Life-Cycle Greenhouse Gas Emissions of Shale Gas, Natural Gas, Coal, and Petroleum

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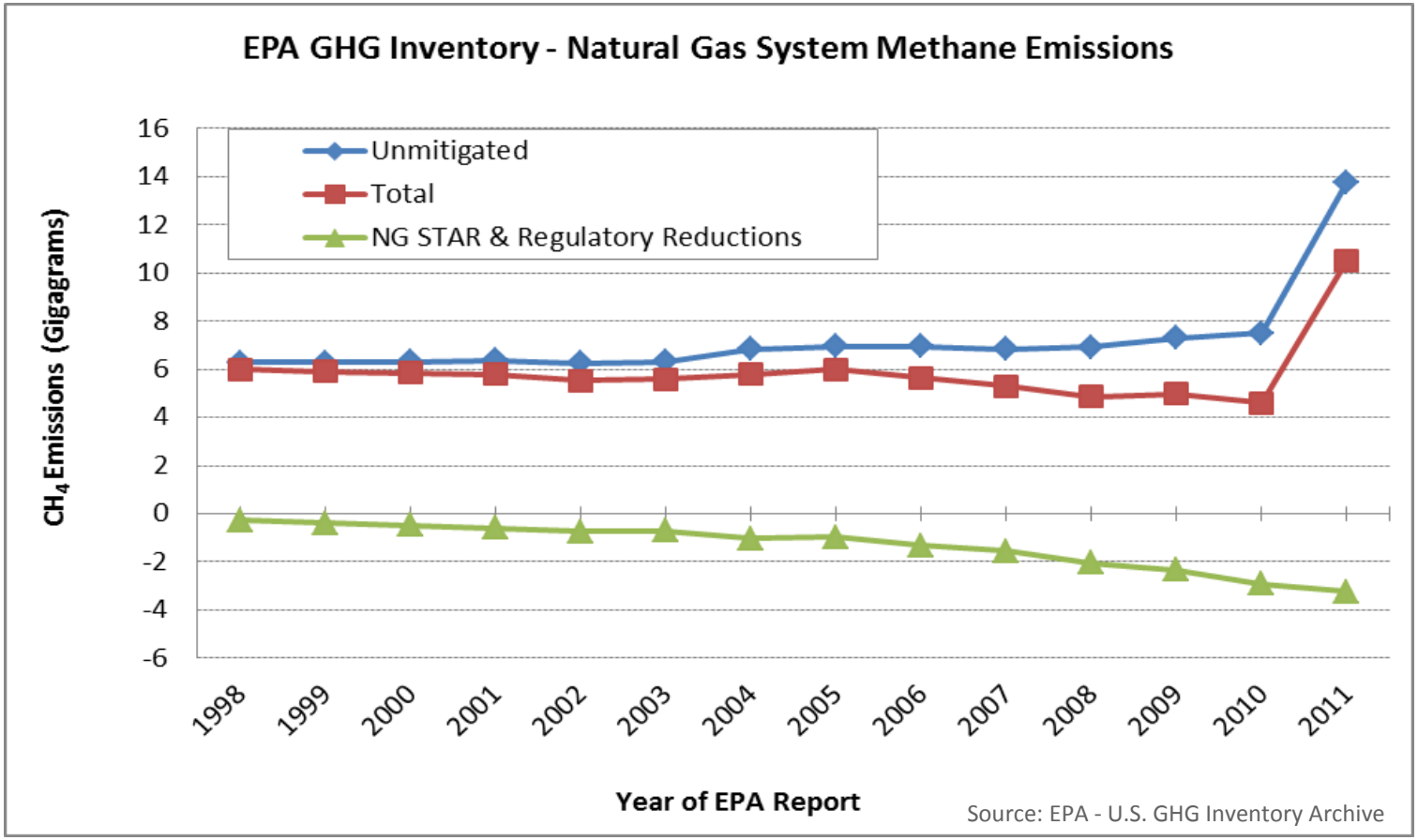
IPIECA Workshop: The Expanding Role of Natural Gas
Arlington, TX
March 7, 2012

Presentation Overview

- Introduction
- Key Issues
  - Estimated ultimate recovery
  - Well completions
  - Liquid unloadings
  - Global warming potential
  - End use efficiency
- Results
  - Direct combustion
  - Electricity generation
  - Passenger transportation
- Conclusions

Interest in Expanded Use of Natural Gas but What Are the GHG Implications with Recent Estimates of CH_4 Leakage?



- Major changes for EPA's 2011 GHG Inventory included
  - Adding shale gas well completions emissions
  - Updating emission factors for conventional NG liquid unloadings

Scope of Argonne's Natural Gas Life-Cycle Analysis

- Developed shale gas pathway and updated CH_4 leakage estimates for conventional NG, petroleum, and coal pathways for Argonne's GREET Model
  - Quantified material and energy requirements for well infrastructure development
  - Looked at 3 functional units: per MJ (direct combustion); per kWh (electricity generation); per mile (passenger transportation)

- Focused on estimating uncertainties and identifying data gaps to provide insight to NG industry and government
  - Developed distribution functions for key parameters

Periodic Well Emissions Must Be Allocated Over Lifetime NG Production

- Several key activities are estimated on a per-well basis
  - Lower the EUR, larger the impact
- Shale gas EURs are highly uncertain
  - Wide range for several plays based on industry and EIA estimates
- Conventional NG productivity is declining
  - Lower EUR than key shale plays
  - Average vs. marginal well

	Low EUR Estimate (Bcf)	High EUR Estimate (Bcf)
Barnett	1.4	3.0
Marcellus	1.4	5.2
Fayetteville	1.7	2.6
Haynesville	3.5	6.5
Shale Per-Well Weighted Avg.	**1.6**	**5.3**
Conventional Avg.	**0.8**	**1.2**

Shale Gas Completions CH_4 Emissions Could Be Large, But Industry Data Says Much is Recovered

- Flowback water contains NG, which can be vented, flared, or captured
  - At first flowback is mostly sand and fluids
  - Gas concentration rises as fluids are removed
  - When well pressure is high enough, operators send gas to gathering lines
- EPA estimates "uncontrolled" CH_4 emissions
  - Data used by EPA to calculate emissions have significant questions
  - Potentially overestimates emissions
    - Applicability of NG STAR program activities to calculate baseline
    - Use of IP rates to estimate flowback emissions
- EPA uses NESHAP regulations and NG STAR reporting to estimate amount of NG flared and captured by industry practices
  - Emissions were reduced by ~40% from 2005-2009
  - Lack of transparency as data is highly aggregated

EPA's Estimates Liquid Unloadings Account for Half of Uncontrolled CH_4 Emissions From NG Production

- Removing liquids can be accomplished by several practices/technologies
  - Largest emissions come from well blowdowns
  - EPA assumes unloadings only occur in conventional wells
- EPA updated well cleanup CH_4 emission factors
  - Previous methodology estimated uncontrolled emissions to be 10 Bcf
  - NG STAR reported 35 Bcf of savings from mitigation technologies
- Similar to issues with completion emissions, there is significant uncertainty
  - Suitability of NG STAR data to calculate baseline (unloadings/year, etc.)
  - Lack of transparency regarding NG STAR reductions
- Found that unloading emissions are potentially more significant than those from shale gas well completions

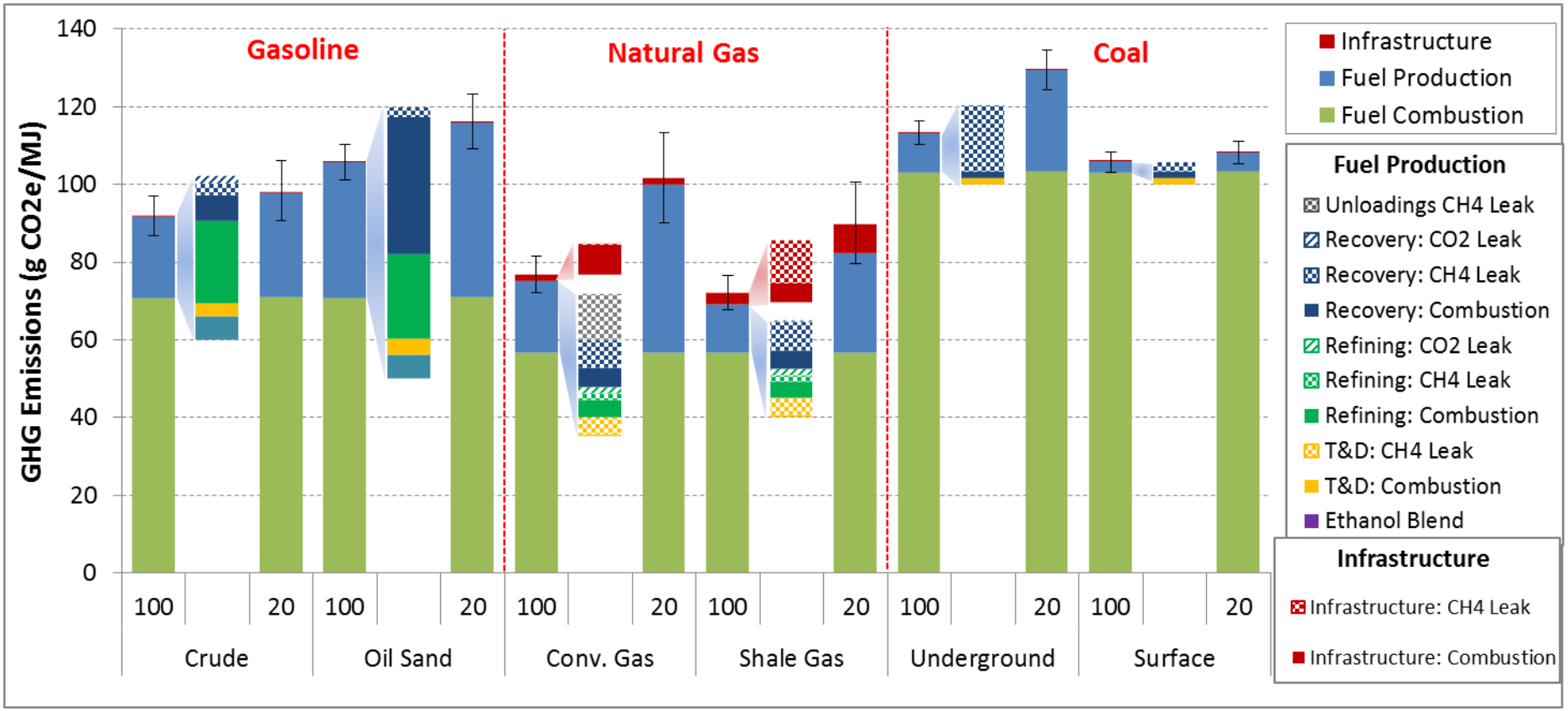
Global Warming Potential is a Simple Measure to Compare Radiative Effects of Different Gases

- Need to choose a time-horizon when comparing emission impacts of different fuels
  - Especially important when comparing contributions of short-lived gases
    - CH_4 has an atmospheric lifetime of ~12 years
- IPCC recommends using a 100-year time-horizon when evaluating climate change mitigation policies
- Other researchers have suggested a 20-year time-horizon should be examined
  - Effects of CH_4 emissions are amplified
- We use the 100-year time-horizon in our analyses
  - Also present 20-year for comparison to other studies

End-Use Efficiency is a Key Factor for LCA Results

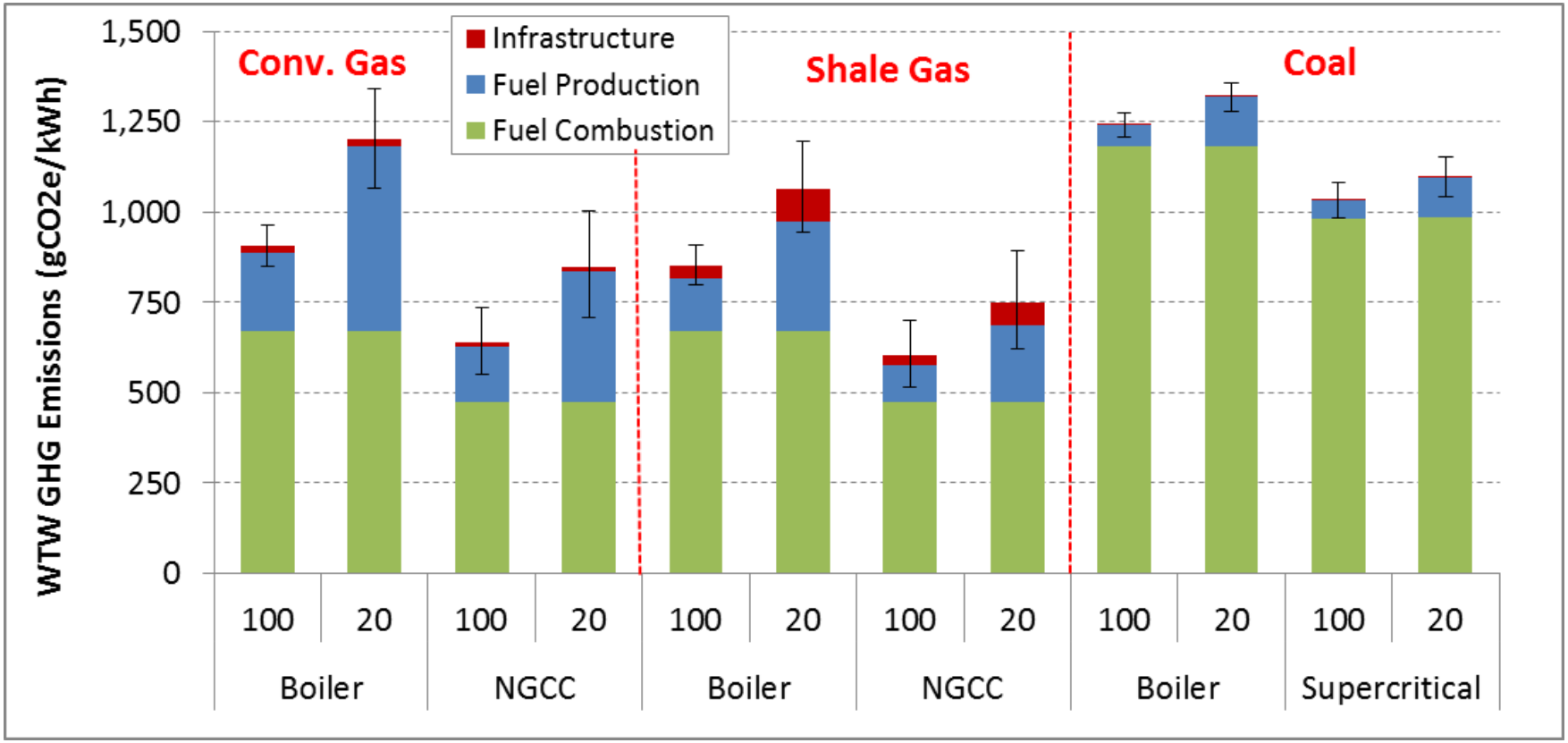
- NGCC power plants have an efficiency advantage over advanced coal plants, while conventional boilers are roughly the same efficiency
  - Base case NGCC = 47% vs. supercritical coal = 42%
- NG cars have slightly lower fuel economy than gasoline cars
  - Base case = 5% reduction
    - Weight penalty of CNG storage tanks
    - Power loss due to oxygen displacement
  - Use of direct injection and turbocharging can improve fuel economy and power
- NG transit buses have moderately lower fuel economy than diesel buses
  - Base case = 15% reduction
    - Spark-ignited engines have low efficiency at low speeds
    - NG spark-ignited engines have closed the gap on compression-ignition engines due to emission regulations

While CH_4 Leakage is Important, Fuel Combustion Accounts for Largest Portion of NG Life-Cycle Emissions

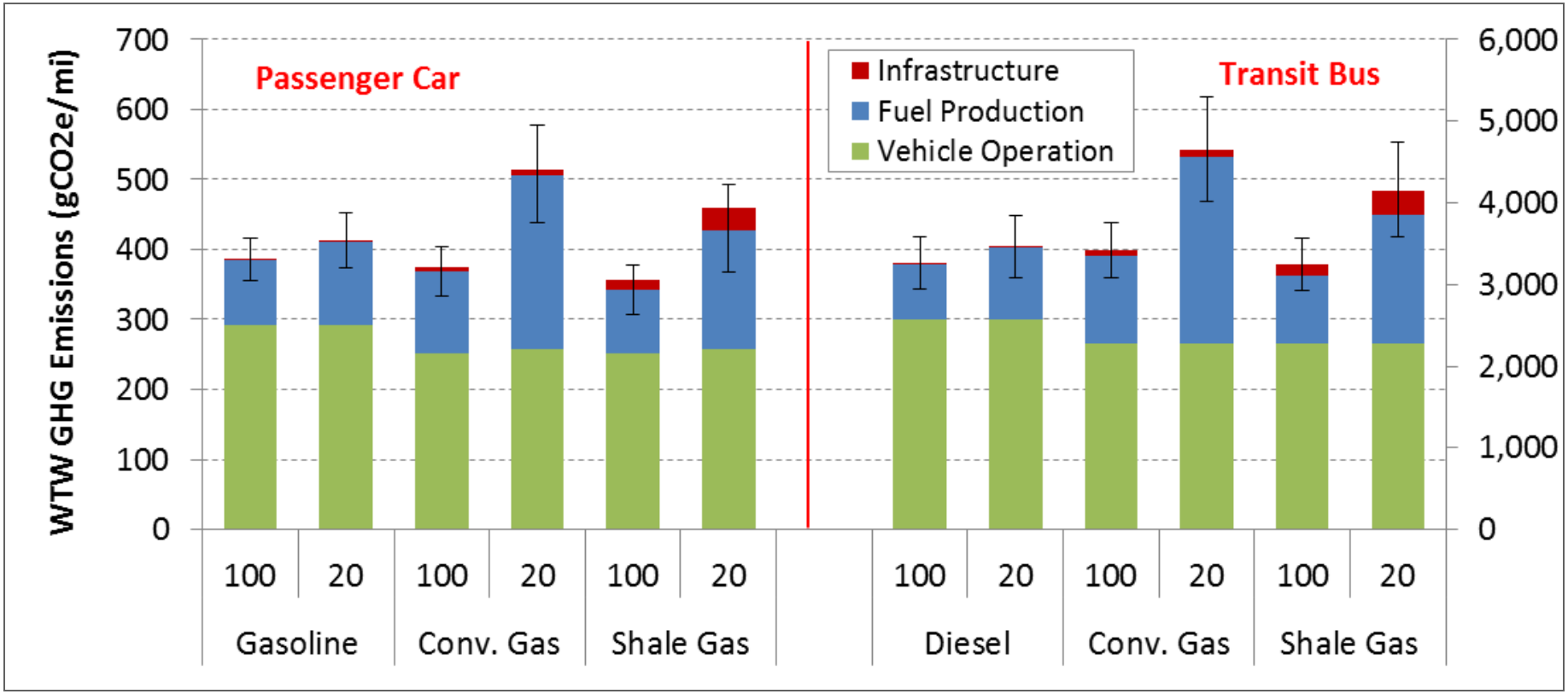


- Interesting result - base-case shale gas emissions are lower than conv. NG
  - Values overlap so can't say one is actually better than the other
- NG shows benefits for direct combustion but must look at the actual end-use
  - Efficiency of energy conversion to energy service key factor for proper comparison

NGCC Power Plants Provide Significant GHG Benefit, Even Compared to Advanced Coal



Compressed NGVs May Provide Small GHG Benefit, Improving Vehicle Efficiency is Important Goal



Better Data Will Improve Accuracy of Natural Gas LCAs

- Shale gas data:
  - Volume of gas and fraccing fluids released during flowback
    - With and without reduced emission completions
  - Survey of number of wells using RECs
  - Survey of flaring of well completions according to regulations & industry practices
  - Workover frequency
  - EUR projections

- Conventional NG data:
  - Volume of gas vented during liquid unloadings for range of technologies
  - Survey of conventional (and shale) wells requiring liquid unloadings
    - Survey of unloading technologies
  - Unloadings frequency by technology and age of well
    - Variance between basins (or even wells in same basin)
  - Survey of flaring of liquid unloadings according to regulations & industry practices

Shale Gas and Conventional NG Summary

- Estimates of CH_4 leakage from NG have increased significantly
- Shale gas completion emissions could be large in theory
  - However, industry reports that a significant amount is captured
  - Data is extremely limited and there is a lack of transparency
- Conventional NG liquid unloadings are potentially a larger source than shale gas completions
  - Causes the greatest amount of uncertainty in our study
  - Again data is extremely limited and there is a lack of transparency
- Using latest estimates of CH_4 leakage, shale and conventional NG
  - Provide <u>significant</u> GHG benefits for power plants as compared to coal
  - Provide <u>minimal</u> GHG benefits for passenger cars and transit buses as compared to gasoline and diesel

Thank you!!!

Argonne National Laboratory's work is supported by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy

This work has been supported and assisted by:

Linda Bluestein: U.S. Department of Energy

Dennis Smith: U.S. Department of Energy

Michael Wang: Argonne National Laboratory

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Presentation based on ES&T journal article available at http://pubs.acs.org/doi/abs/10.1021/es201942m

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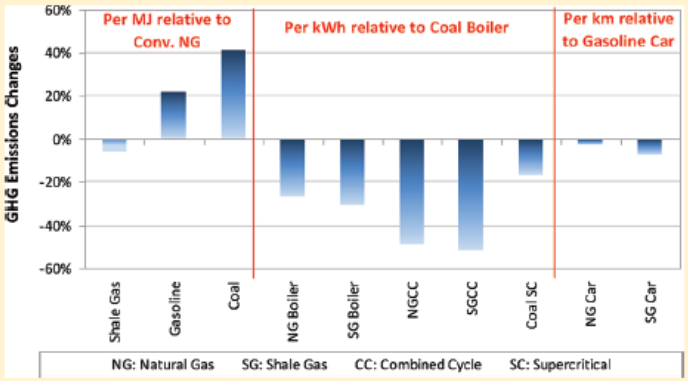
Supporting Information

ABSTRACT: The technologies and practices that have enabled the recent boom in shale gas production have also brought attention to the environmental impacts of its use. It has been debated whether the fugitive methane emissions during natural gas production and transmission outweigh the lower carbon dioxide emissions during combustion when compared to coal and petroleum. Using the current state of knowledge of methane emissions from shale gas, conventional natural gas, coal, and petroleum, we estimated up-to-date life-cycle greenhouse gas emissions. In addition, we developed distribution functions for key parameters in each pathway to examine uncertainty and identify data gaps such as methane emissions from shale gas well completions and conventional natural gas liquid unloadings that need to be further addressed. Our base case results show that shale gas life-cycle emissions are 6% lower than conventional natural gas, 23% lower than gasoline, and 33% lower than coal. However, the range in values for shale and conventional gas overlap, so there is a statistical uncertainty whether shale gas emissions are indeed lower than conventional gas. Moreover, this life-cycle analysis, among other work in this area, provides insight on critical stages that the natural gas industry and government agencies can work together on to reduce the greenhouse gas footprint of natural gas.