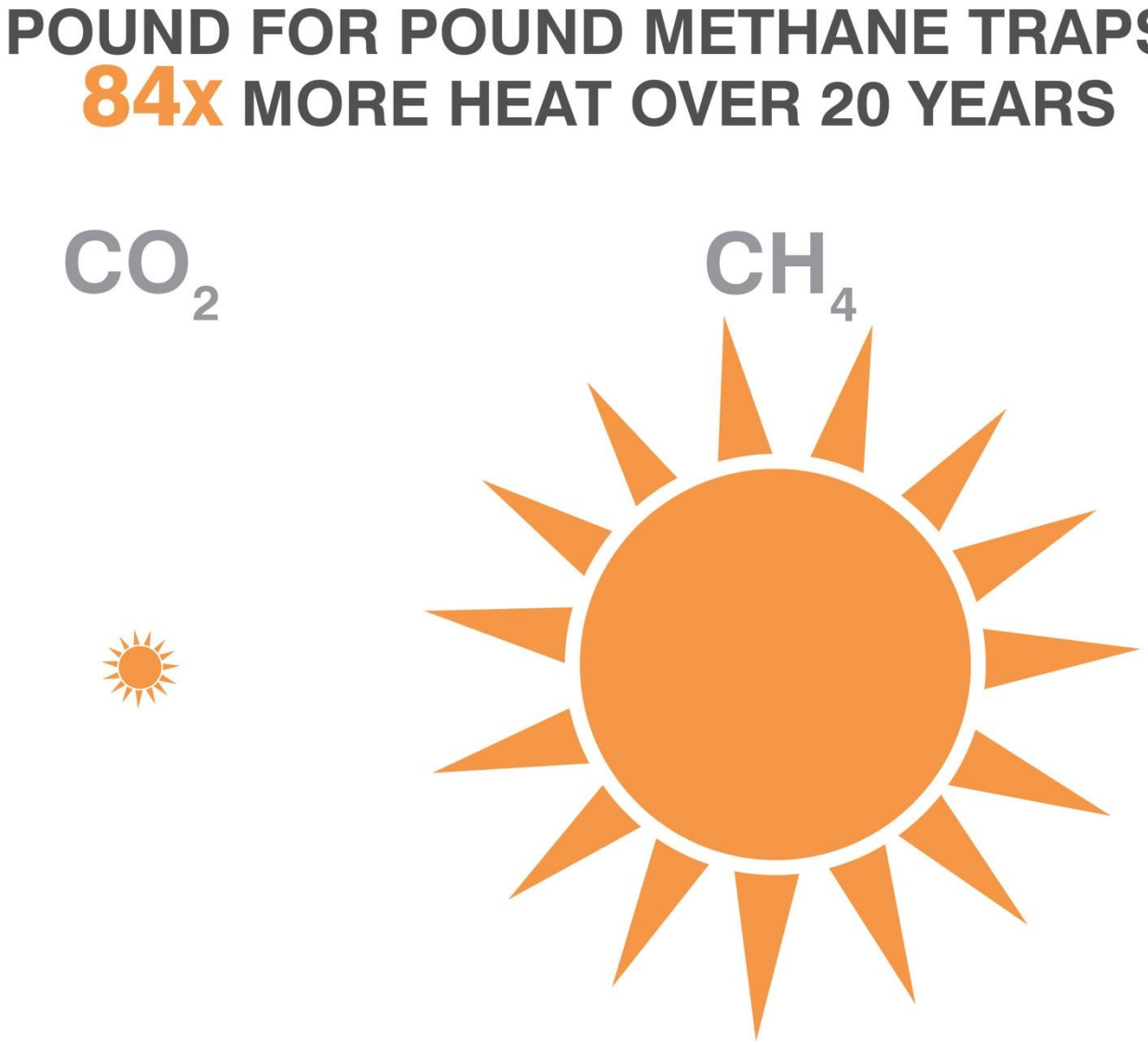
PROCESSING

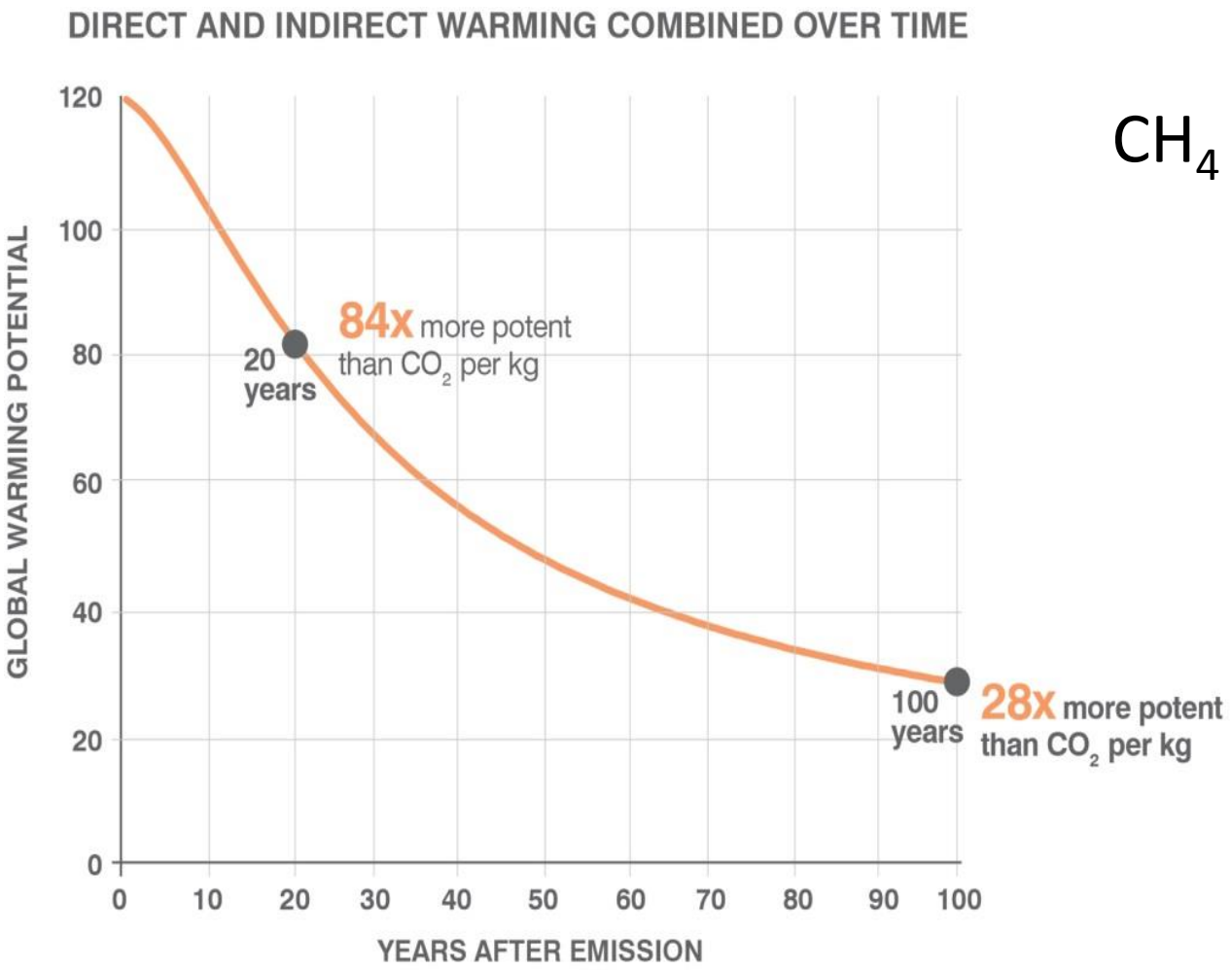
TRANSMISSION
& STORAGE

NATURAL GAS
COMBUSTION

Source: Adapted from Jaramillo et al., (2007) EST 41, 6290,

Climate implications of methane

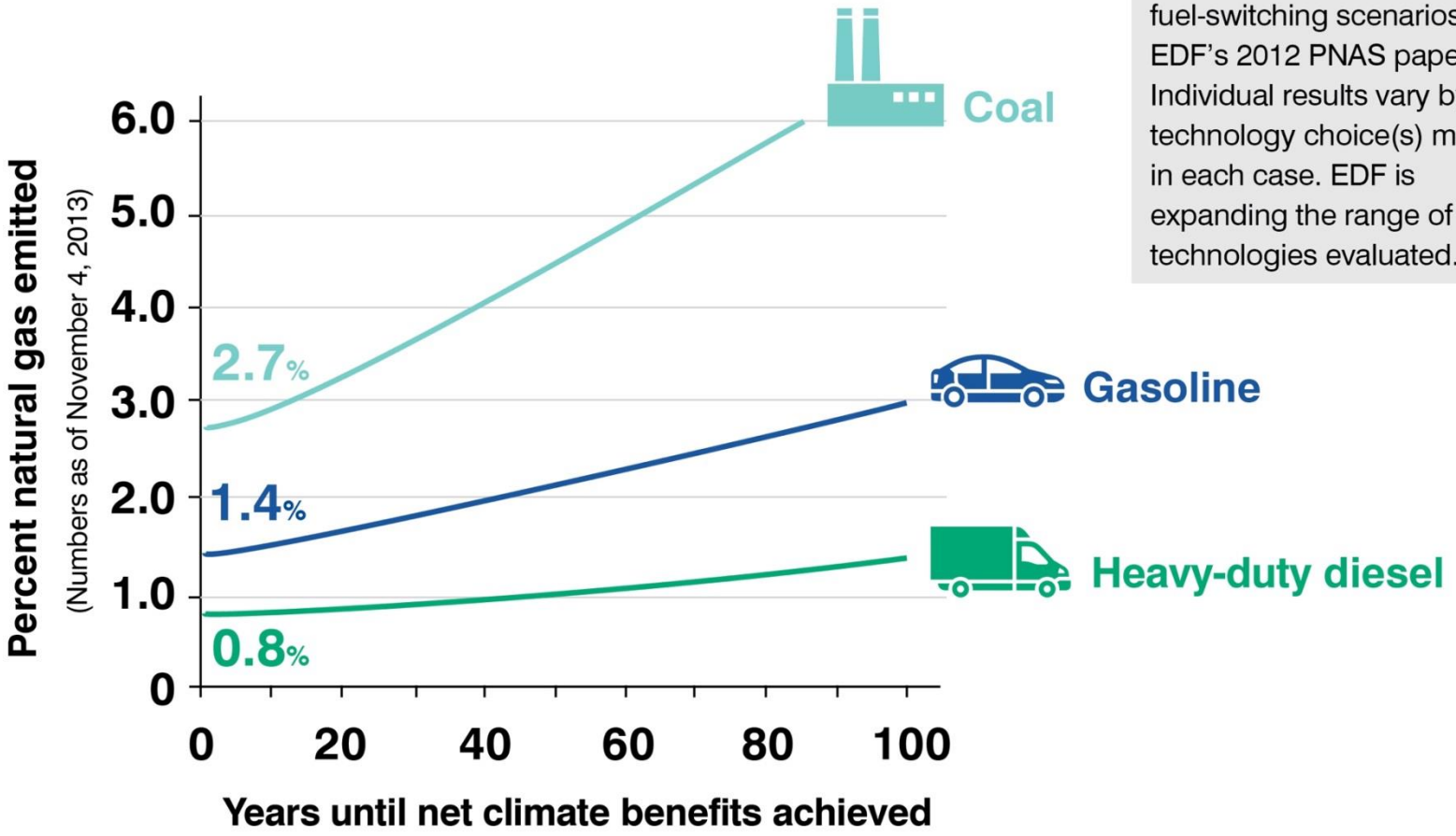




$CH_4 + OH \longrightarrow CO_2$

~10 years

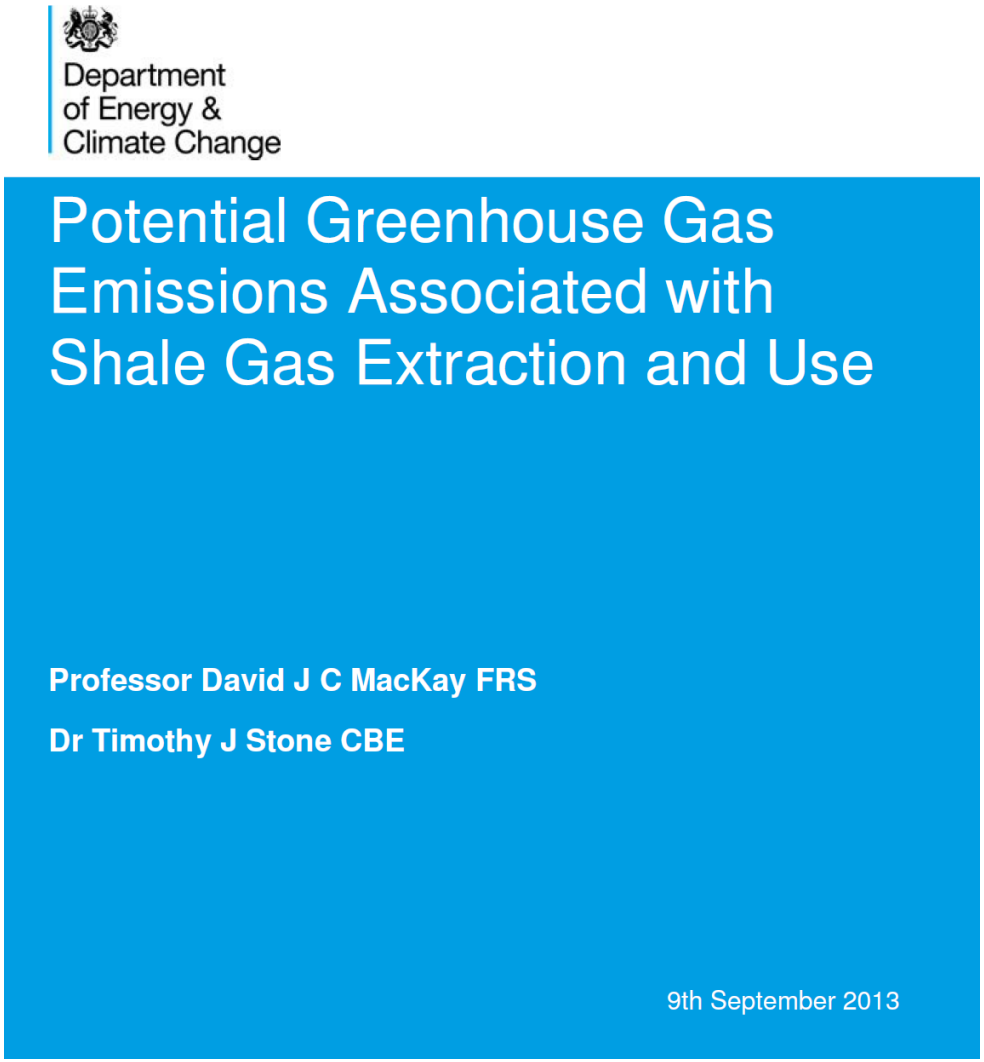
Can natural gas deliver sustained climate benefits?



Updated calculations of fuel-switching scenarios in EDF's 2012 PNAS paper.* Individual results vary by the technology choice(s) made in each case. EDF is expanding the range of technologies evaluated.

*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.

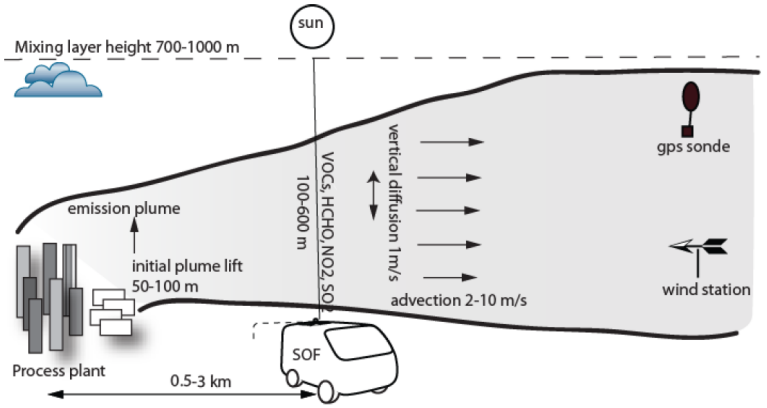
Leak estimates vary (1%-10+%)

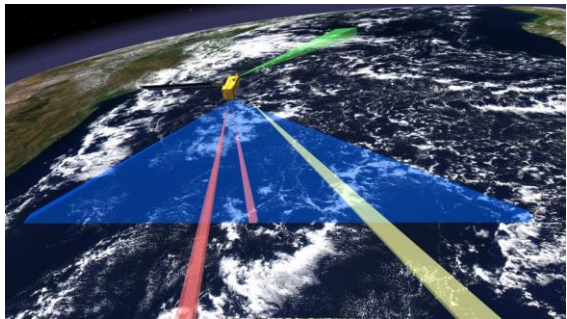


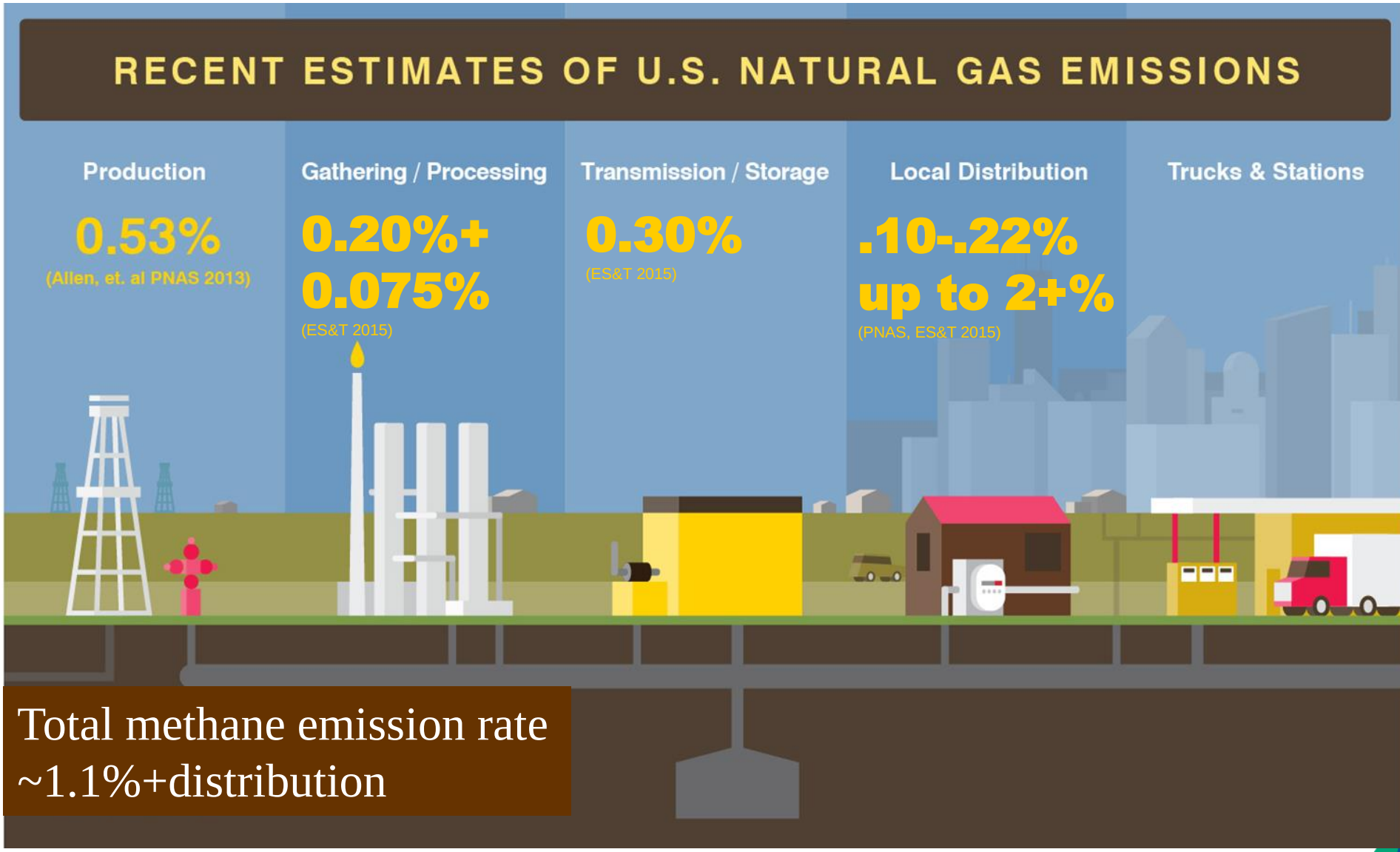
https://www.gov.uk/government/publications/potential-greenhouse-gas-emissions-associated-with-shale-gas-production-and-use

Many recent measurement campaigns (2012-date)
(bottom-up and top-down)

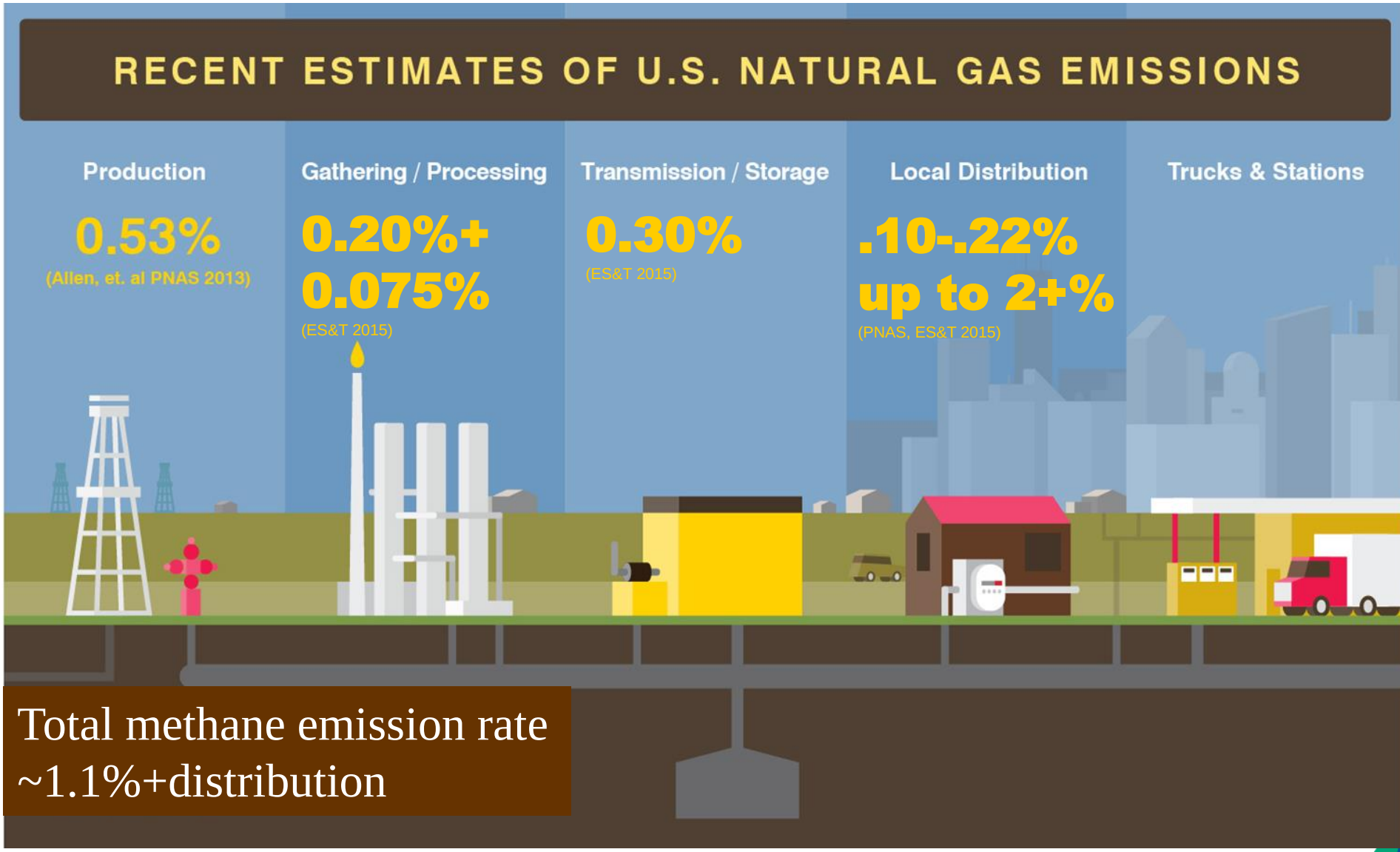
- Direct measurements of sources
- Mobile ground monitoring
- Aircraft monitoring
- Measurements focused on different parts of the US natural gas supply chain







Total methane emission rate ~1.1%+distribution



But, not all natural gas goes through all parts of the supply chain and some methane emissions should be allocated to co-produced oil

Averages don’t tell the entire story

- 2% of sites in the Barnett shale lead to >50% of the emissions
- 19% of pneumatic controllers lead to 95% of emissions
- 3-5% of wells with liquid unloadings account for more than half of emissions……..

1% of annual natural gas supply chain emissions from one large leak at a storage facility near Los Angeles (equivalent to >10,000 wells in routine operation)

Summary

- Shale oil and gas may transform the world energy landscape
- Understanding the environmental implications of this transformation will require new, spatially and temporally resolved data along complex supply chains and life cycles
- Data and analysis methods are beginning to emerge