Understanding the Life Cycle Environmental Footprint of the Natural Gas Value Chain

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U.S. DEPARTMENT OF ENERGY | National Energy Technology Laboratory

OFFICE OF FOSSIL ENERGY

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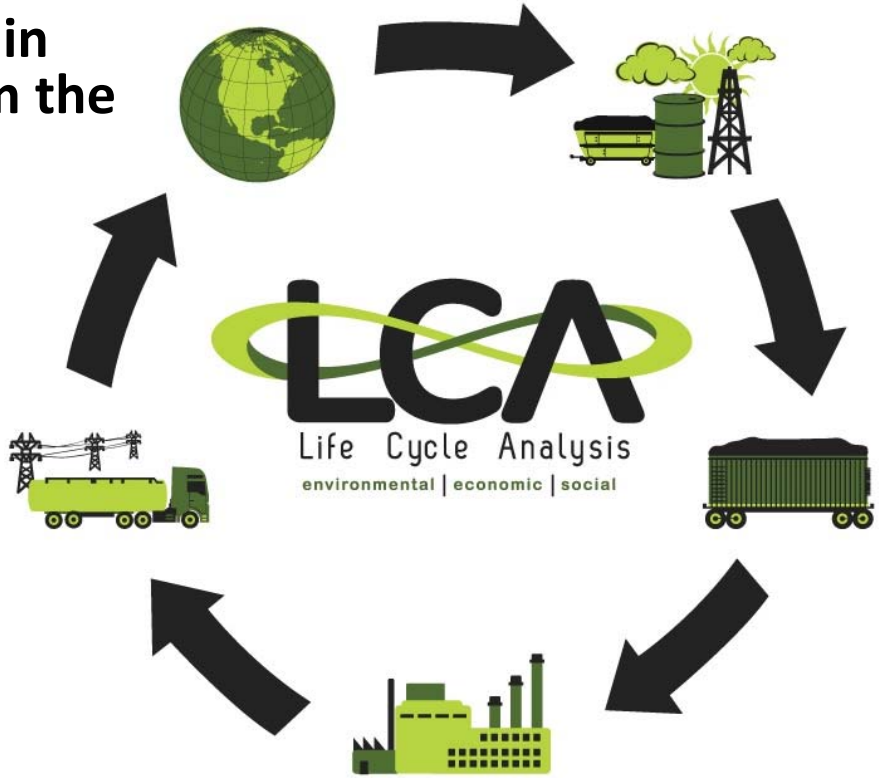
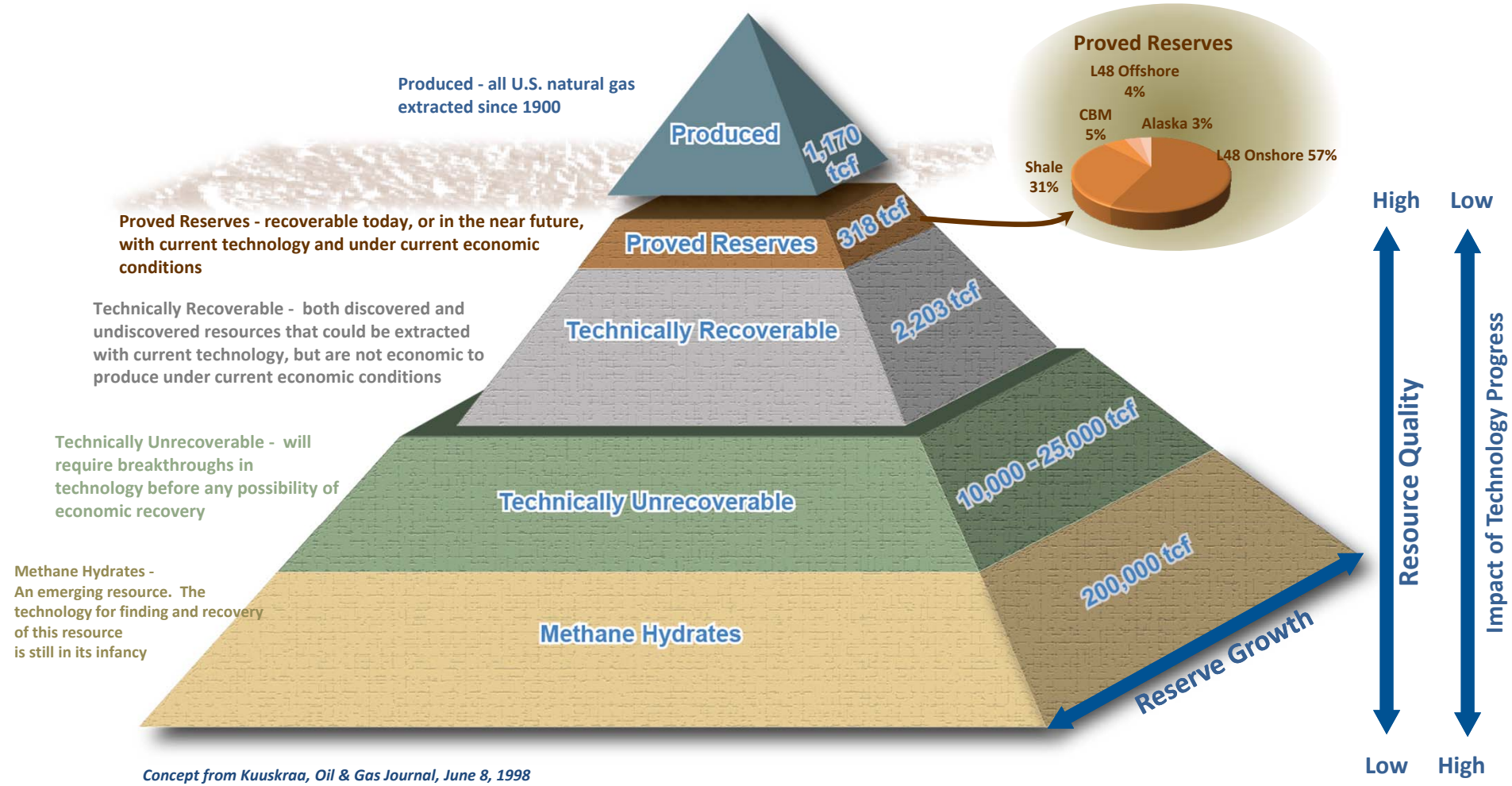
Agenda

- **Importance of Understanding Methane Emissions from the Natural Gas Sector**
- **DOE's Office of Fossil Energy Role in Reducing Methane Emissions from the Natural Gas Value Chain**
- **Primer on LCA**
  - What is it?
  - How is it used?
- **Understanding the Life Cycle Environmental Footprint of the Natural Gas Value Chain**

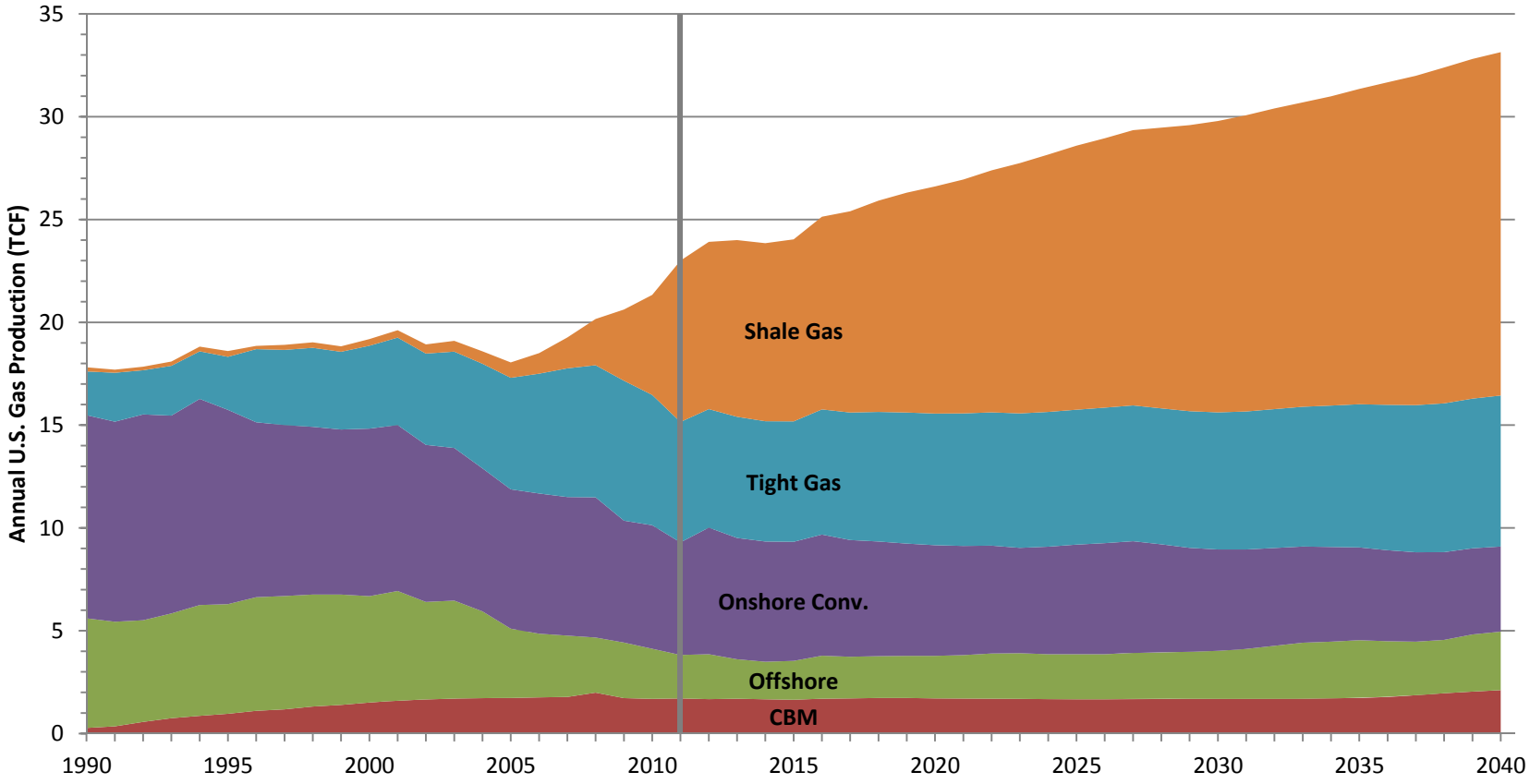


U.S. Natural Gas Resource Pyramid



Concept from Kuuskraa, Oil & Gas Journal, June 8, 1998
Data Sources – EIA and NETL

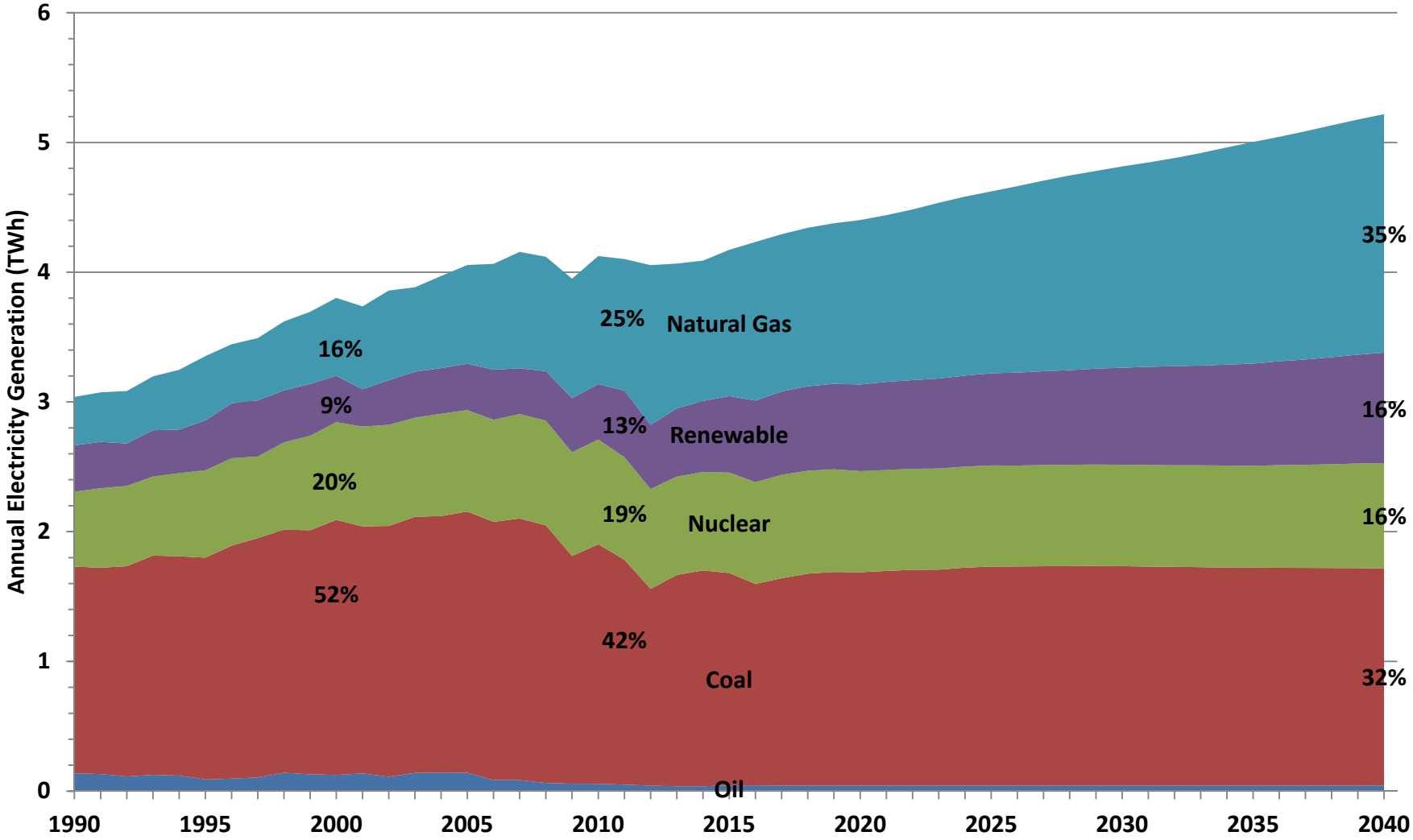
Unconventional Sources of Natural Gas are Changing the Resource Profile of Natural Gas Production



- Total U.S. demand for natural gas was 28 Tcf in 2011 and is projected to grow to 37 Tcf by 2040 (EIA 2013)
- Unconventional sources of natural gas are a growing share of U.S. production
- LCA is well suited to analyze the effect of shale gas growth on the environmental profile of natural gas systems

Source: EIA AEO 2013

Today, Natural Gas is Growing in it's Share of Power Generation in the U.S., Largely Displacing Coal Power



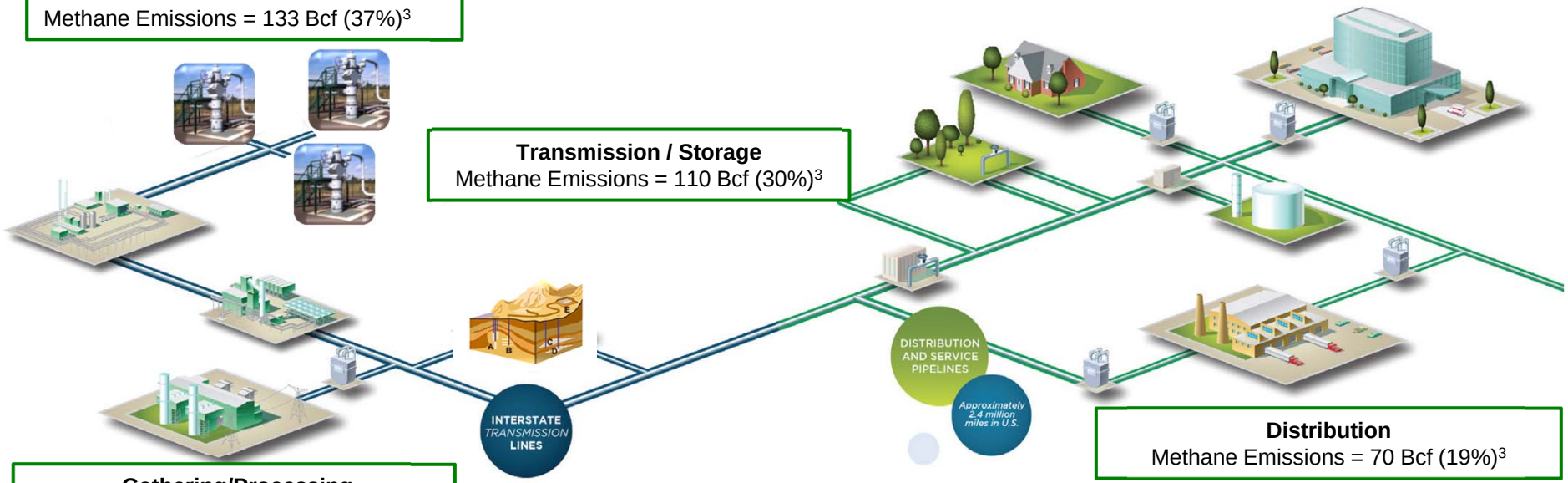
Source: EIA AEO 2014ER

Natural Gas Sector Methane Emissions

25% of Total U.S. Emissions, 392 BCF (6,893 Gg), ~1.4% loss from extraction to distribution in 2011

Gas Wells
Methane Emissions = 133 Bcf (37%)[3]

Transmission / Storage
Methane Emissions = 110 Bcf (30%)[3]



Distribution
Methane Emissions = 70 Bcf (19%)[3]

Gathering/Processing
Methane Emissions = 49 Bcf (14%)[3]

Wells
500,000 gas wells
40,000+ new wells annually
6,300 production companies
21 major production companies

Gathering
10,000+ gathering stations
100,000+ gathering compressors
200,000 Miles of gathering pipe
(typically 8-5/8" or less) 500 psi

Processing
580 Natural Gas Processing Plants

Transmission
320,000 Miles of large diameter transmission pipe 24"-48"1,000 psi **1,500** Compressor Stations for transmission
- **7,500** engines
- **1,500** turbines
- 50 million hp
- **37.5** gW

400 Underground storage facilities

Distribution
1200 Distribution companies
2.1 million Miles of distribution pipe.
1,700 natural gas-fired power plants
62 million Homes with natural gas service in U.S

[1] U.S. Department of Transportation (2013). Annual Report Mileage Summary Statistics. (Retrieved October 31, 2013 from http://www.phmsa.dot.gov/portal/site/PHMSA/menuitem.7c371785a639f2e55cf2031050248a0c/?vgnextoid=3b6c03347e4d8210VgnVCM1000001ecb7898RCRD&vgnextchannel=3b6c03347e4d8210VgnVCM1000001ecb7898RCRD&vgnextfmt=print)

[2] EIA (2013). Natural Gas Annual. Table 1: Summary statistics for natural gas in the United States, 2007-2011. Retrieved October 31, 2013 from http://www.eia.gov/naturalgas/annual/pdf/table_001.pdf.

[3] EPA (2013). Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990 - 2011, Table 3-44: CH4 Emissions from Natural Gas Systems (Gg). USEPA, April, 2013. (Retrieved October 31, 2013 from http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2013-Chapter-3-Energy.pdf)

DOE's Office of Fossil Energy Role in Reducing Methane Emissions from the Natural Gas Value Chain

DOE's Office of Fossil Energy Role

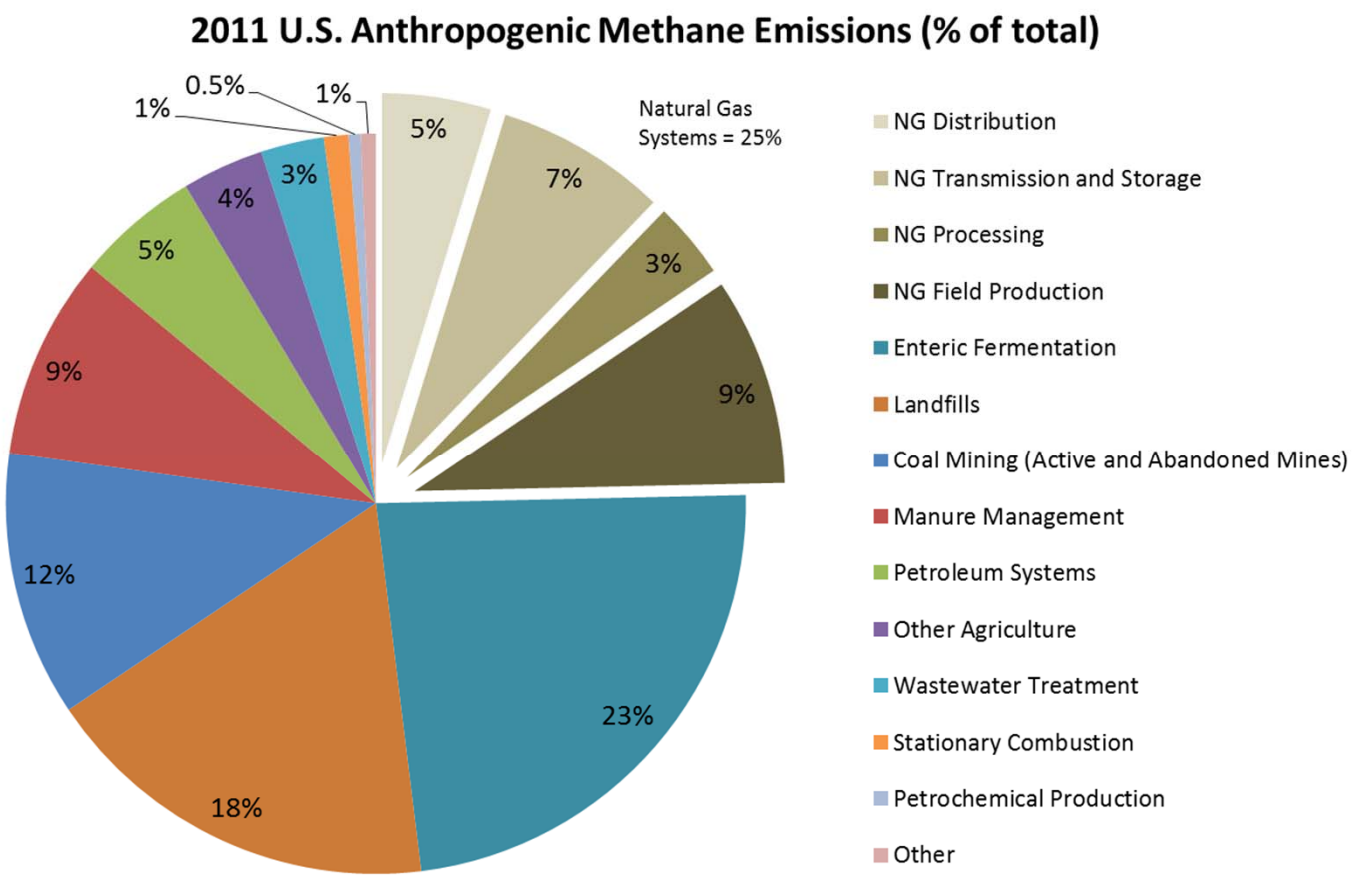
Reducing Methane Emissions from the Natural Gas Sector

1. **Conduct science and research in understanding greenhouse gas emissions, water impacts, and other environmental impacts from the natural gas sector**

2. **Collaborate with industry and academia to develop technology solutions that will improve the natural gas sector's environmental stewardship while enhancing national energy security**

3. **Inform industry and the public on the key issues and potential solutions related to the environmental performance of the natural gas sector**

Where do U.S. Methane Emissions Come From?

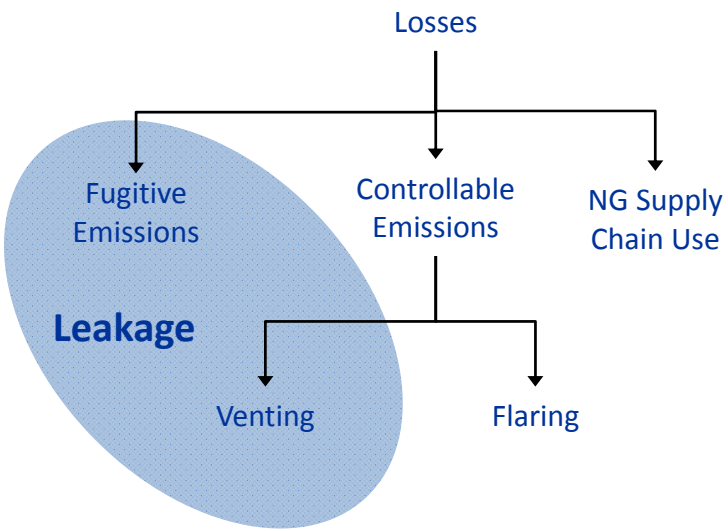


- Methane emissions are 9% of total 2011 anthropogenic U.S. GHG emissions
- Current U.S. fossil fuel related methane emissions are ~ 40% of U.S. anthropogenic methane emissions

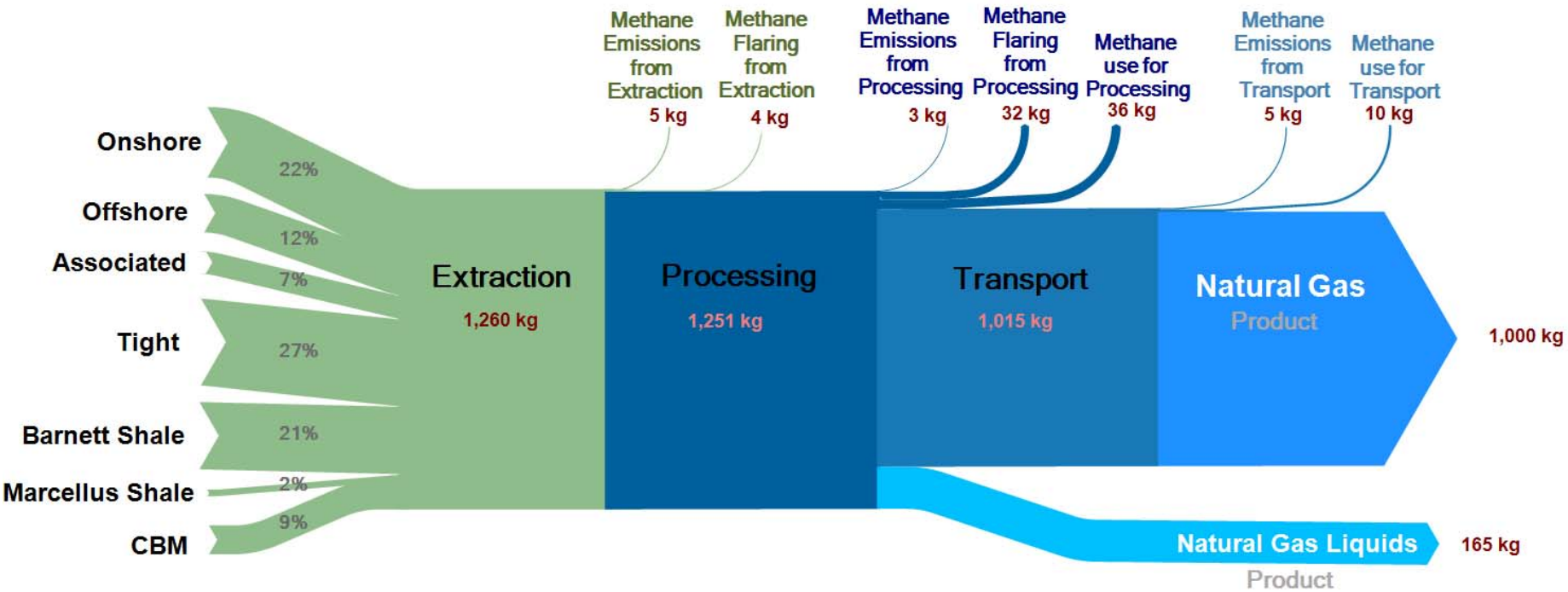
note: Percentages may not add exactly to 100 due to rounding errors)

Natural Gas is both Used and Lost in the Value Chain

- **Fugitive Emissions**
  - Cannot be practically recovered by control technologies
  - Examples: pneumatic or flange leaks
- **Controllable Emissions**
  - Can be reduced by using capture equipment
  - *Venting* releases CH_4 and *flaring* converts CH_4 to CO_2
  - Examples: flowback emissions or venting from acid gas removal
- **Natural Gas Use**
  - Natural gas is used as a fuel in processing and transmission equipment
  - CO_2 emissions result from fuel combustion
  - Examples: processing reboilers or gas-powered compressors



Mass Balance of Natural Gas Value Cain from Extraction to a Large End User (e.g., Power Plant)



- NETL's *cradle-to-delivered* fugitive emission rate is 1.2% to a large end user; 1.4% including distribution to small end users
- NETL's *extraction* fugitive emission rate is 0.54%, which is close to loss rates measured by EDF and University of Texas[1]

[1] Allen, David T., et al. "Measurements of methane emissions at natural gas production sites in the United States." *Proceedings of the National Academy of Sciences* (2013): 201304880.

Natural Gas Losses Are Not Defined Consistently

- **EPA GHG Inventory (as defined in Subpart W[1])**
  - ***Vented*** emissions are "intentional or designed releases of CH_4 or CO_2 containing natural gas or hydrocarbon gas (not including stationary combustion flue gas), including process designed flow to the atmosphere through seals or vent pipes, equipment blowdown for maintenance, and direct venting of gas used to power equipment (such as pneumatic devices)"
  - ***Fugitive*** emissions "could not reasonably pass through a stack, chimney, vent, or other functionally-equivalent opening"
  - ***Combustion*** emissions "result from the use of petroleum-derived fuels and natural gas as fuel in equipment (e.g., heaters, engines, furnaces, etc.) in the petroleum and gas industry"
- **Intergovernmental Panel on Climate Change (IPCC)[2] broadly defines all venting, flaring, and other non-fuel-combustion emissions as fugitives**
  - ***Fugitives*** include
    - "venting of natural gas and waste gas/vapour streams at gas facilities"
    - "flaring of natural gas and waste gas/vapour streams at gas facilities"
    - "equipment leaks, storage losses, pipeline breaks, well blowouts, gas migration to the surface around the outside of wellhead casing, surface casing vent bows and any other gas or vapour releases not specifically accounted for as venting or flaring"
- **Energy Information Administration (EIA) Natural Gas Reporting[3]**
  - ***Fugitive*** emissions are " unintended leaks of gas from the processing, transmission, and/or transportation of fossil fuels"
  - ***Extraction losses*** include volumes of natural gas used at production (lease) site and by processing losses

[1] *EPA (2011) Background Technical Support Document – Petroleum and Natural Gas Industry. Retrieved November 18, 2013 from http://www.epa.gov/ghgreporting/documents/pdf/2010/Subpart-W_TSD.pdf*
[2] *IPCC (2006). 2006 IPCC Guidelines for National GHG Inventories. Retrieved November 18, 2013 from http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_4_Ch4_Fugitive_Emissions.pdf*
[3] *EIA Glossary: http://www.eia.gov/tools/glossary/index.cfm*

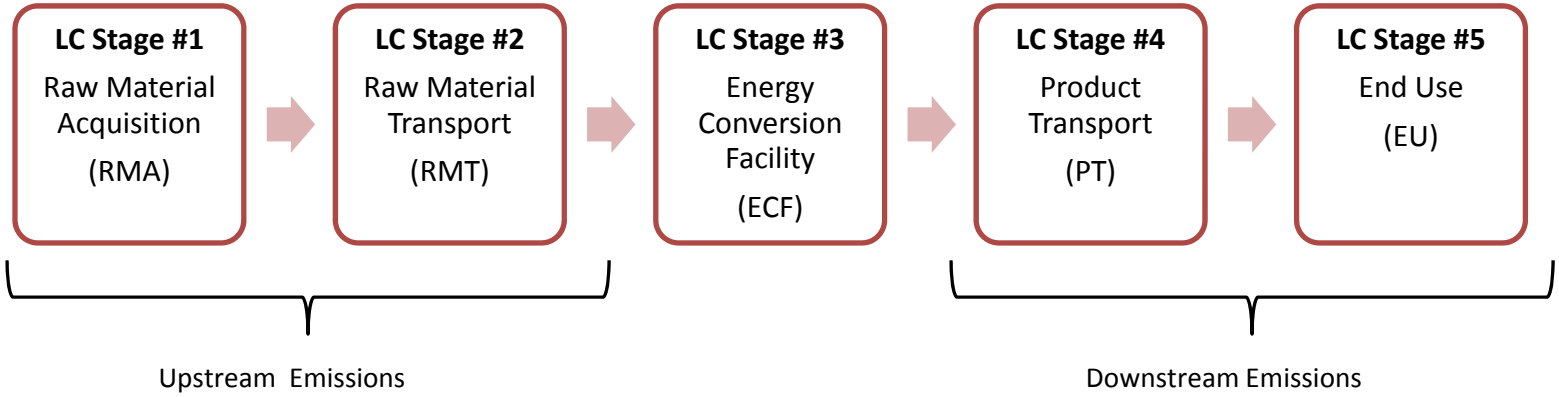
A Deeper Understanding of CH_4 Emission Sources and Measurement is Needed to Target Reduction Strategies

- **Not all natural gas plays and systems are equal**
  - Regional differences in operator practice, natural gas composition, and estimated ultimate recovery
  - Existing and new wells have different emission profiles
- **Significant differences exist between "bottom-up" and "top-down" methane measurements**
  - Reasons for differences are not well understood
  - Additional measurement/verification is needed to support policy decisions
- **A life cycle analysis approach is needed**
  - Understand temporal, technological, play level, and other key emission source differences
  - Evaluate methane emissions over a 30-year operating perspective, reducing single year activity bias
  - Evaluate natural gas sector methane reduction opportunities in other sectors

Primer on LCA

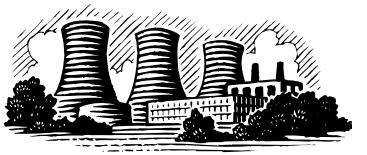
Introduction to Life Cycle Analysis

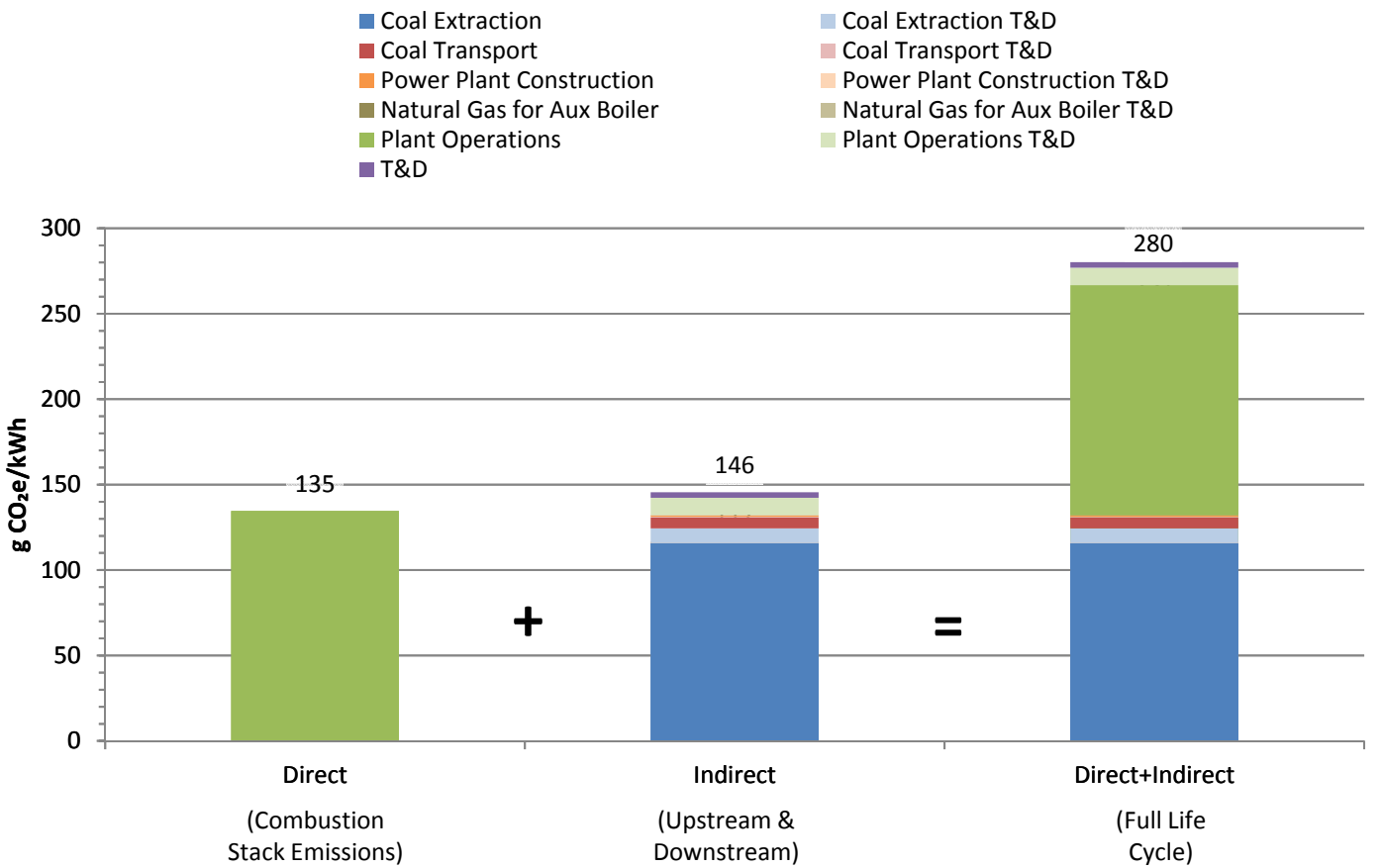
- **Compilation and evaluation of the inputs, outputs, and potential environmental impacts of a product or service throughout its life cycle, from raw material acquisition to final disposal**



- **Ability to compare different options depends on functional unit (denominator)**
  - 1 kWh of electricity delivered to the end user
  - 1 MJ of fuel combusted

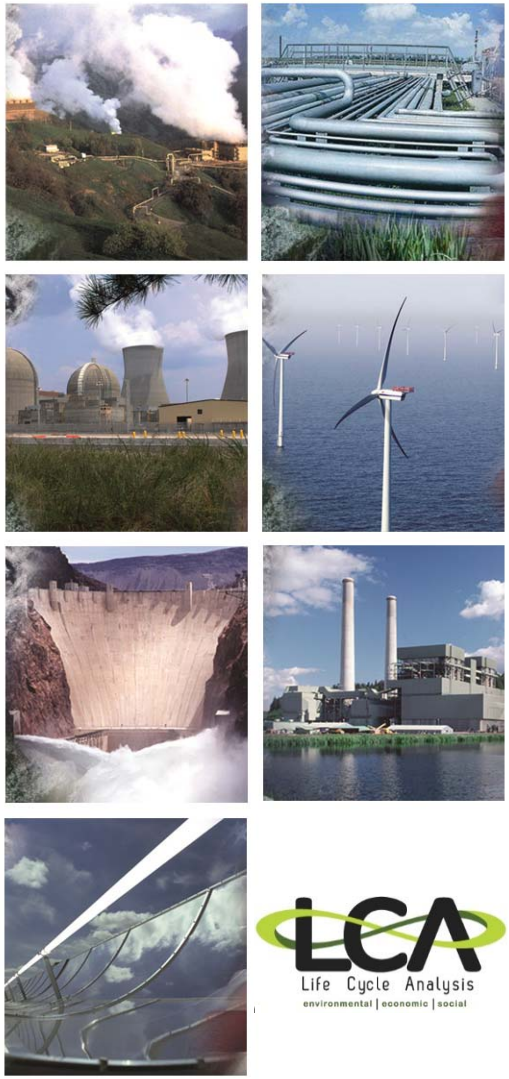
LCA Shows the Importance of Each Portion of the Life Cycle





LCA is Well Suited for Energy Analysis

- **Draws a more complete picture than one focused solely on stack or tailpipe emissions**
- **Allows direct comparison of dramatically different options**
- **Includes methods for evaluating a wide variety of burdens**



LCA Answers are Sensitive to the Question Asked

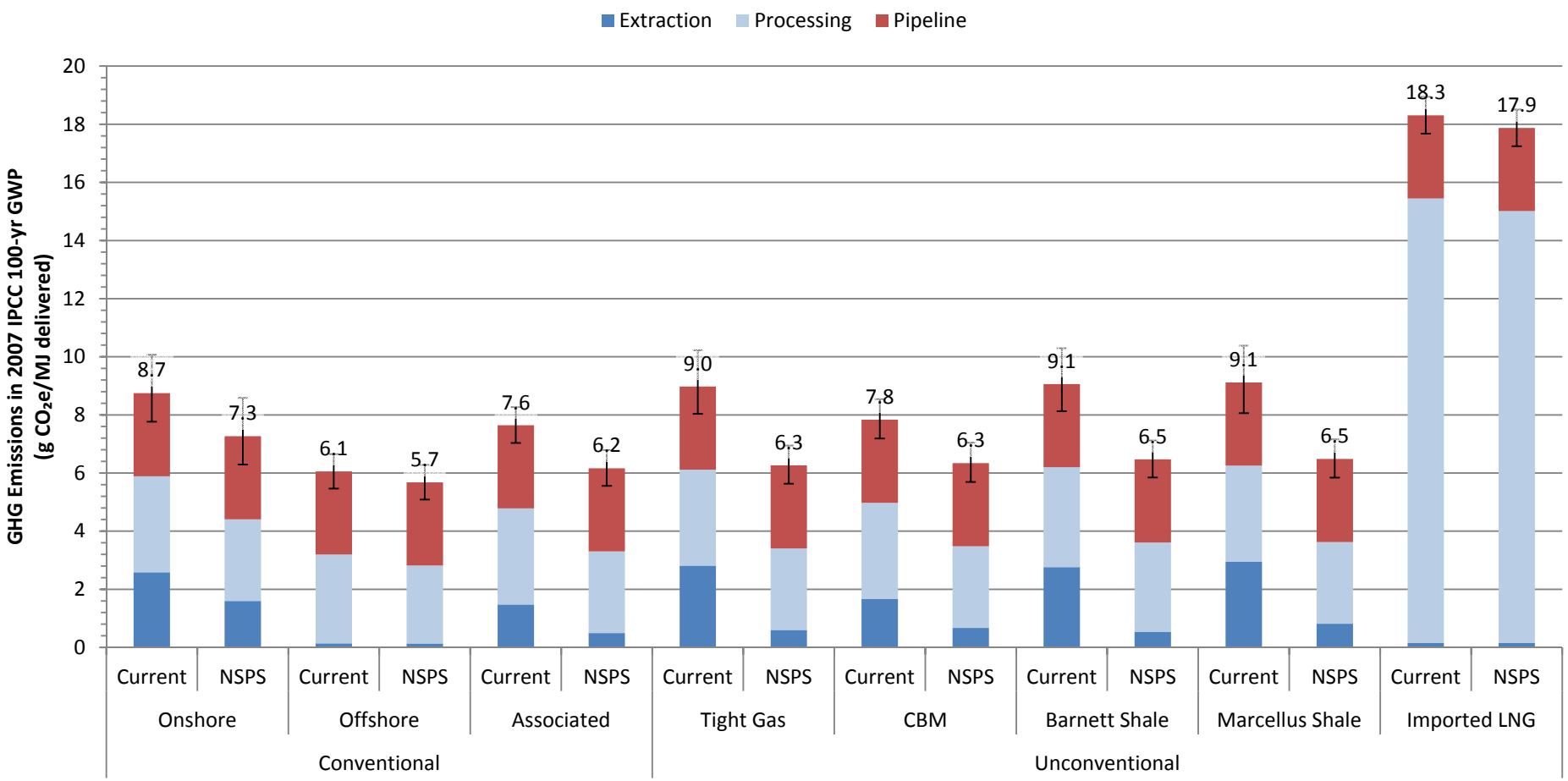
- **How does a given technology compare to other options?**
  - Narrow boundaries and attributional results
  - Example: Life cycle emissions from 1 MWh of electricity from NGCC vs. SCPC power
- **How will a given policy affect an entire system?**
  - Broad boundaries and consequential results
  - Example: Changes to global energy supply and associated GHG emissions if U.S. exports liquefied natural gas (LNG)

Potential trade-off between usefulness and uncertainty

The more complete the picture, the more uncertain it becomes

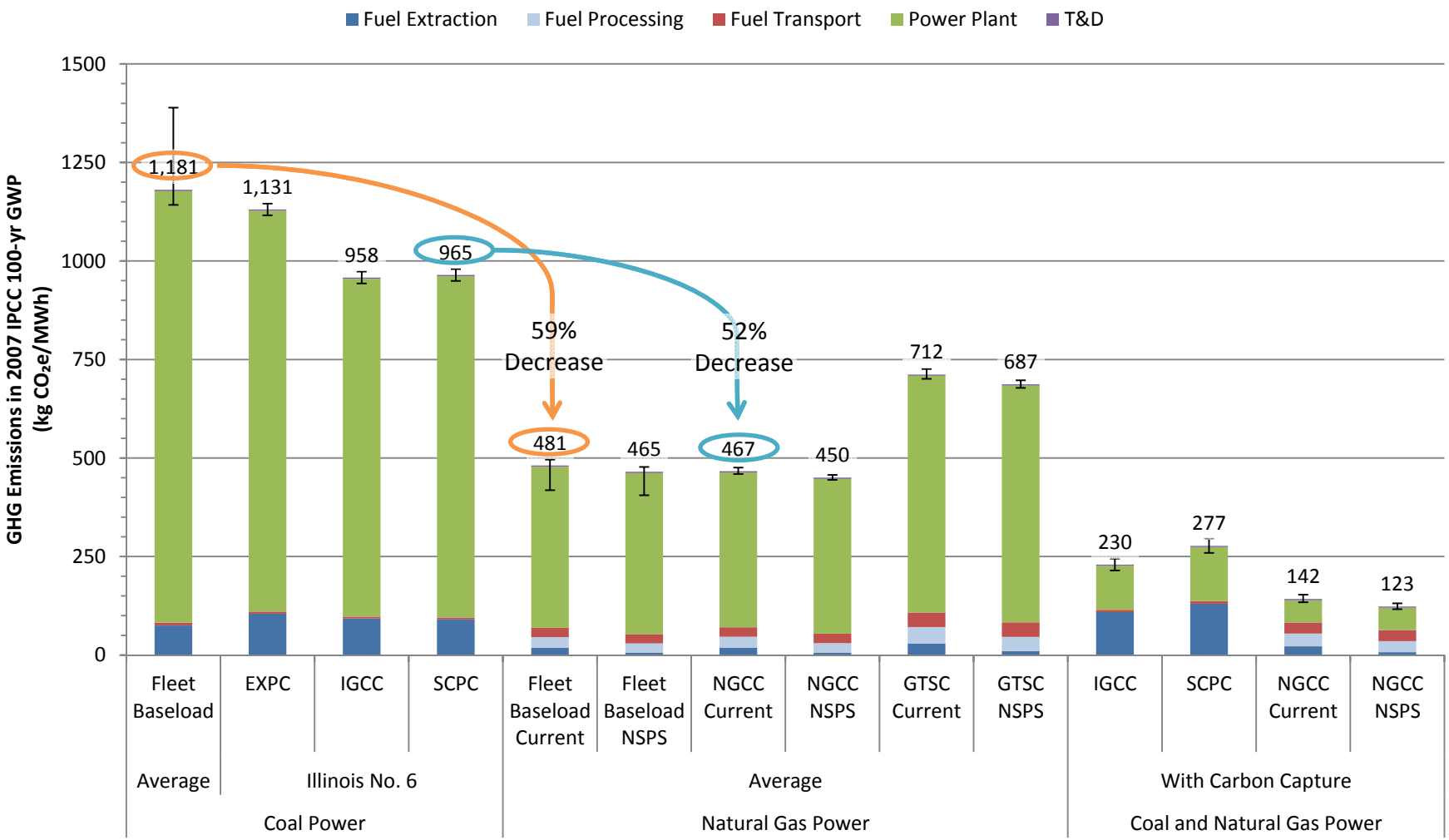
Understanding the LCA of Natural Gas

Upstream Summary for Eight Natural Gas Types

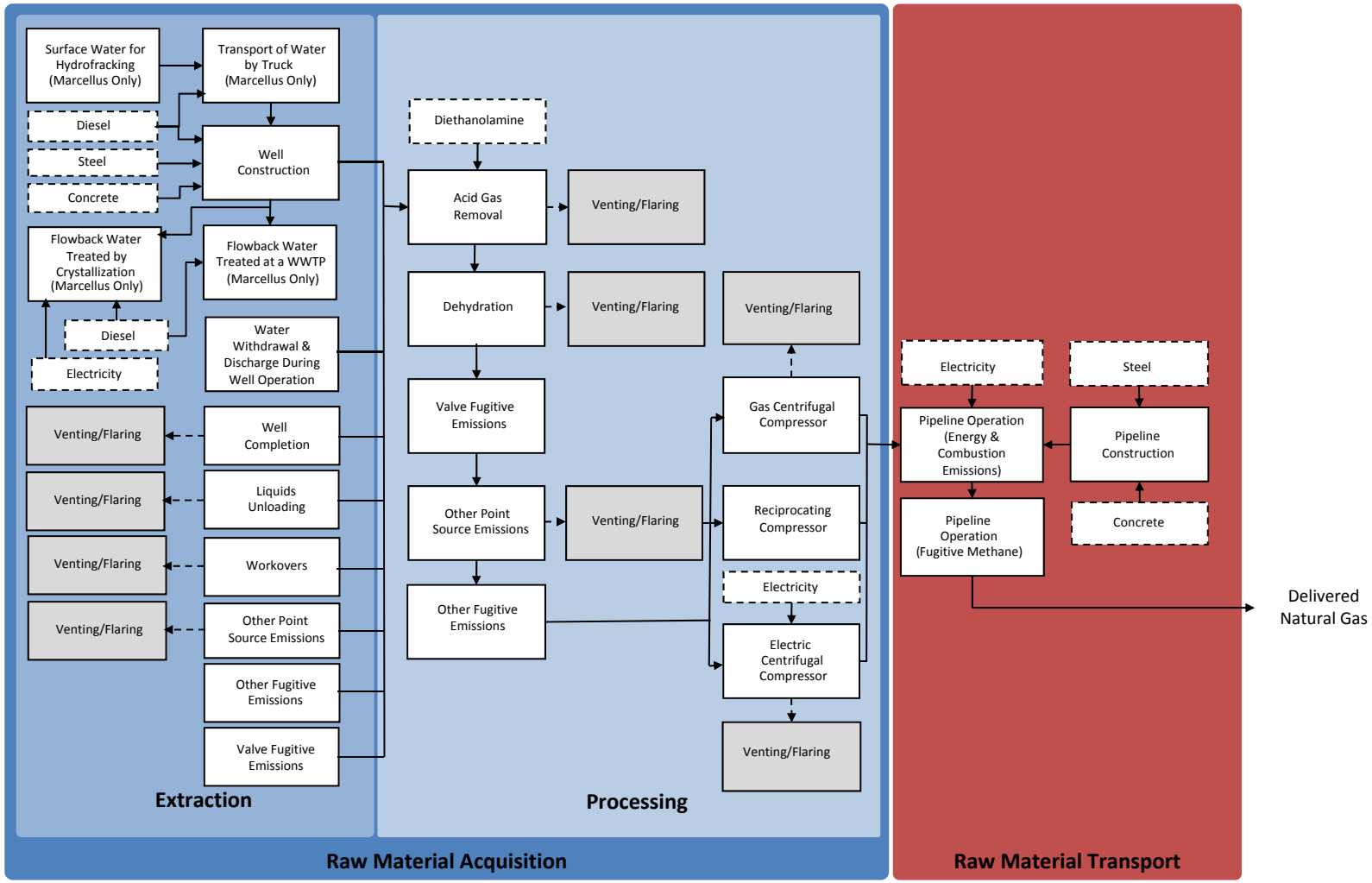


- All sources of natural gas are modeled using a uniform, consistent framework
- Model is not restricted to the 8 natural gas sources shown above
- Parameters can be easily altered as new data become available

From a Life Cycle Perspective, Baseload Power is the Preferred Basis for Comparing Energy Sources



NETL's Upstream Natural Gas Model



Over 20 unique unit processes, bottom-up and parameterized

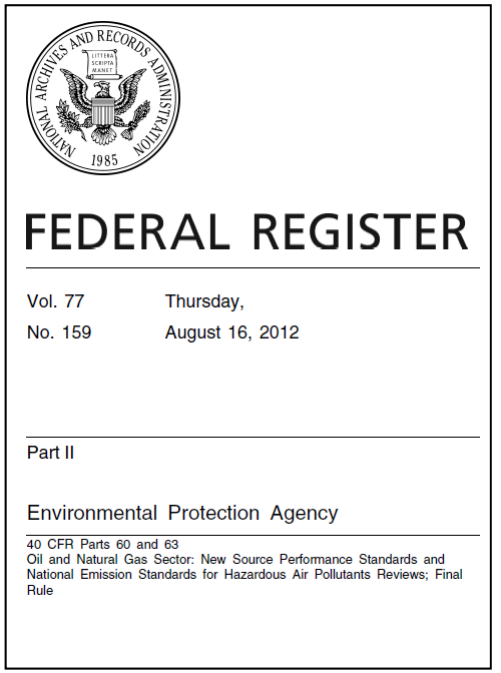
Model Parameters allow Flexibility, which allows Scenario, Uncertainty, and Sensitivity Analysis

Property (Units)		Onshore	Associated	Offshore	Tight Gas	Barnett Shale	Marcellus Shale	CBM
Natural Gas Source								
Contribution to 2010 U.S. Domestic Supply		22%	6.6%	12%	27%	21%	2.5%	9.4%
Average Production Rate (Mcf /day)	low	46	85	1,960	77	192	201	73
	expected	66	121	2,800	110	274	297	105
	high	86	157	3,641	143	356	450	136
Expected EUR (Estimated Ultimate Recovery) (BCF)		0.72	1.32	30.7	1.20	3.00	3.25	1.15
Natural Gas Extraction Well								
Flaring Rate (%)		51% (41 - 61%)			15% (12 - 18%)			
Well Completion (Mcf natural gas/episode)		47			3,600	9,000	9,000	49.6
Well Workover (Mcf natural gas/episode)		3.1			3,600	9,000	9,000	49.6
Lifetime Well Workovers (Episodes/well)		1.1			0.3			
Liquid Unloading (Mcf natural gas/episode)		3.57	n/a	3.57	n/a	n/a	n/a	n/a
Lifetime Liquid Unloadings (Episodes/well)		930	n/a	930	n/a	n/a	n/a	n/a
Valve Emissions, Fugitive (lb CH_4/Mcf natural gas)		0.11		0.0001	0.11			
Other Sources, Point Source (lb CH_4/Mcf natural gas)		0.003		0.002	0.003			
Other Sources, Fugitive (lb CH_4/Mcf natural gas)		0.043		0.01	0.043			

- Parameters include expected values and uncertainty/variability ranges
- Similar level of parameterization is used for processing and pipeline transmission

EPA New Source Performance Standards (NSPS) Regulate VOC Emissions from the Oil and Gas Sector

- **Final Oil & Gas Sector NSPS rule under CAA established August 16, 2012**
- **Methane is a key component of the VOC category for the oil and gas sector**
- **Reduces emissions from some processes by as much as 95%**
  - Well completions and workovers
  - Centrifugal compressors
  - Reciprocating compressors
  - Storage tanks
  - Pneumatic controllers
- **Does not regulate all upstream natural gas processes**
  - Liquid unloading
  - Pipeline transmission



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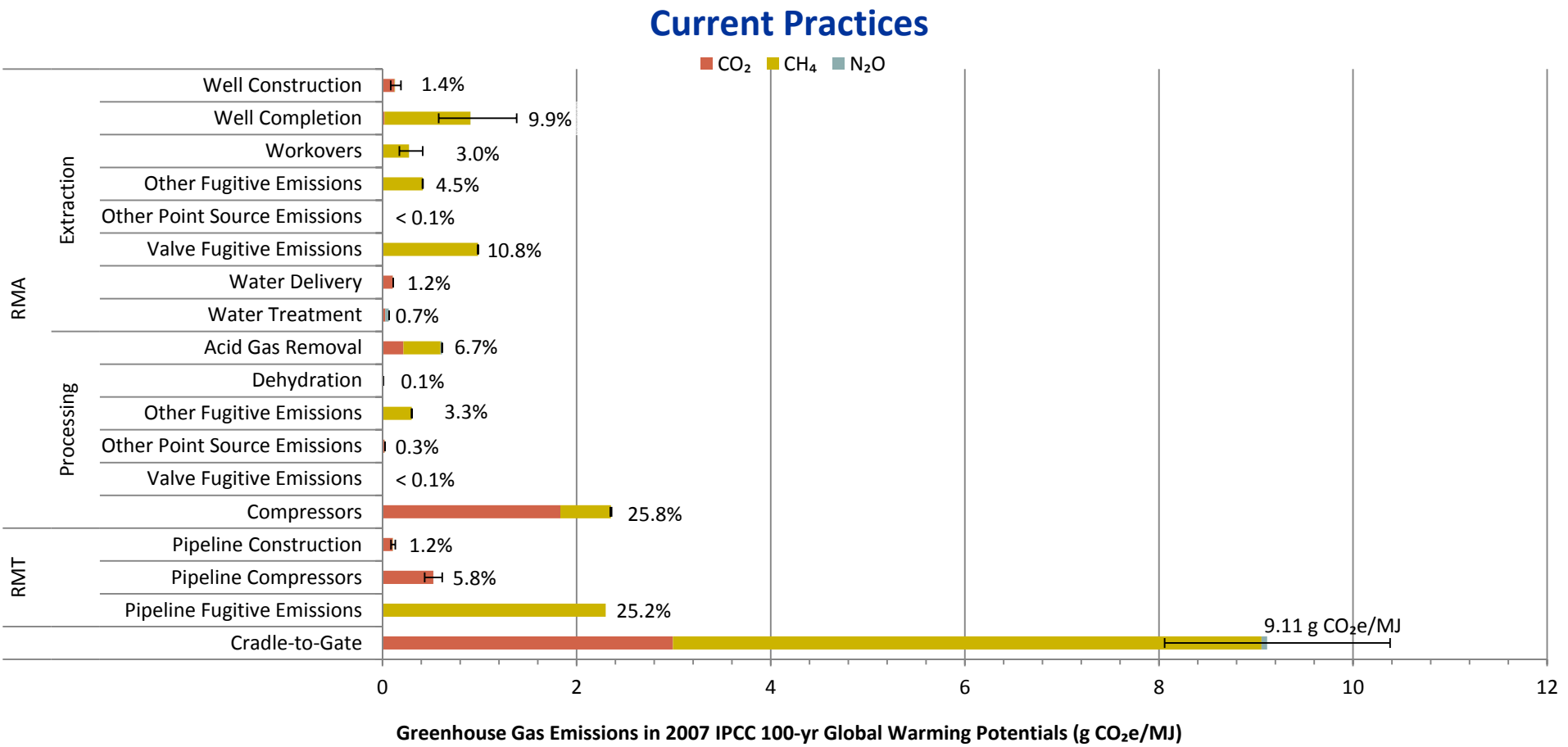
Part II

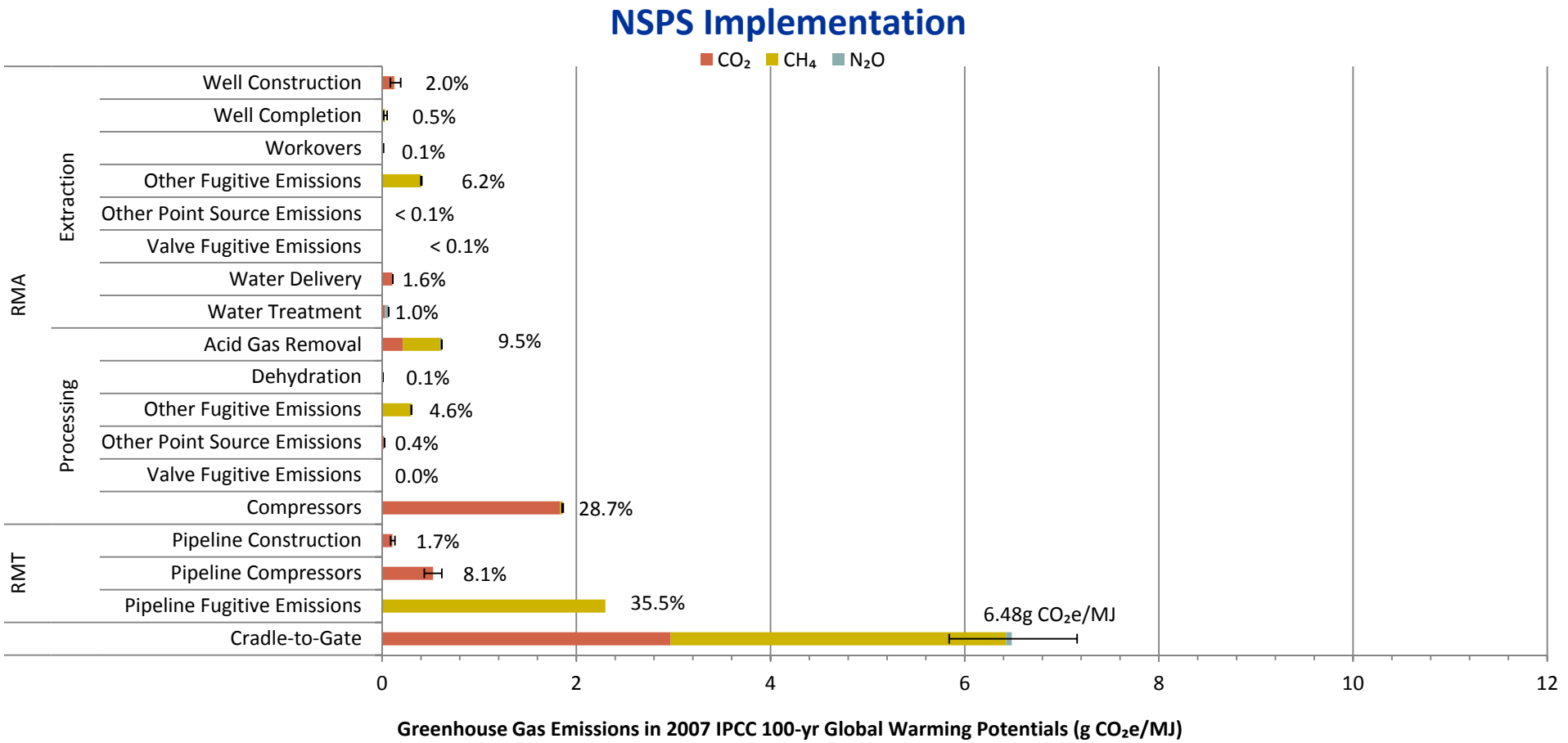
Environmental Protection Agency

40 CFR Parts 60 and 63
Oil and Natural Gas Sector: New Source Performance Standards and National Emission Standards for Hazardous Air Pollutants Reviews; Final Rule

Marcellus Shale Life Cycle Contribution Analysis



Marcellus Shale Life Cycle Contribution Analysis



NSPS implementation for Marcellus Shale can reduce upstream GHG emissions by 30%

Knowledge is Not Perfect – More Work is Needed to Improve the Life Cycle Understanding

1. Regional variation in gas composition
2. Estimated Ultimate Recovery (EUR)
3. NSPS implementation
4. Pipeline compressor leakage and efficiency
5. Completion and workover emissions
6. Workover frequency
7. Flaring rates
8. Fugitive emissions at extraction
9. Non-GHG emissions (VOCs) from extraction
10. Water use for hydrofracking

Summary

- Natural gas's role in the U.S. continues to grow as a result reducing methane emissions remains a high priority
- DOE's Office of Fossil Energy is working to improve the environmental performance of the natural gas value chain
- Consistent modeling approach developed by NETL allows for incorporation of latest research to produce precise results on a common basis
- Flexible, bottom-up modeling approach has allowed NETL to respond to questions from government, academia, industry, and NGO stakeholders
- Additional data improvements will further increase the accuracy and representativeness of NETL's results

Contact Us

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