Methane Emissions from Natural Gas

With focus on R&D AND PUBLIC ACCEPTANCE

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IEA GOT Workshop

Addressing Environmental Risks Associated with Shale Gas and Oil through Worldwide R&D

Brussels, Belgium, October 28, 2015

Sustainability

Arapaho Indian Proverb

- Treat the Earth well. It was not given to you by your parents, it was loaned to you by your children.
- We do not inherit the Earth from our ancestors, we borrow it from our children.

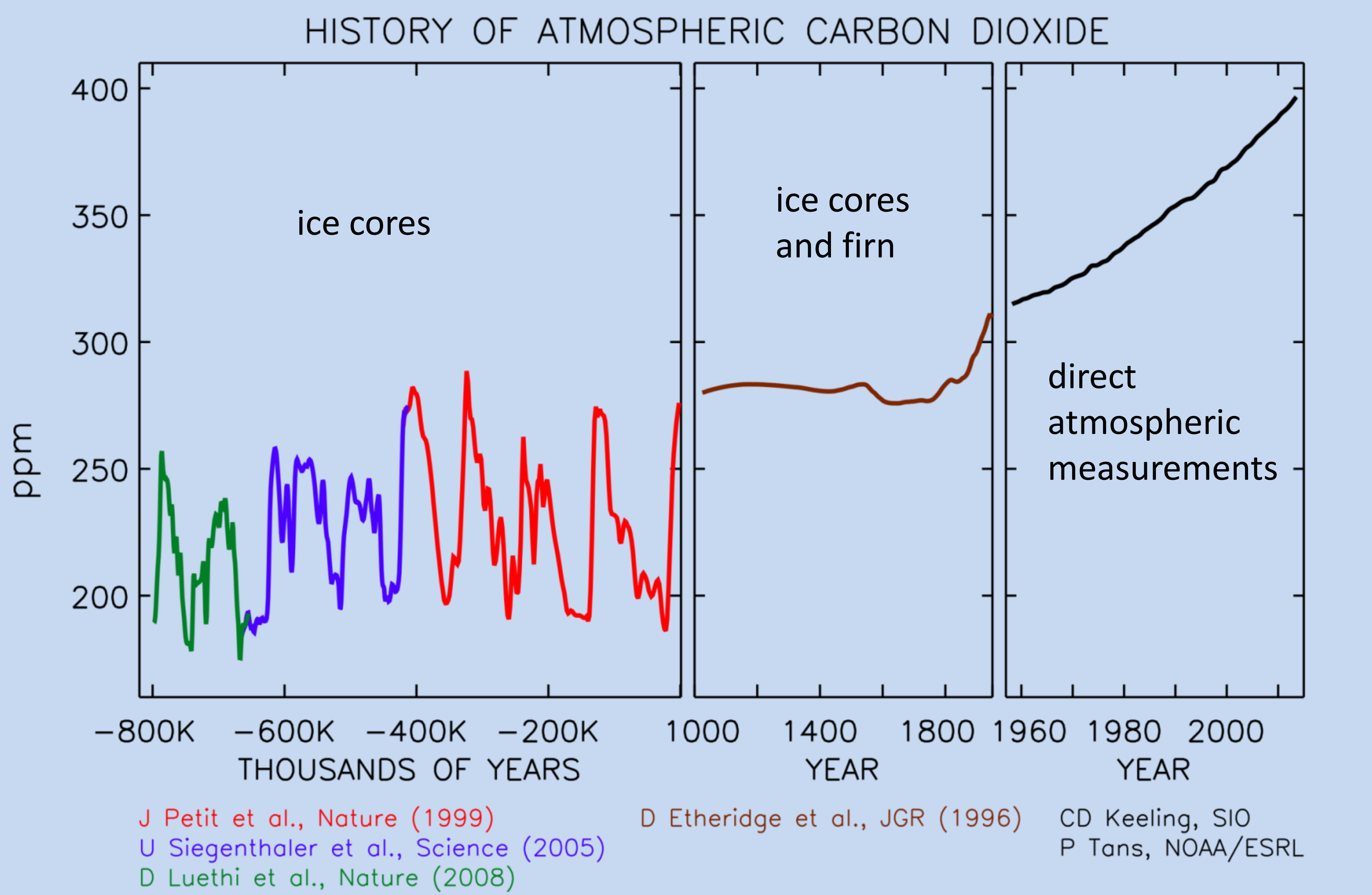
A sustainable activity requires

Science – to understand what we are doing

Technology – to be efficient and cost effective in what we do

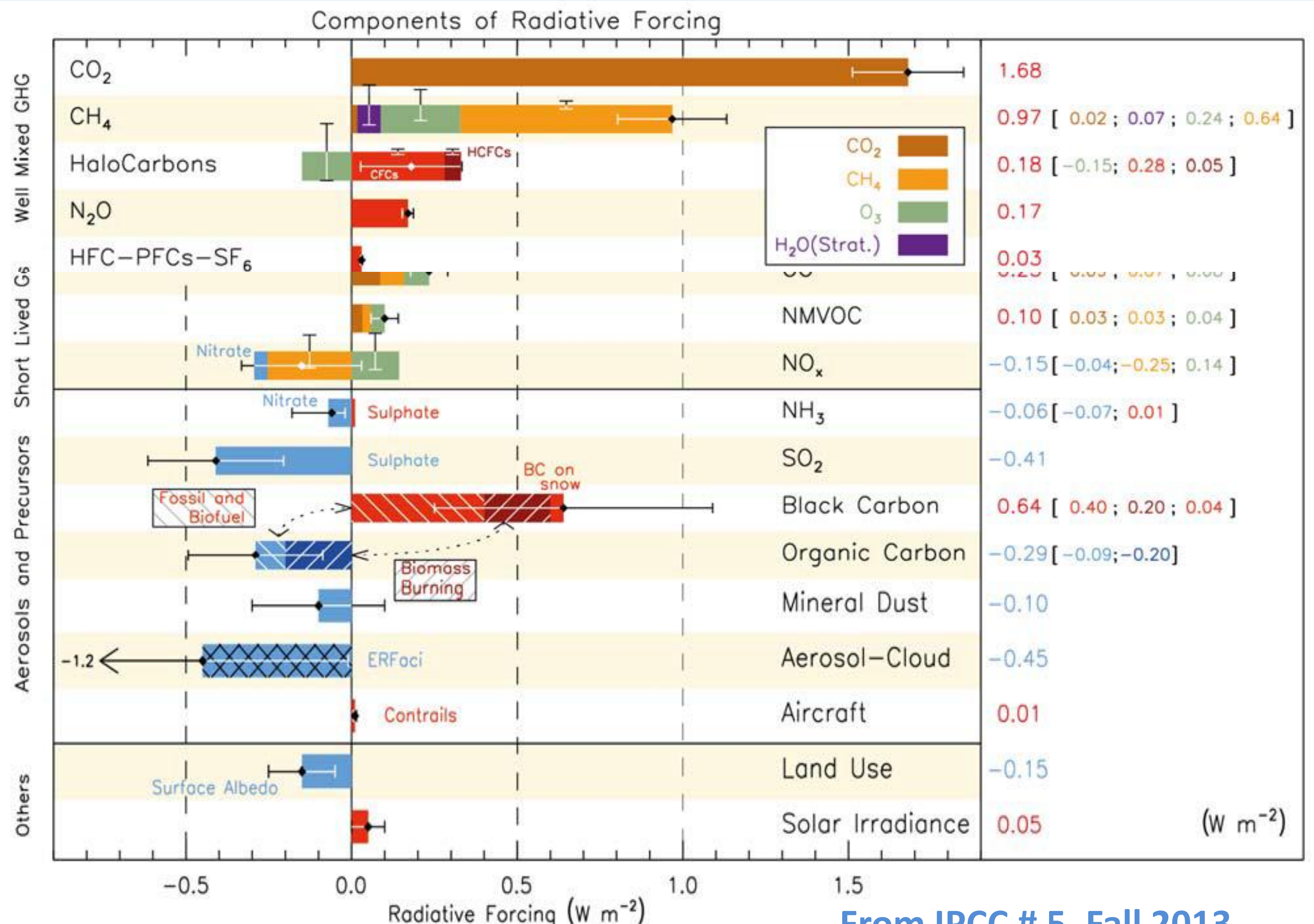
Discipline – to do the right things right

Records of Atmospheric CO_2 Over Time
Note Time-Scale Changes



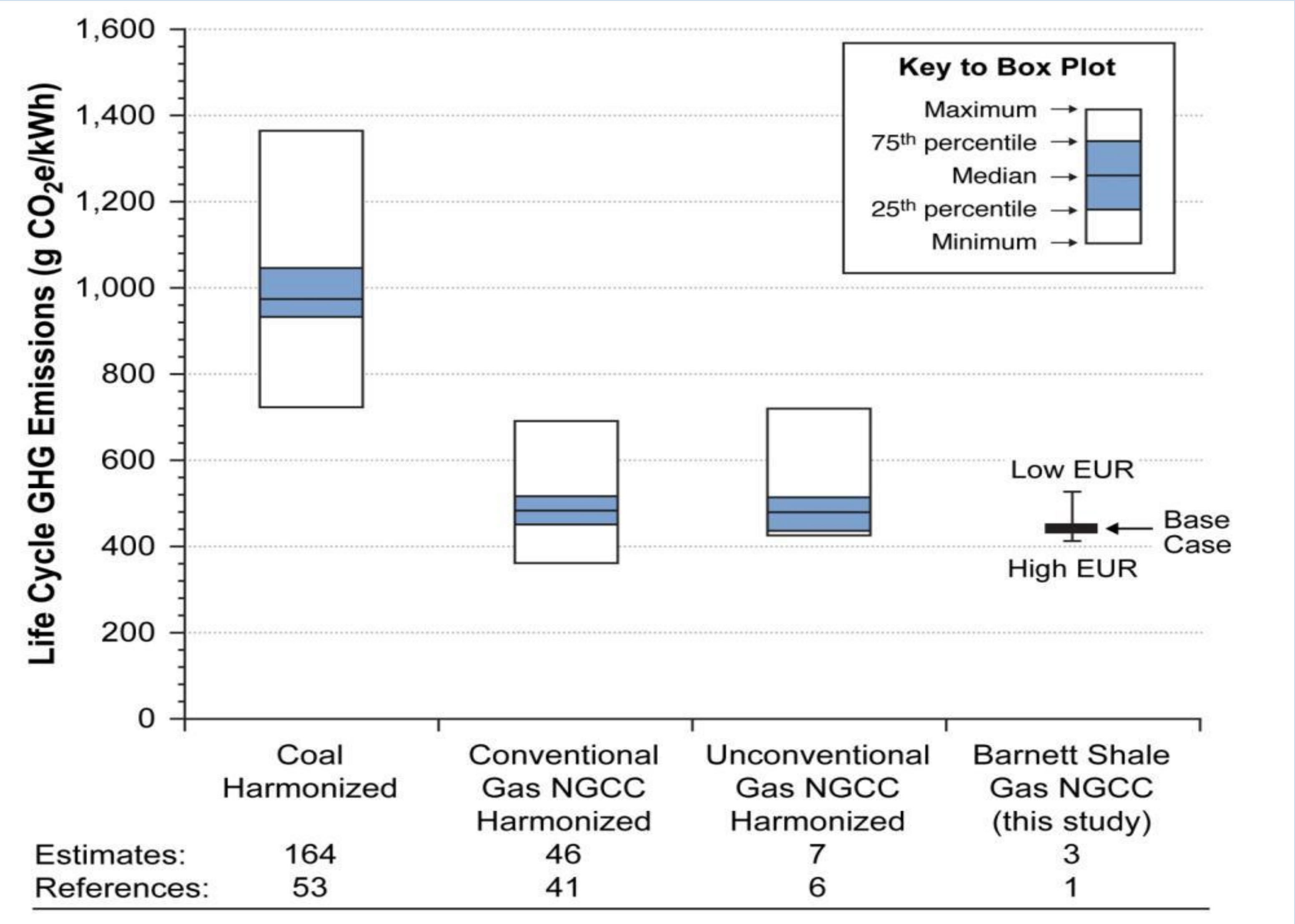
Personal Comm. from Pieter Tans, NOAA

Why Focus on Methane? 2nd Biggest Warming Gas



From IPCC # 5, Fall 2013

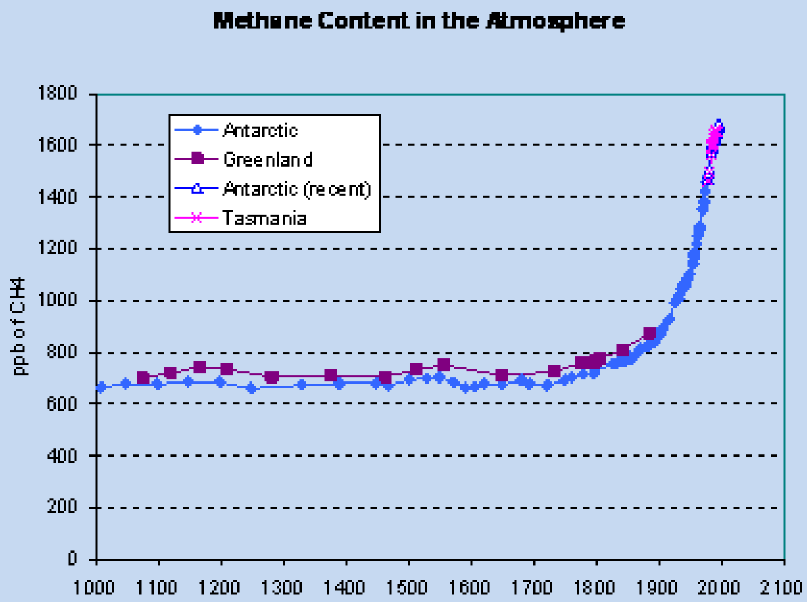
Natural Gas LCA
Meta-Analysis (Harmonization)



Sources: Figure from JISEA, 2013. Conventional results – O'Donoughue, P.; Heath, G.; Dolan, S. Vorum M.; (2012). *Journal of Industrial Ecology* (accepted); Unconventional results – Heath. G.; O'Donoughue, P.; Arent, D.; Bazilian, M. (in review). Coal: Whitaker et al. 2012.

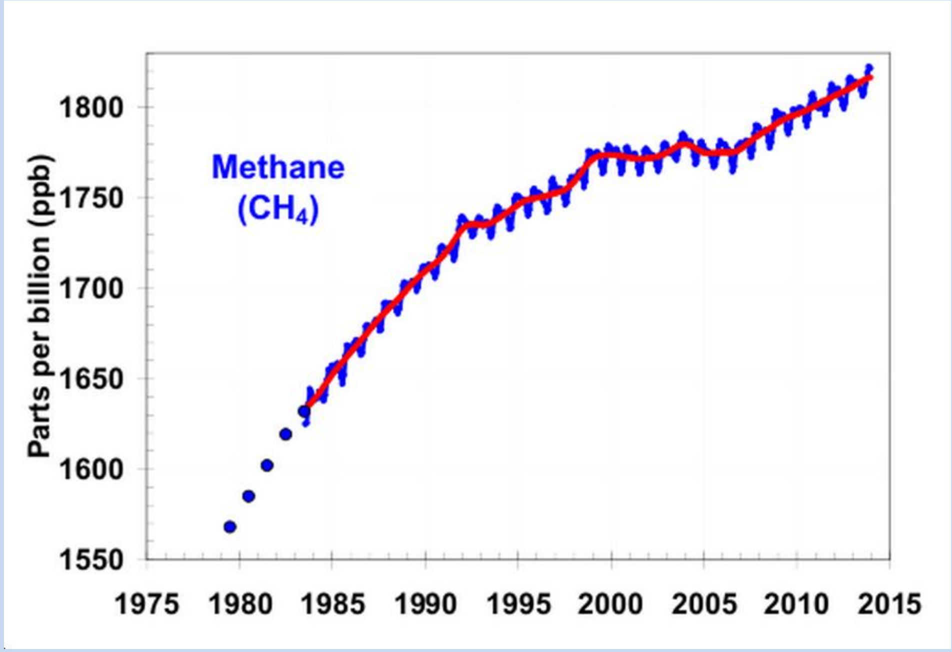
NGCC = natural gas combined cycle

Trends in Atmospheric Methane



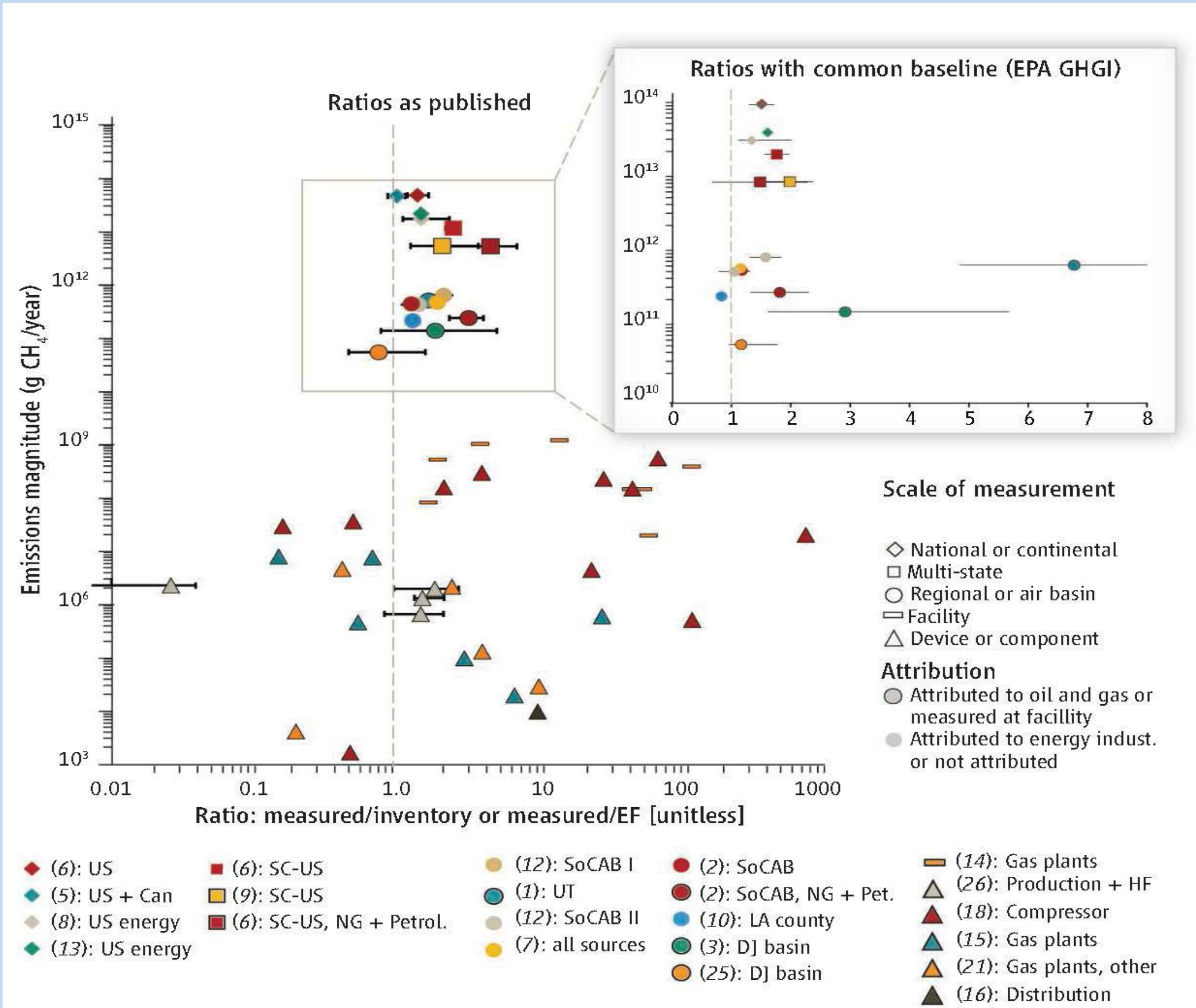
http://ecen.com/eee55/eee55e/growth_of%20methane_concentration_in_atmosphere.htm

NOAA's Earth System Research Laboratory - Annual Greenhouse Gas Index



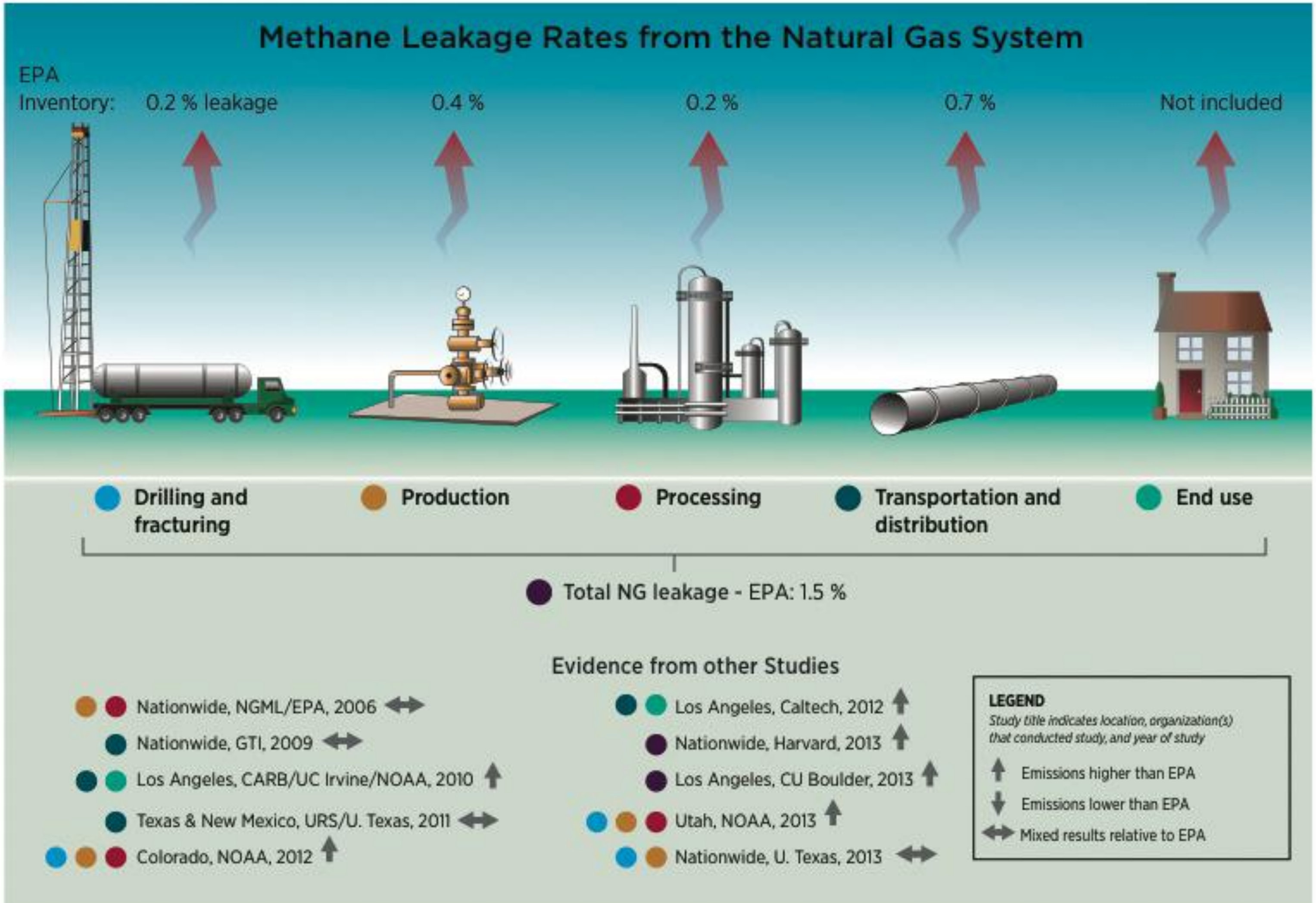
Bottom-up Inventories (accounting) yield Lower Emissions than Those Measured by Aircraft Sampling

Ratios >1 indicate measured emissions are larger than inventories



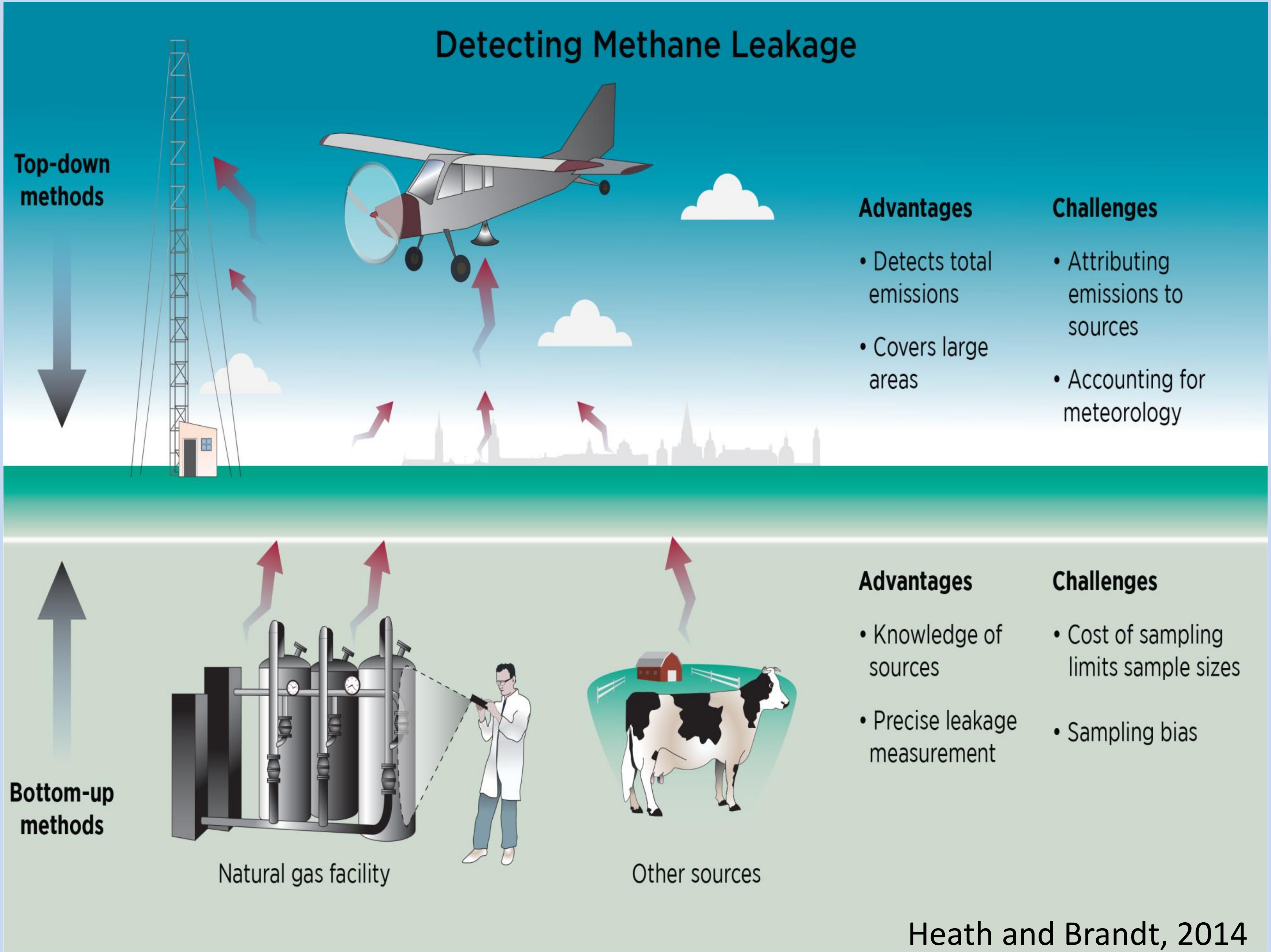
A R Brandt et al. Science 2014;343:733-735

Typical Component Leakage Rates



Heath and Brandt, 2014

Research: “Reconcile” Top-down vs. Bottom-up Estimates



DEVELOPMENT OF A PROTOCOL TO RECONCILE TOP-DOWN AND BOTTOM-UP METHANE EMISSION ESTIMATES FROM ONSHORE GAS DEVELOPMENT IN MULTIPLE BASINS

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With Data/Slides/input from *Gaby Petron* (CU/NOAA), *Stephan Schwietzke* (CU/NOAA), *Garvin Heath* (NREL), *Jeremy Boak* (CSM/OU)and *Dan Zimmerle* (CSU)

Research Team Members

Top-Down Measurements

INSTAAR
University of Colorado Boulder

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

CIRES
Cooperative Institute for Research in Environmental Sciences

UCDAVIS
UNIVERSITY OF CALIFORNIA

Scientific Aviation

Bottom-Up Measurements

POWERHOUSE
ENERGY INSTITUTE
Colorado State University

JISEA Joint Institute for Strategic Energy Analysis

CESEP

Center for experimental study of subsurface environmental processes at CSM

AECOM

UW

University of Wyoming

GHD

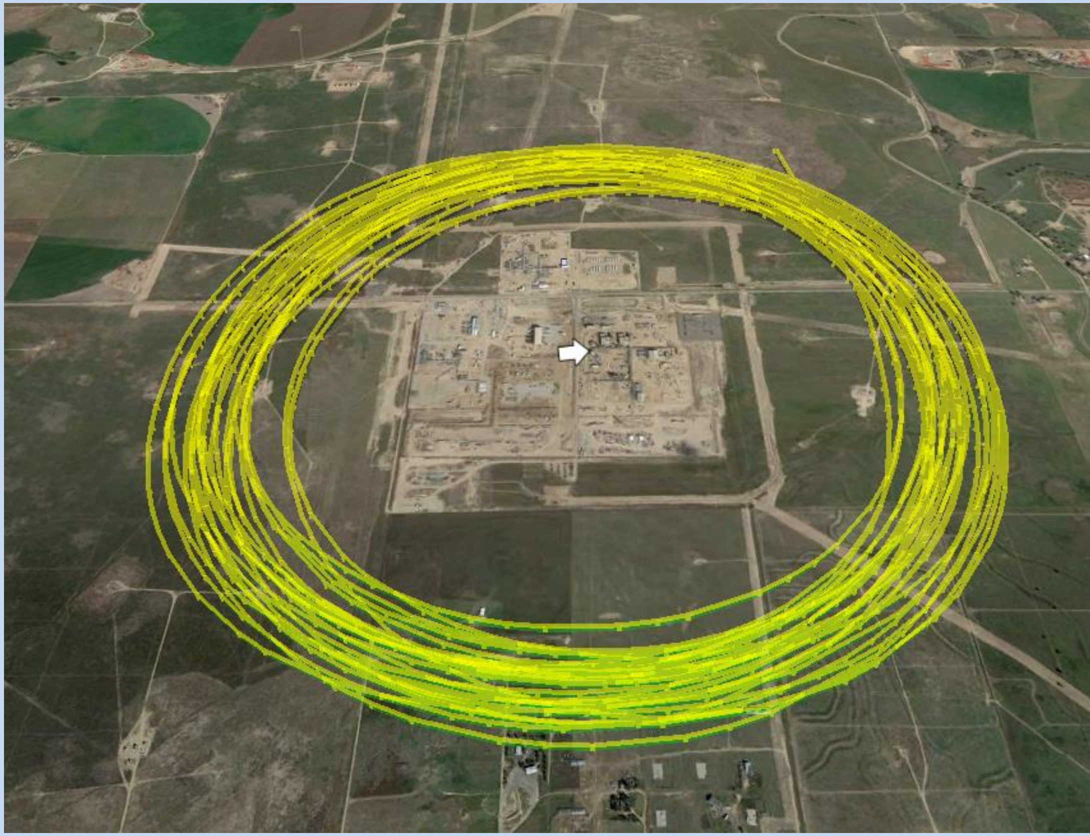
Washington State University

Aerodyne Research

Actual Flight Path…

- The radius is a compromise between getting so close that a substantial portion of the flux passes beneath our lowest altitude or so far that the plume is obscured by instrument noise.

- If the goal is to estimate emission from a single site, the flight path must also ensure that no adjacent sources are captured along with the source of interest.



Two challenges remain: what happens below us, and how long must we circle to achieve a statistically robust estimation?

Spiral Flights / Mass Conservation

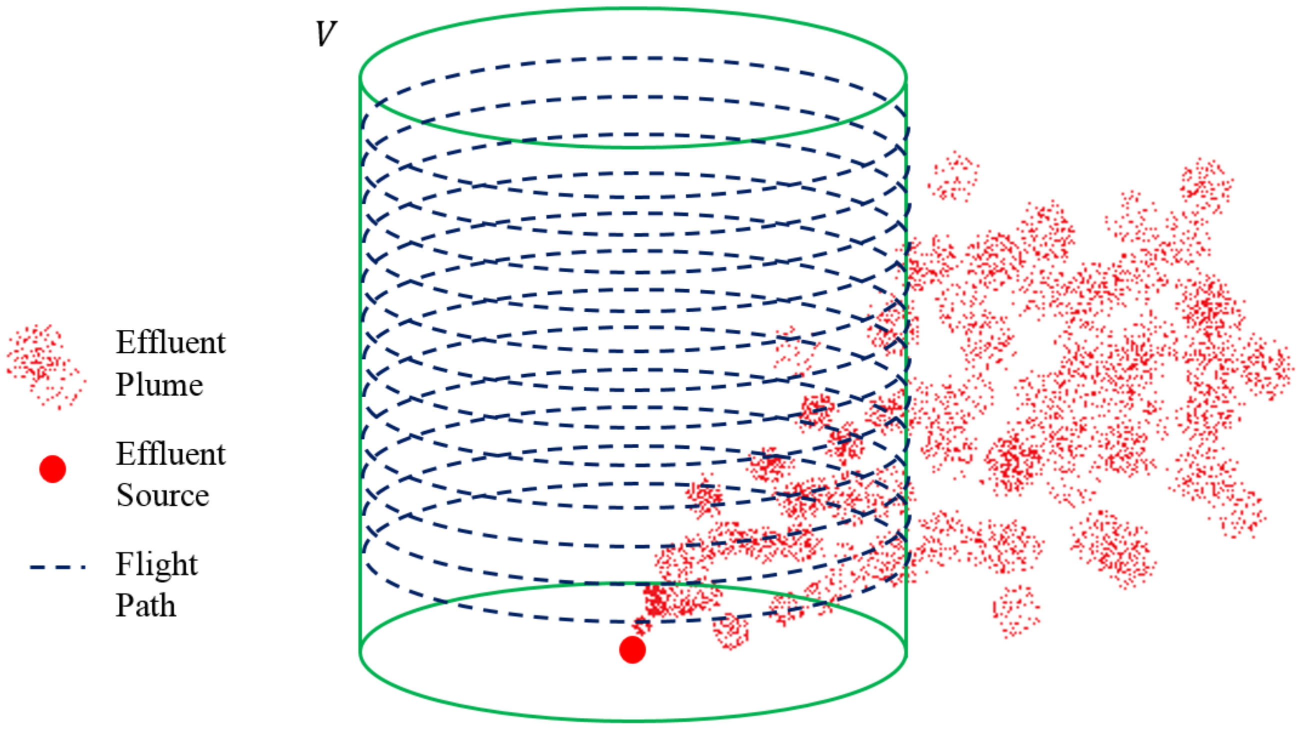
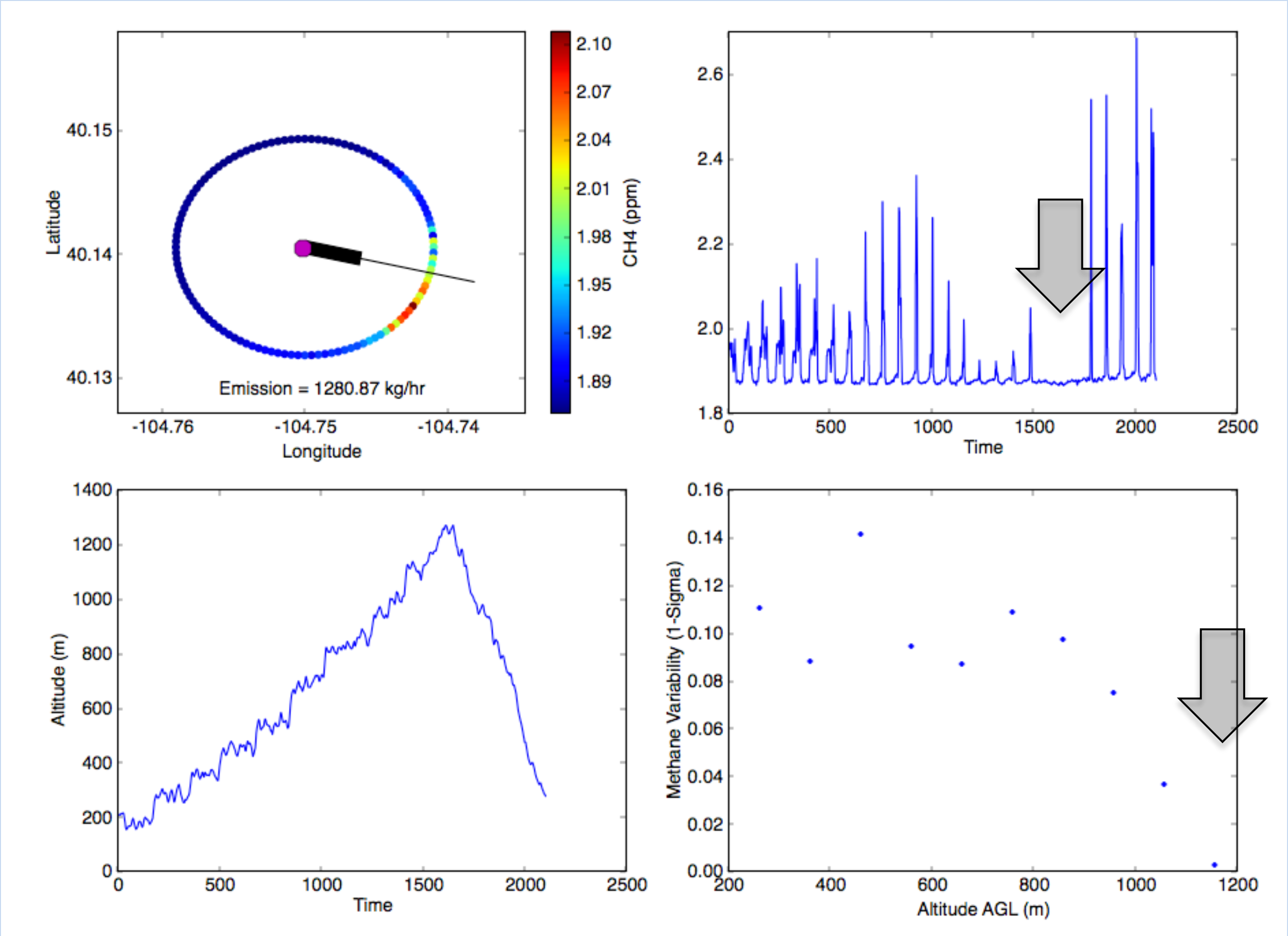


Figure 13: Sketch of flight path pattern for source leak rate estimation.

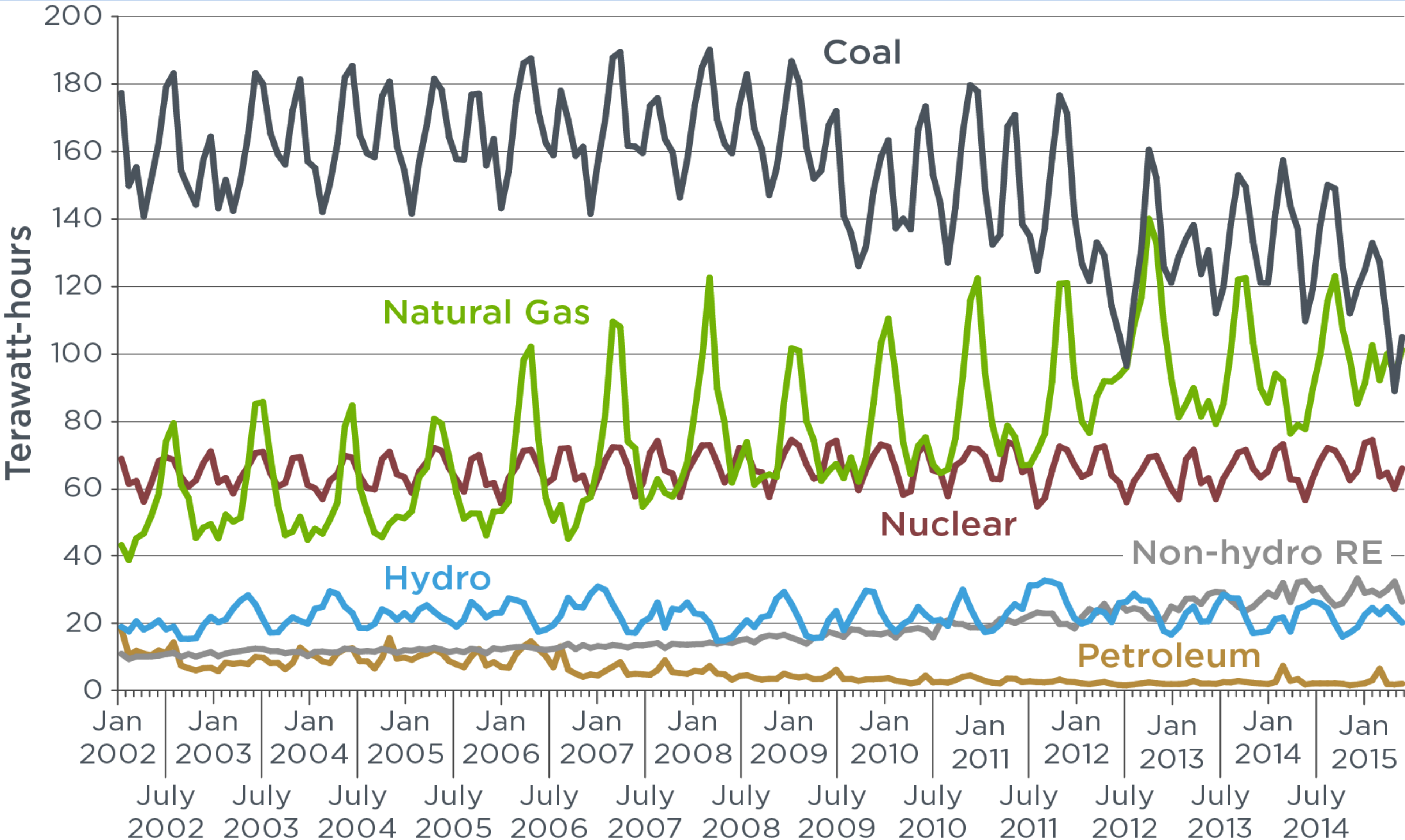
If we define a closed volume around the source, mass conservation dictates that the difference between the methane entering our volume and leaving it (flux divergence) is equal to the source.

How can we know we got it?



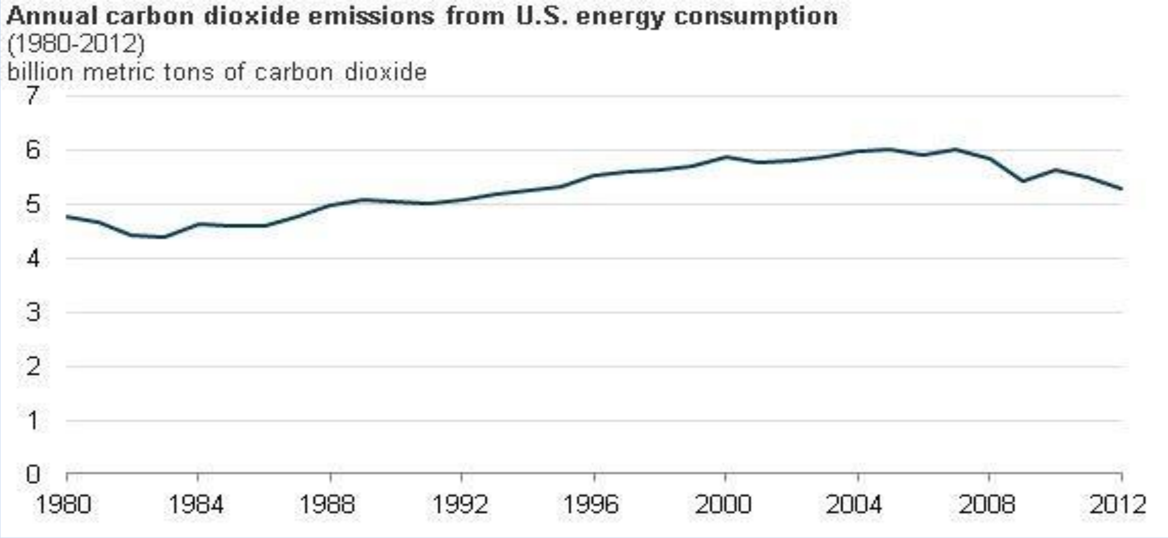
- Clear downwind signal
- Variability approaches zero at top altitudes

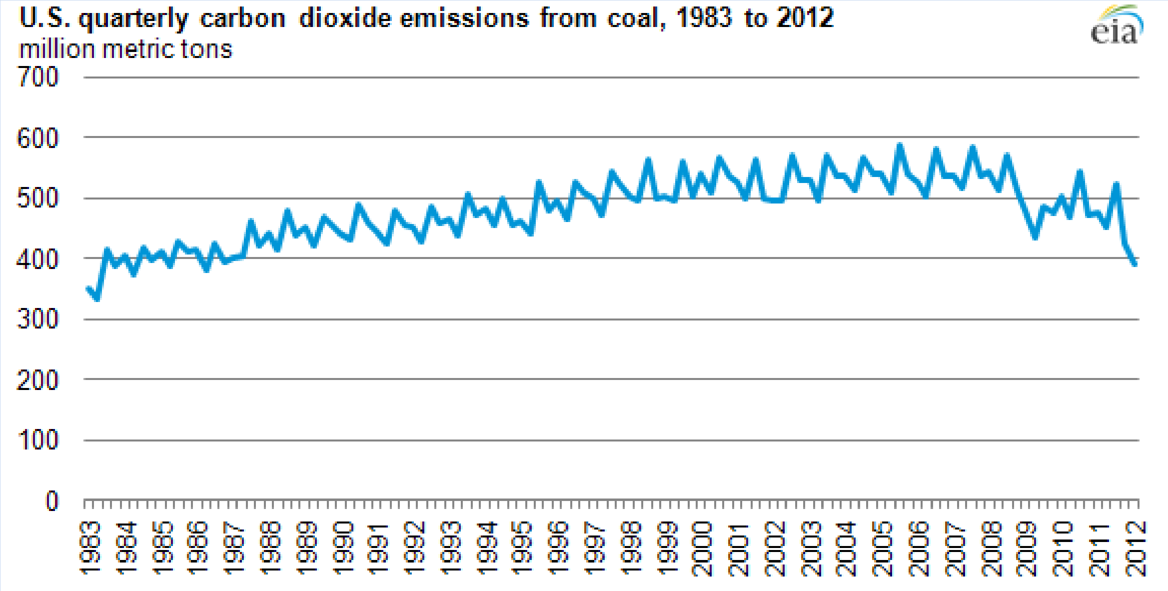
US Power Generation Trends



Source: EIA Monthly Statistics

US CO_2 Emissions Trends





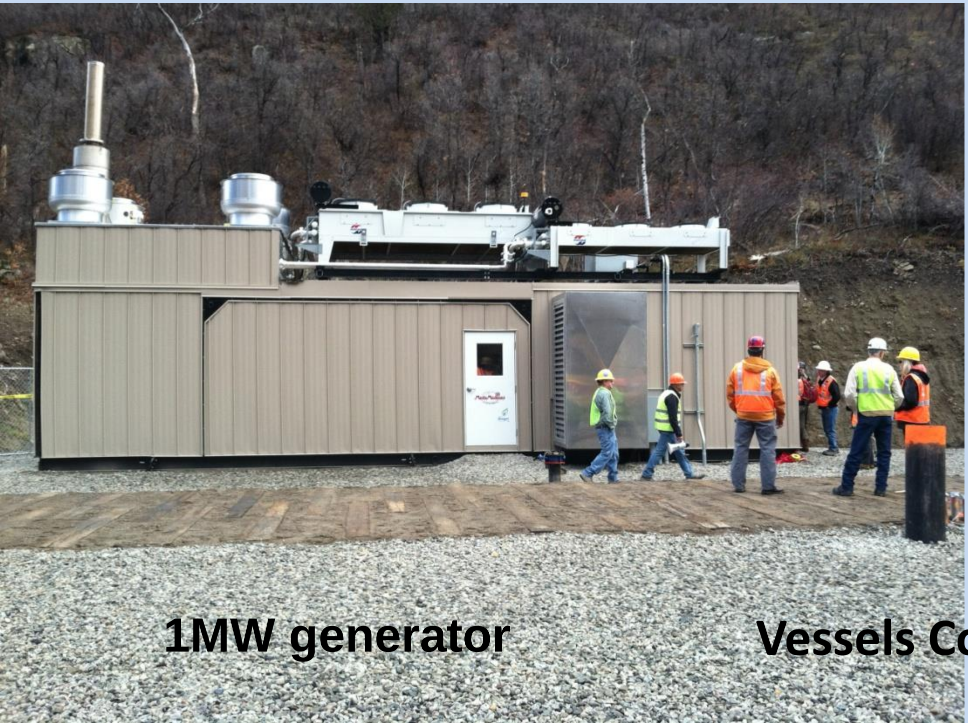
EIA - Website

Finally, Some “Next Steps” – in the Natural Gas Industry’s Applications, Research, and Regulations

Methane Emissions Reductions Practices

- 3MW at Oxbow Elk Creek Mine
- Collaboration resulted in project overcoming multiple barriers:
  - 2010 - Oxbow Mining and Gunnison Energy collaborate on vent gas at Elk Creek mine
  - 2011 - Holy Cross Energy agree to buy Oxbow vent gas CMM electricity
  - 2012- Aspen Ski Company agrees to invest $5.4 Million to pay for plant investment in partnership with Vessels Coal Gas
  - Source: Colorado Energy Office

E.g. Holy Cross Energy Buys Coal Mine Methane Electricity. Colorado's 1st Coal Mine Methane Project



OXBOW Mine Somerset CO Dedication Fall 2012

Vessels Coal Gas INC™

DOE - ARPA-E MONITOR Program

New Sensor Technologies
Research Programs Underway (Fall 2015)

http://arpa-e.energy.gov/?q=arpa-e-programs/monitor

Aeris Tech – Methane Leak Detection System Bridger Photonics - Mobile Methane Sensing System
CU-Boulder - Frequency Combs for Methane Detection
Duke - Advanced Spectrometer for Methane Detection
GE - Optical Fibers for Methane Detection
IBM - Multi-Modal Methane Measurement System
LI-COR - Optical Sensors for Methane Detection
Maxion - Tunable Laser for Methane Detection
PARC - Printed Sensors for Methane Detection
PSI - Methane Leak Detection System
Rebellion - Portable Methane Detection System

Colorado Methane Regulations, as of 2014

- Direct regulation of methane, a highly potent greenhouse gas (some previous rules had achieved methane reduction as a co-benefit of reducing other pollutants)
- Dramatic reductions in “fugitive” emissions (equipment leaks) through the nation’s strongest leak detection and repair (LDAR) program, including requirements for monthly inspections at the largest sources.
- Statewide requirements to retrofit key high-emitting existing sources with low-emitting equipment.
- Statewide requirements to target reductions from under-regulated but important sources of emissions from well maintenance activities, such as “liquids unloading,” when producing wells are cleared of water and other liquids inhibiting the flow of gas.

Wyoming has very similar regulations

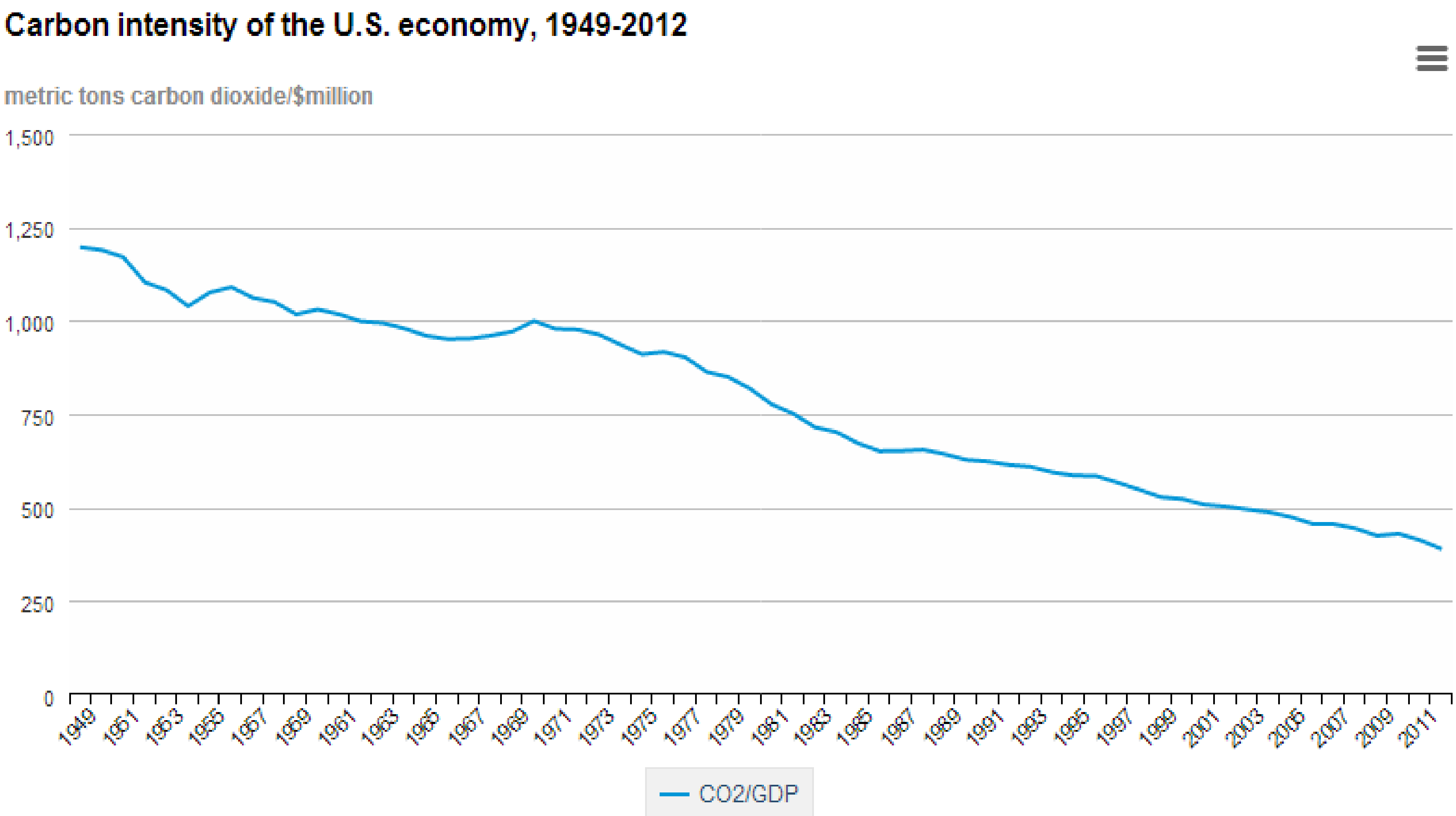
EPA is currently proposing similar national regulations

Gina McCarty
EPA Administrator, Oct. 22, 2015

- Rules to limit methane emissions from oil and gas operations that the US Environmental Protection Agency expects to issue before yearend will reflect voluntary programs the agency already has worked on with the industry and states for several years, EPA Administrator Gina McCarthy said.
- "One reason oil and gas is such an opportunity for improvement is that the industry itself has been dealing with this problem [...]. "The pollutant basically is its product, and companies have been working hard on this." "We wanted to get it back into the system so it could be sold as product and be wasted."
- States and local communities also have been important partners in taking early voluntary steps to reduce methane emissions from oil and gas operations, McCarthy said.
- EPA achieved its initial methane reduction success from oil and gas operations when it started to regulate hydraulic fracturing in 2012, McCarthy noted. "The fact that so few people remember this reflects how successful it was," she said..

Oil and Gas Journal, Oct. 22, 2015

Ultimately, emissions reductions are driven by innovation, economics and regulations



From: DOE – EIA, 2013

Conclusions

- In terms of the “Environmental Risk of Shale Gas and Oil”, the use of natural gas (mostly methane) production for power generation is a net positive because it displaces coal from that market
- Emissions from natural gas drilling, fracking, production, processing, transportation and use are now being quantified through studies that “reconcile” top-down and bottom-up measurements (and inventories)
- The next steps are better leak-detection technology, more direct industrial use of previously ‘vented’ natural gas, improved infrastructure repair (particularly in old urban gas distribution lines), and tighter regulations
- Natural gas, conventional and unconventional, is driving down US CO_2 emissions. Together with renewable energy technology, natural gas can accelerate such a trend globally