Greenhouse Gas Emissions from Natural Gas: Overview of Recent Developments

Gib Jersey

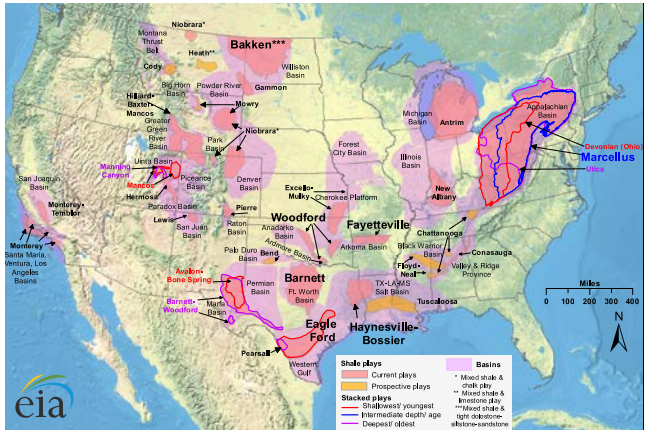
2014 Transportation Research Board Annual Meeting

Outline of Presentation

- Natural Gas in Transportation
- Methane – Some Background
- The Natural Gas Life Cycle
  - The nature of methane emissions from gas production
- Approaches for Estimating Methane Emissions
  - Pros and Cons of the approaches
- Results from Some Recent Methane Studies
- A Recommendation for Further Work

Natural Gas in Transportation

- Natural gas has been a transportation fuel for many years
  - Niche or centrally fueled fleets
    - Buses, taxis, some trucking
- Increased availability and favorable economics have resulted in interest for broader application
  - Heavy Duty sector appears to be particularly primed
- Many questions and issues still exist:
  - Availability of infrastructure
  - Driving range (CNG)
  - Wells-to-Wheels GHG impact
    - CO_2 from combustion
    - Methane from supply chain



Shale Gas Plays in the Lower 48 States

NETL 2013

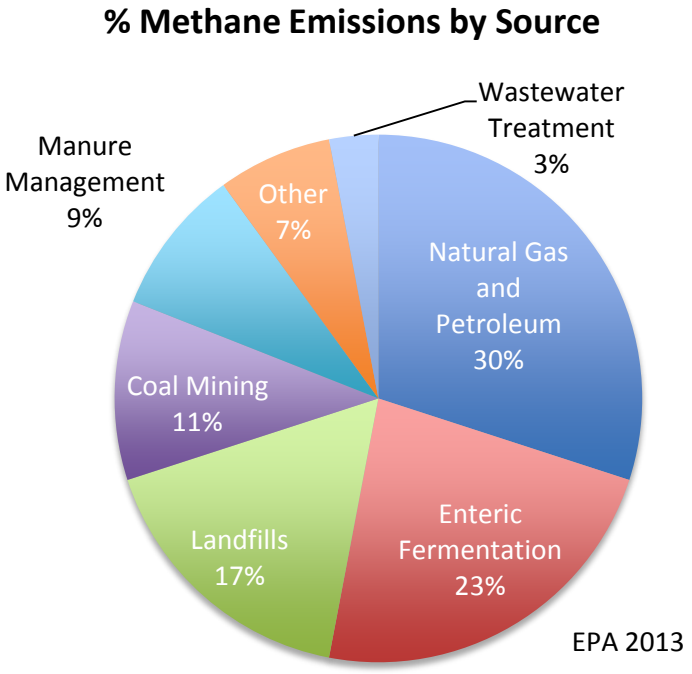
Quadrillion BTUs

U.S. energy production by fuel, 1980-2040

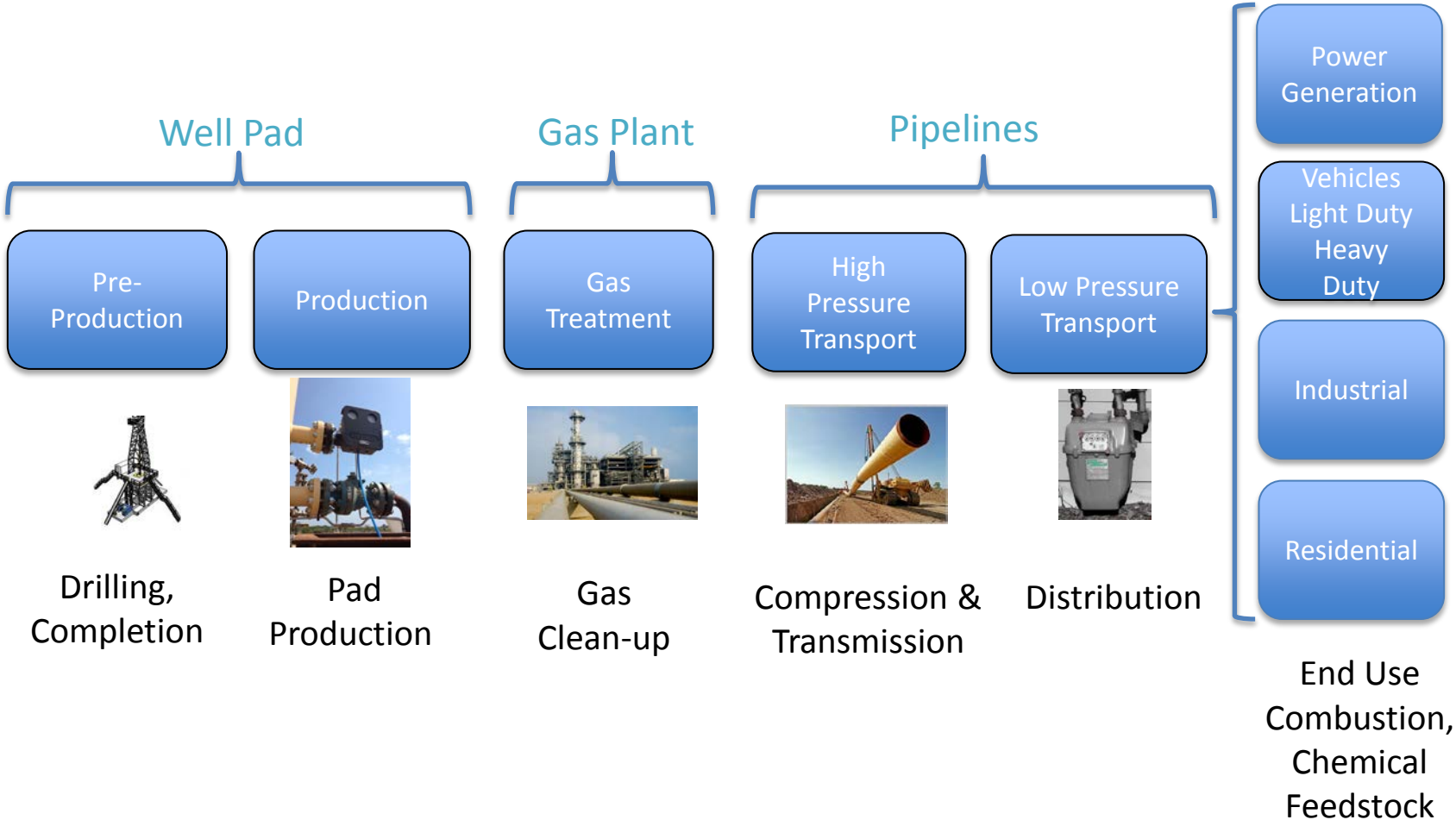
EIA AEO 2014

Methane – Some Background

- The largest component of natural gas
- Methane is a potent greenhouse gas
  - 25 times CO_2 on a 100-year time scale
- Sources of Methane:
  - Oil and gas development/production
  - Landfills
  - Agricultural activities
  - Livestock
  - Wetlands
- U.S. methane emissions inventories
  - Annual EPA GHG emissions inventory
  - Recent EPA reporting rule requirement
- Several studies published in the past few years with methane implications
  - Comparison between coal and natural gas for power generation
  - Methane emissions estimates from various sources; focus on gas production 'leakage'



Typical Life Cycle of Natural Gas Production and Use



Accurately quantifying the potential methane emissions from all stages of the natural gas life cycle is not trivial

Typical Life Cycle of Natural Gas Production and Use

Nature of Methane Emissions

Well Pad

Pre-Production

Drilling, Completion

Short duration events during first weeks of well lifetime

Production

Pad Production

Mix of short duration events, continuous, and intermittent emissions

Gas Plant

Gas Treatment

Gas Clean-up

Generally, steady-state emissions

Pipelines

High Pressure Transport

Compression & Transmission

Steady-state and short-duration events

Low Pressure Transport

Distribution

Steady state, some intermittent

End Use

- Power Generation
- Vehicles Light Duty Heavy Duty
- Industrial
- Residential

Combustion, Chemical Feedstock

Approaches for Estimating Methane Emissions

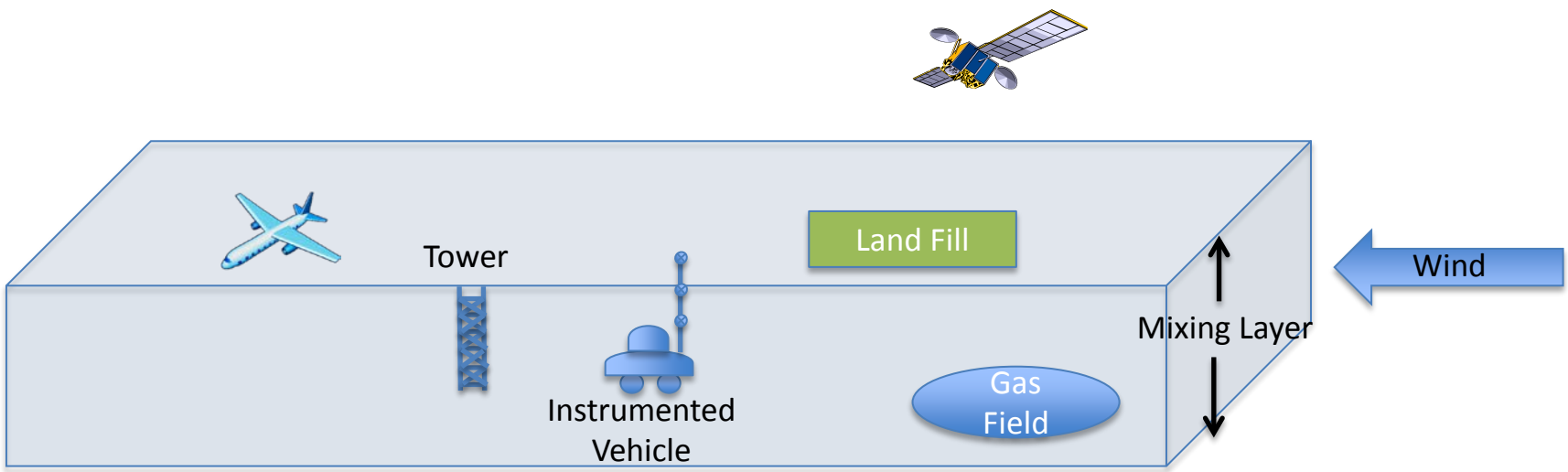
Bottom-Up Approach

- Evaluates each emission source
- Engineering calculations estimate potential emissions rate, and/or
- Directly measure emission rate at source; validate engineering calculation
- Sum up all sources at each site; annualize emissions
- Basis for EPA emissions inventories and is standard practice for other emissions

Approaches for Estimating Methane Emissions

Top-Down Approach

- Downwind ambient concentration of methane is determined
  - Directly measured (aircraft, towers, instrumented vehicles)
  - Calculated via mathematical inversion techniques (satellite)
- Models used to back-calculate emission rate responsible for the ambient concentration
  - Using concurrent meteorological data
  - Subtracting background concentration
  - Making assumptions on allocation for source type



Comparison of the Two Techniques

Bottom-Up

Advantage	Limitation
Basis for historical emissions inventories	Does not identify outliers
Characterizes individual sources or source categories	Does not capture unknown leak sources
Engineering calculations can be verified with direct measurements	
Can address temporal/spatial emissions variability	

Top-Down

Advantage	Limitation
Identifies 'hot spots' or emission outliers	Measurements are time 'snapshots'. Time-varying or episodic emissions are difficult to quantify
Can be used to assess large-scale, regional trends with time with repeat measurements	Requires several assumptions or detailed atmospheric measurements to back-cast emissions rates
Can represent large regions or basins with moderate resources	Disaggregation of methane contribution by source is a challenge

Some Result from Recent Studies

- Some recent findings
  - Field studies - Top-down approaches show a wide-range of methane emissions from oil and gas operations; imply bottom-up inventories underestimate methane emissions
    - Denver-Julesburg (DJ) Basin (Petron, 2012) 4%
    - Uintah Basin (Karion, 2013) 9%
    - Los Angeles Basin (Peischl, 2013) 17%

    Methane 'leakage' as % of production
    Compare to EPA inventory of 1-2% leakage

    - Miller 2013 – Methane from fossil fuel and animal husbandry greater than indicated by inventories

- Other methane studies currently underway
  - Top-down studies: Fayetteville, Haynesville, Marcellus, Barnett and DJ basins
  - Satellite studies
  - Bottom-up studies looking at specific stages of the natural gas life cycle
    - Today's presentations by EDF and University of Texas

- Implication for transportation: A natural gas vehicle Wells-to-Wheels analysis would have a wide uncertainty band, due to uncertainty in methane leakage

Why the Difference in Results?

- Hypotheses for differences between top-down and bottom-up:
  - Not all sources represented in a bottom up emissions inventory
  - A few large outliers responsible for a large fraction of emissions and not being correctly characterized by a bottom-up inventory
  - An incomplete accounting of natural sources of methane - seeps, wetlands
  - Inadequate characterization of temporal variability of emissions; not enough top-down 'snapshots' to represent the true average of a time-varying emission.
  - Inadequate allocation of top-down estimates to various source sectors (oil and gas, landfills, livestock, etc.)
  - Assumptions in atmospheric or inversion models not adequate or appropriate
  - …..

- What is needed – A study that links <u>concurrent</u> bottom-up methane emissions to top-down measurements.

A Recommendation for Further Research

- A well-designed program based on calculations, experiments, and field studies to test several of the hypothesis for the difference between top-down and bottom-up approaches. Such a study would contain
  - Calculations, atmospheric dispersion modeling, and/or wind tunnel studies to
    - Assess the impact of temporal and spatial variation of emissions on downwind ambient methane concentrations
    - Use information from above to guide top-down study design….how long do measurements need to be made to represent an average of time-varying emissions
  - A well-defined bottom-up emissions inventory for a specific location for the period of the the top-down field study
  - Top-down measurements (towers, drive-bys, fly-overs) and tracer studies with concurrent operational data

Summary

- Recent studies indicate a notable difference in estimates for methane emissions between bottom-up and top-down approaches
- Several hypothesis can be identified that potentially explain why the two approaches differ
- The range of results between the two approaches will greatly affect a Well-to-Wheel assessment of GHG emissions from natural gas vehicles for transportation
- Additional research and analysis is required to reduce the uncertainty of methane emissions to better understand the GHG impact of natural gas in transportation

Questions?