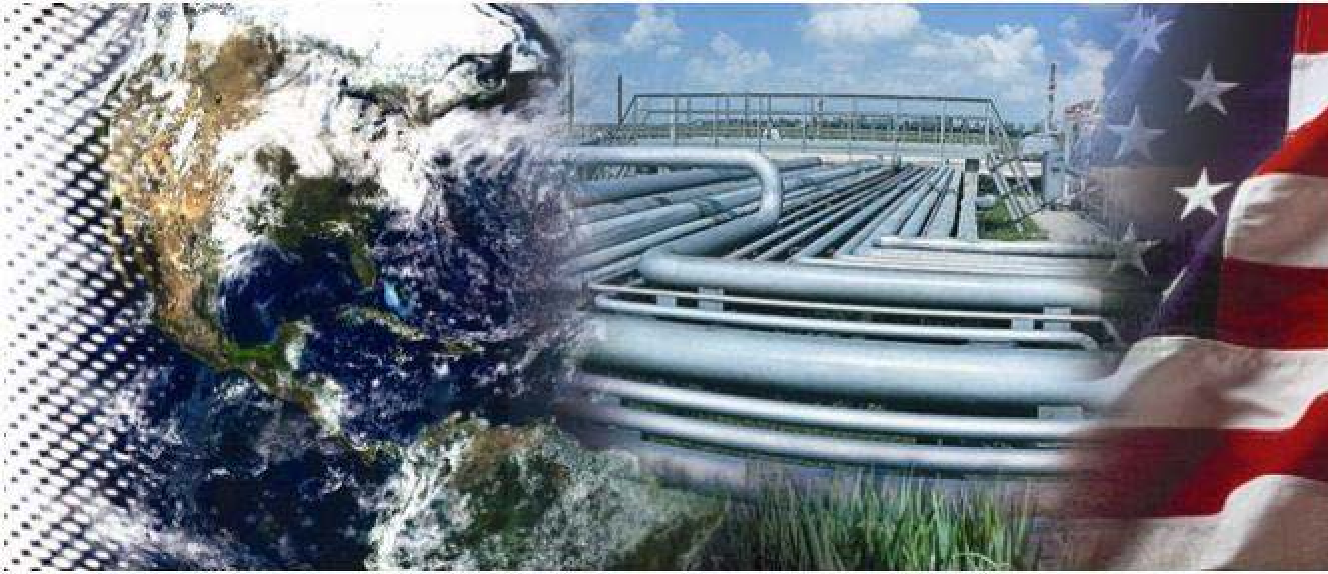
NATIONAL ENERGY TECHNOLOGY LABORATORY



Unconventional Natural Gas: An LCA With a Conventional Answer

James Littlefield – Booz Allen Hamilton

Joe Marriott, PhD. – Booz Allen Hamilton

Timothy J. Skone, P.E. – National Energy Technology Laboratory

2012 University Turbine Systems Research Workshop
October 3, 2012

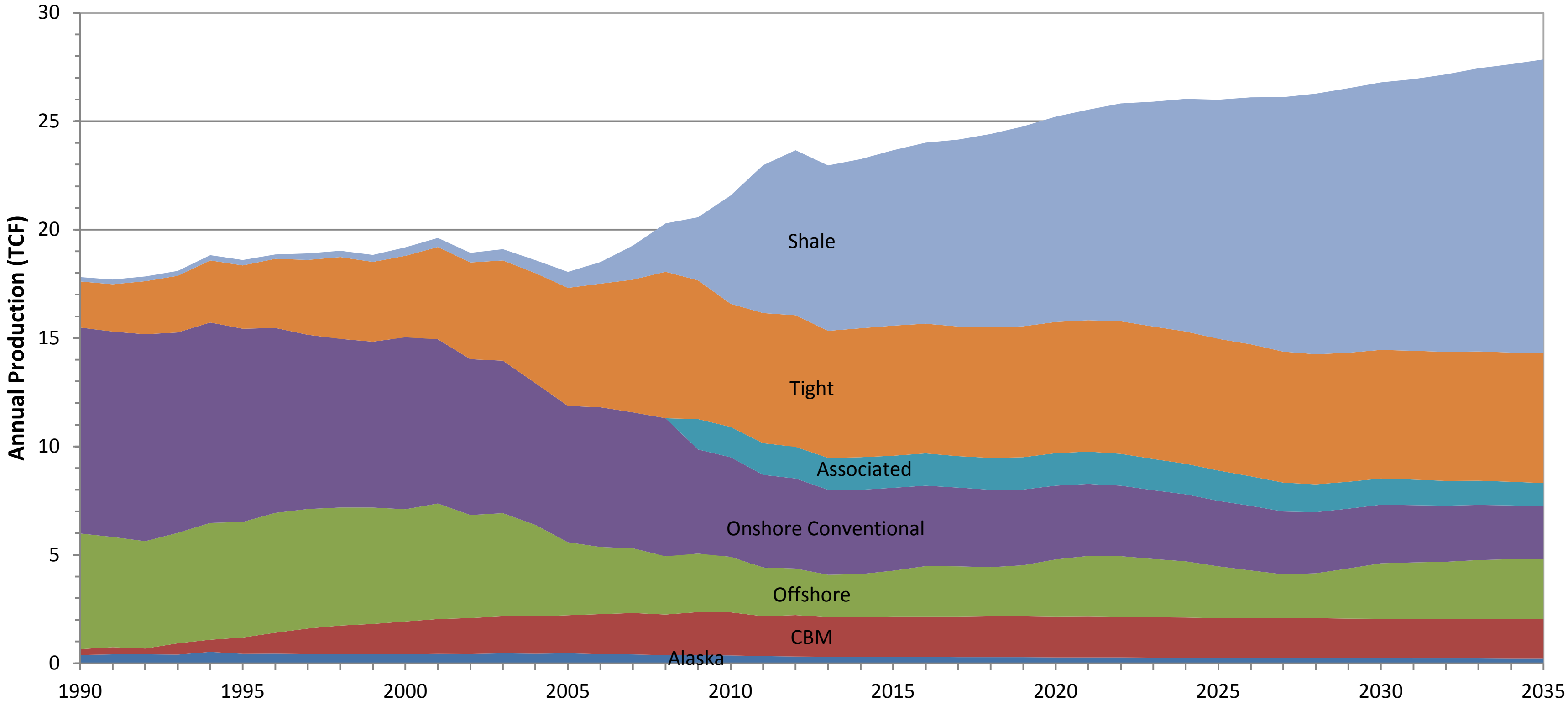
U.S. DEPARTMENT OF ENERGY

Agenda

- Resource Profile of Natural Gas
- Life Cycle Analysis (LCA)
- NETL's LCA of Natural Gas
- Role of Policy and Voluntary Actions
- Role of Power Plants

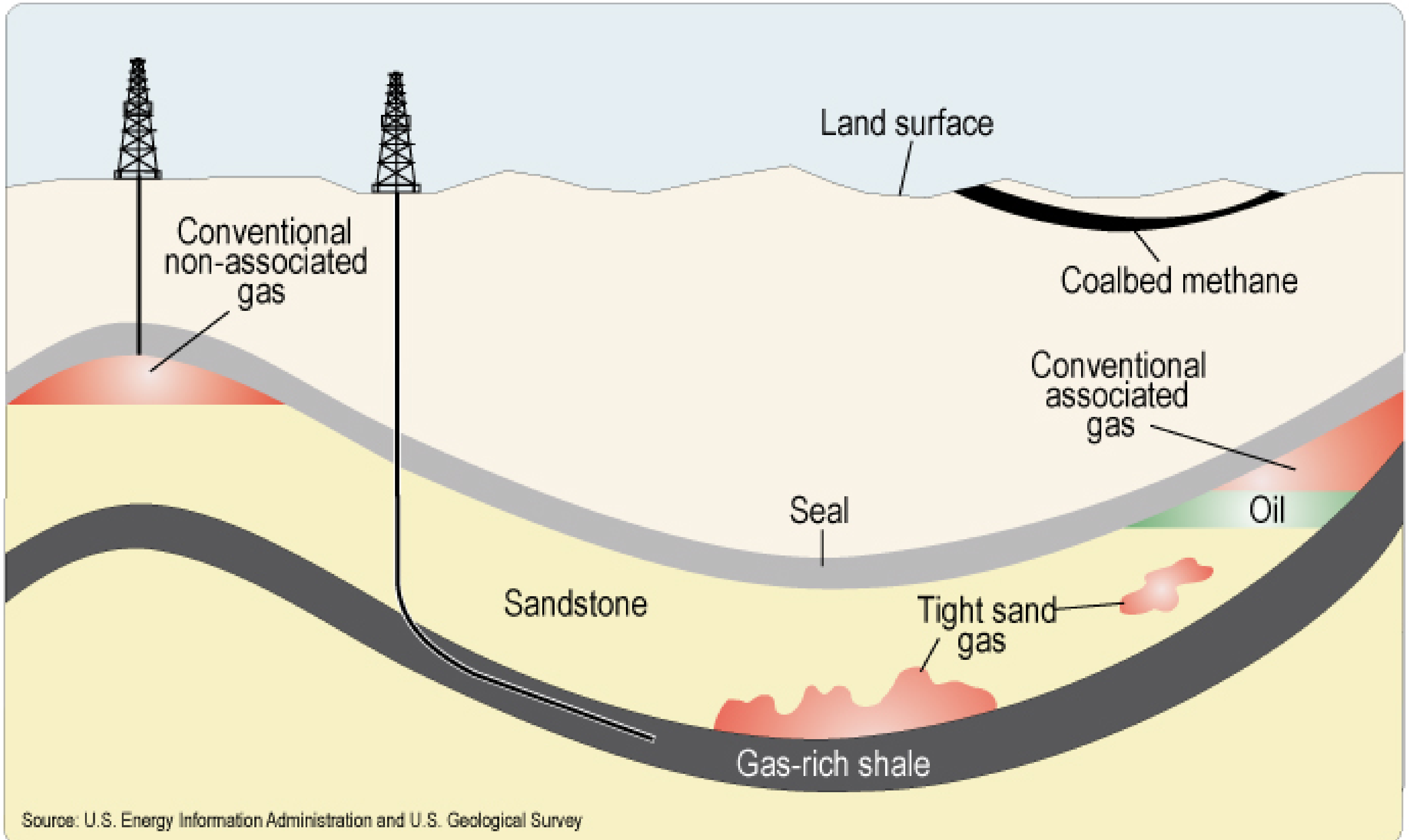
In what ways is the resource profile of domestic natural gas changing?

Unconventional sources of natural gas are changing the resource profile of natural gas production



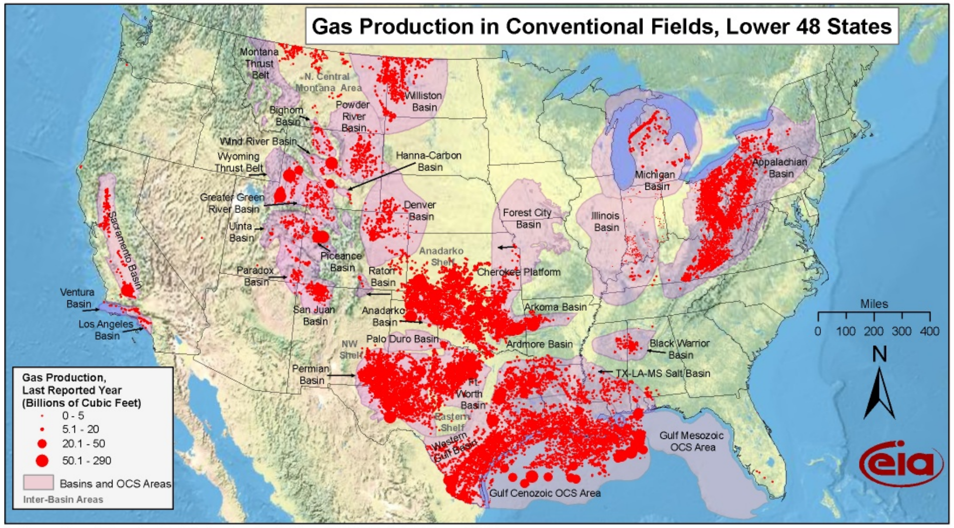
- Total U.S. demand for natural gas was 24.1 Tcf in 2010 and is projected to grow to 26.5 Tcf by 2035 (EIA, 2012a)
- Unconventional sources of natural gas are a growing share of U.S. production

Natural gas is extracted from several types of geological formations

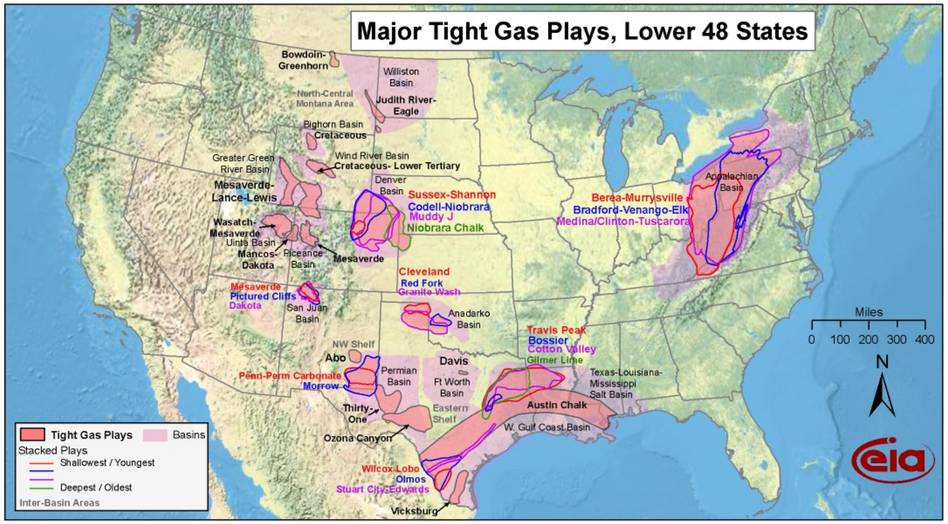


Source: EIA, Today in Energy, February 14, 2011; Modified USGS Figure from Fact Sheet 0113-01; www.eia.doe.gov/todayinenergy/detail.cfm?id=110 Last Accessed May 5, 2011.

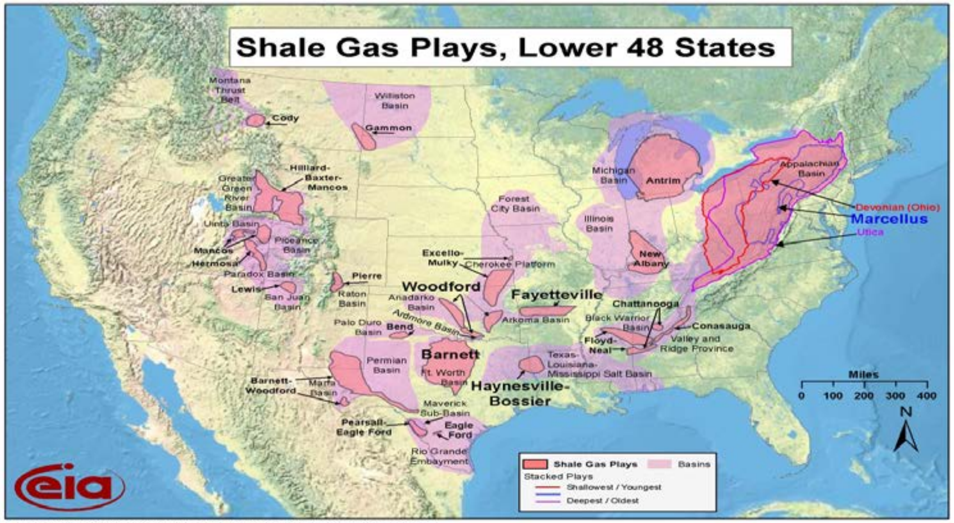
Natural gas extraction locations are also changing



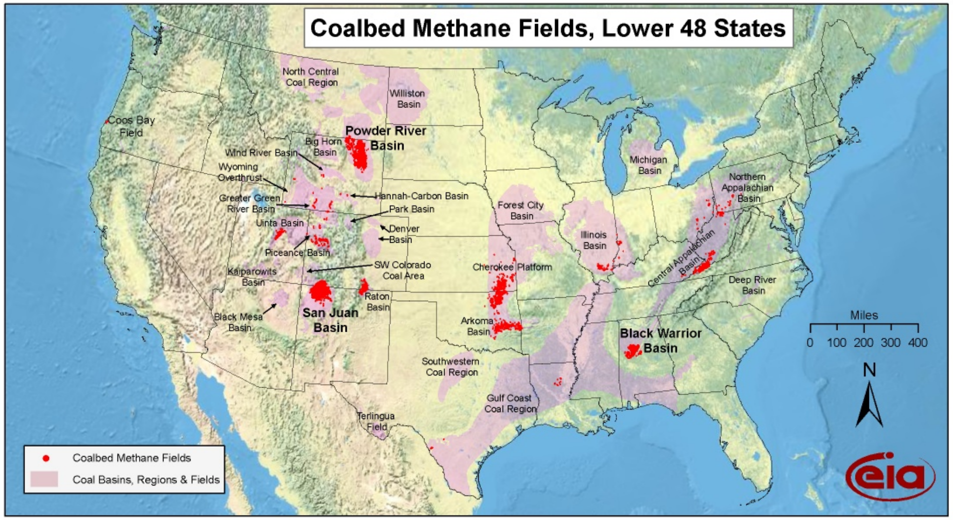
Source: Energy Information Administration based on data from HPDI, IN Geological Survey, USGS
Updated: April 8, 2009



Source: Energy Information Administration based on data from various published studies
Updated: June 6, 2010



Source: Energy Information Administration based on data from various published studies.
Updated: March 10, 2010



Source: Energy Information Administration based on data from USGS and various published studies
Updated: April 8, 2009

Source: EIA, Natural Gas Maps, http://www.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/maps/maps.htm Last Accessed May 5, 2011.

What is LCA?

LCA Defined

- **Compilation and evaluation of inputs, outputs, and potential environmental impacts of a product or service throughout its life cycle, from raw material acquisition to final disposal**
- **Used to identify hot spots or opportunities for improving environmental performance of products or systems**
- **NETL uses LCA to inform policy**

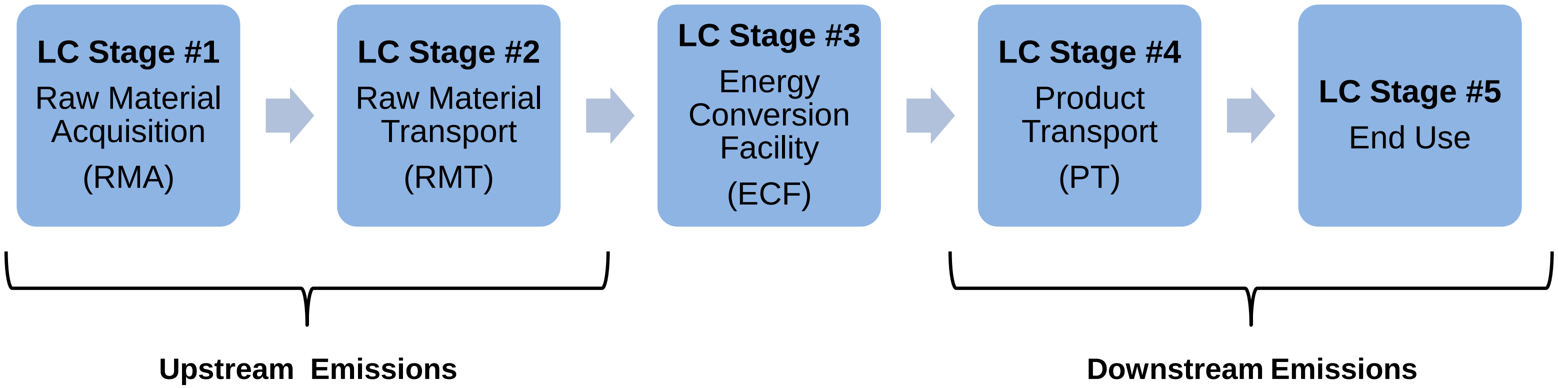
NETL uses a comprehensive set of life cycle metrics

- **Greenhouse Gases**
  - CO_2, CH_4, N_2O, SF_6
- **Criteria Air Pollutants**
  - NO_X, SO_X, CO, PM10, Pb
- **Air Emissions Species of Interest**
  - Hg, NH_3, radionuclides
- **Solid Waste**
- **Raw Materials**
  - Energy Return on Investment
- **Water Use**
  - Withdrawn water, consumption, water returned to source
  - Water Quality
- **Land Use**
  - Acres transformed, greenhouse gases

Converted to Global Warming Potential using IPCC 2007 100-year CO_2 equivalents

CO_2 = 1
CH_4 = 25
N_2O = 298
SF_6 = 22,800

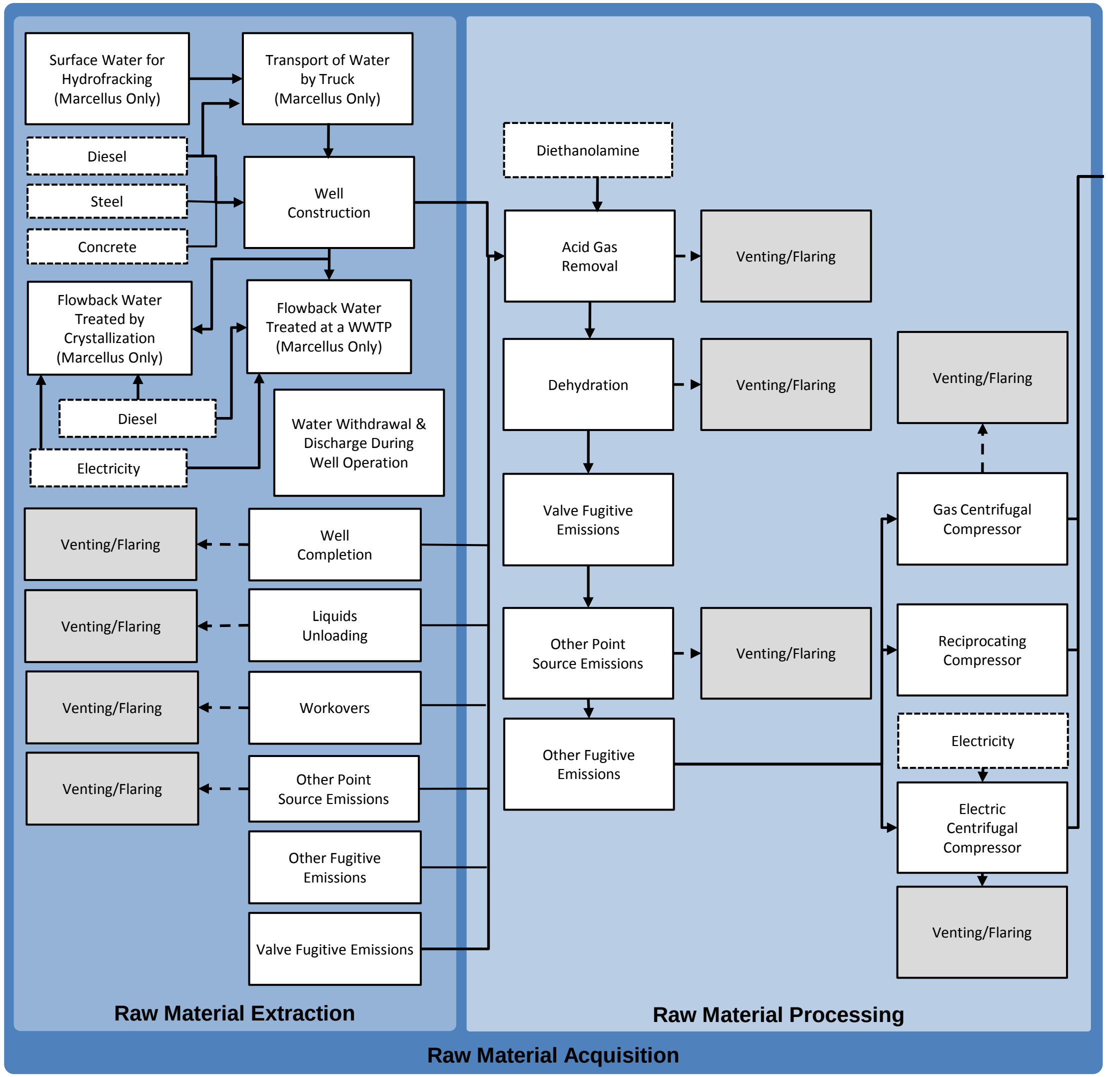
NETL has also defined life cycle stages for energy systems



- **The ability to compare different technologies depends on the functional unit (denominator)**
  - Power LCAs: 1 MWh of electricity delivered to the end user
  - Fuel LCAs: 1 MJ of delivered fuel

How does NETL's LCA model of natural gas work and what does it tell us?

NETL has developed a detailed LCA model that allows modeling of all types of natural gas sources

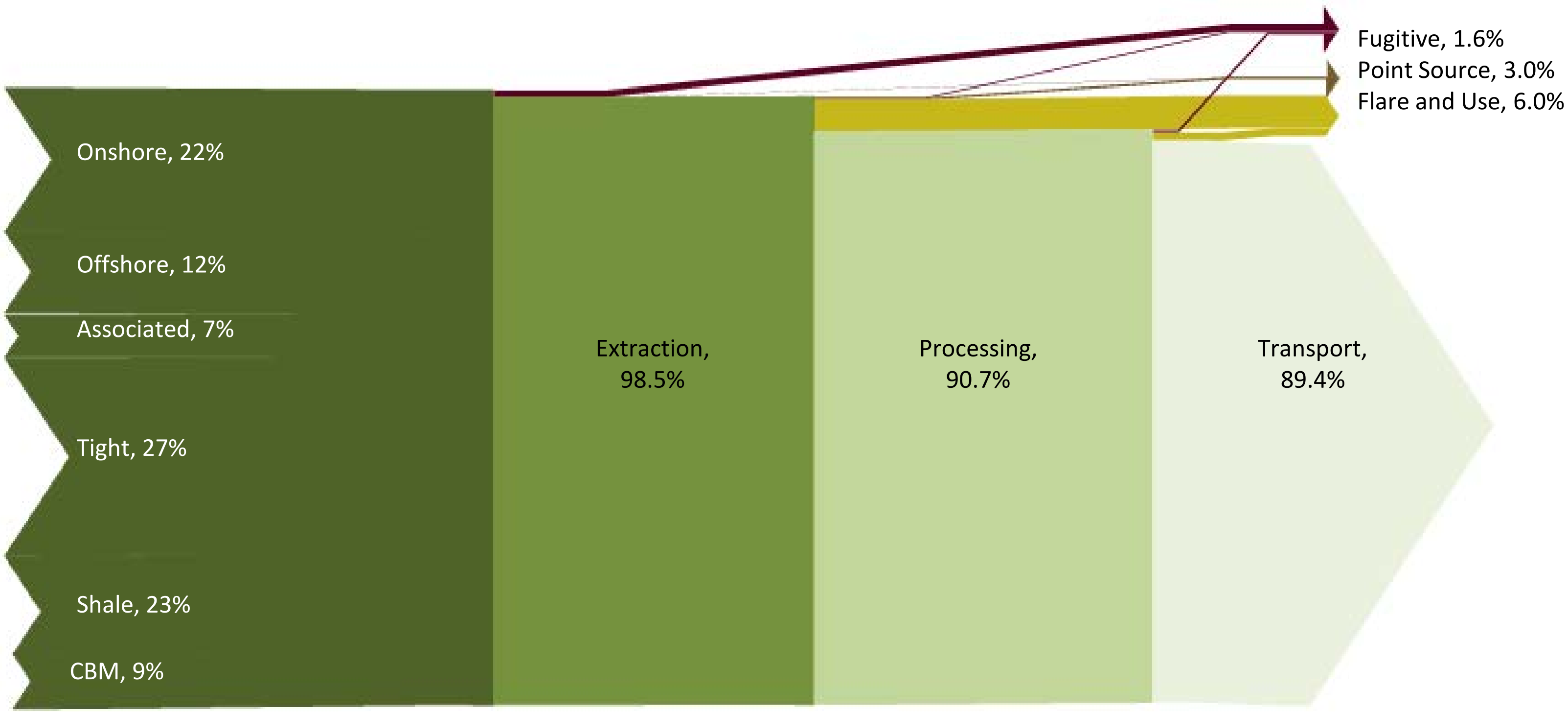


A detailed list of parameters allows modeling of natural gas from various extraction sources

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			3,670	9,175	9,175	49.6
Well Workover (Mcf natural gas/episode)		3.1			3,670	9,175	9,175	49.6
Lifetime Well Workovers (Episodes/well)		1.1			3.5			
Liquids Unloading (Mcf natural gas/episode)		23.5	n/a	23.5	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			

- 3 types of episodic emissions: completion, workover, liquids unloading
- Routine emissions include valve emissions, other fugitives, and other point sources
- Valve emissions & other fugitives are not recoverable; other point sources are recovered and flared
- NETL's model uses a similar parameterization approach for other stages, including gas processing and transport

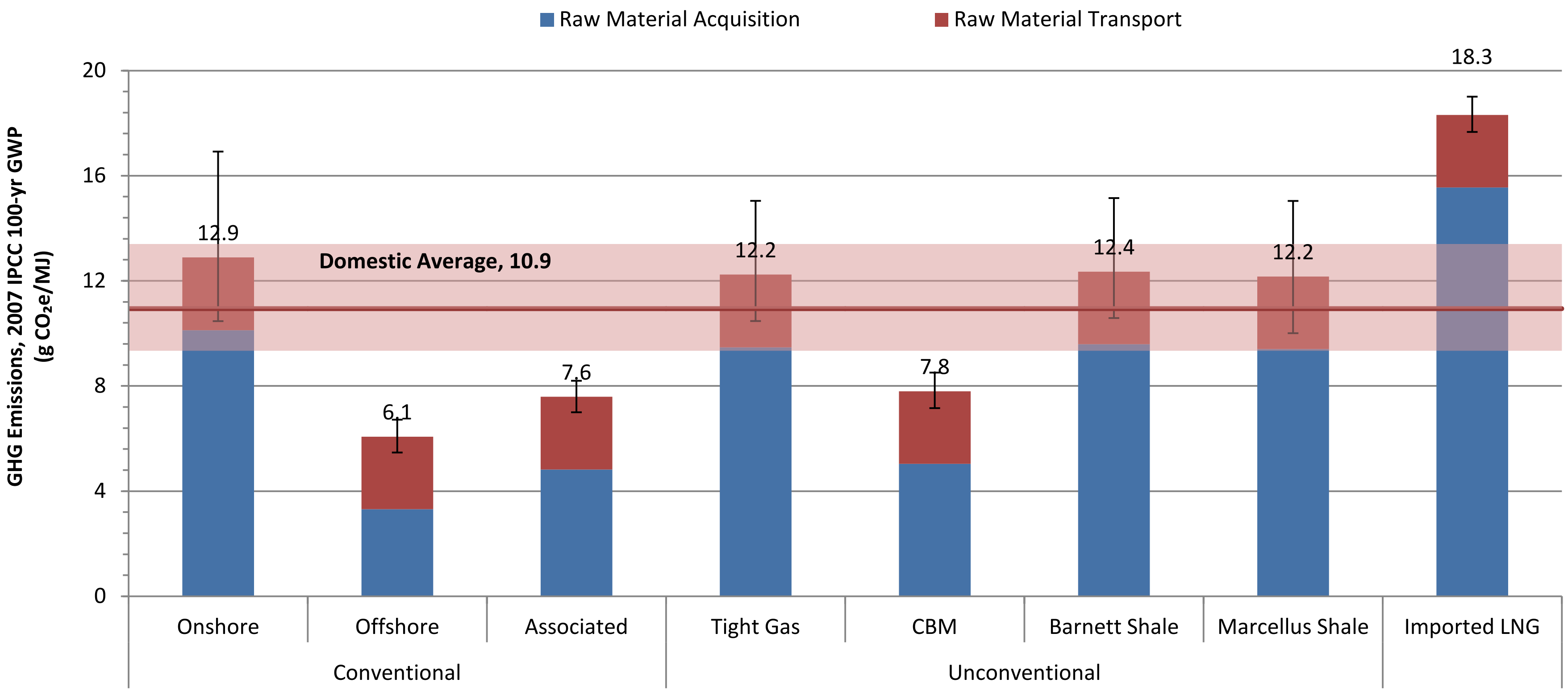
89% of natural gas extracted from the ground is delivered to the power plant or city gate



Of the 11% reduction:

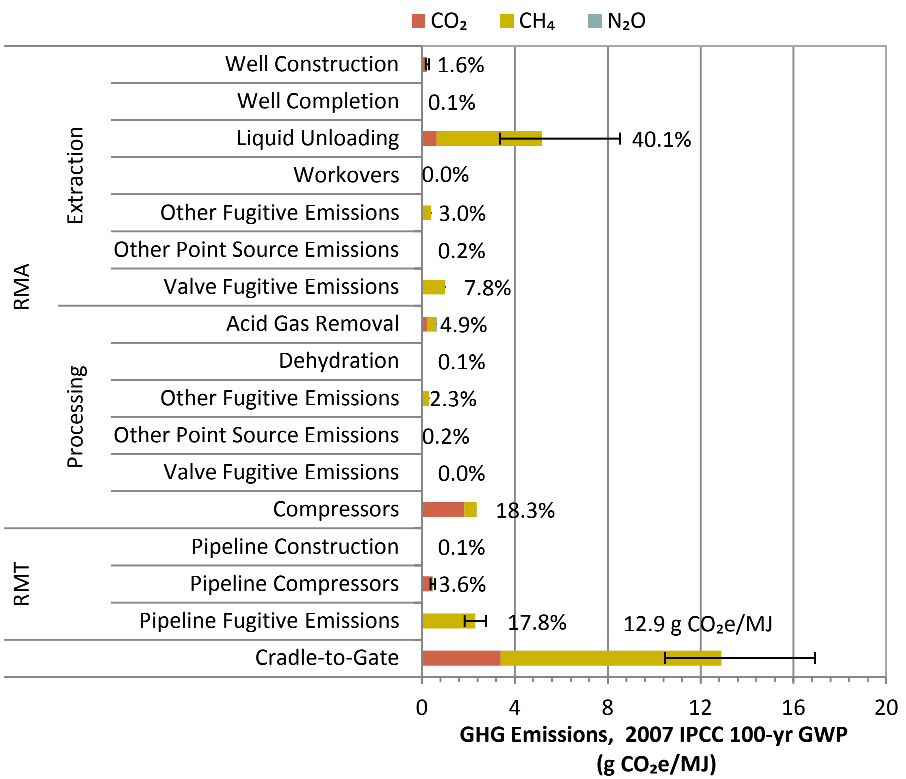
- 57% is used to power various processing and transport equipment
- 28% is point source emissions that can be captured and flared
- 15% is fugitive emissions (spatially separated emissions difficult to capture or control)

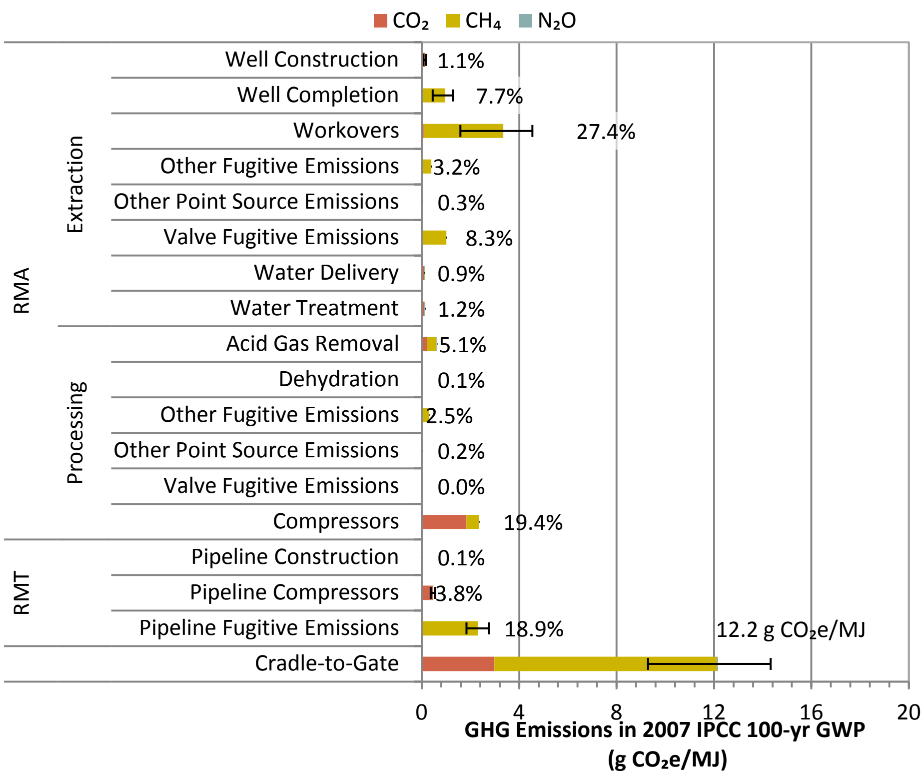
GHG results show variability among natural gas types



- Variability driven by differences in production rates and episodic emission factors
- Offshore natural gas has lowest GHGs of any source; it has a high production rate and offshore wells are motivated to control methane emissions for safety and risk-mitigation reasons
- Imported gas (LNG) has highest GHG emissions; liquefaction and regasification is energy intensive

Drilling down into the results shows the activities that contribute the most to the upstream GHG profiles

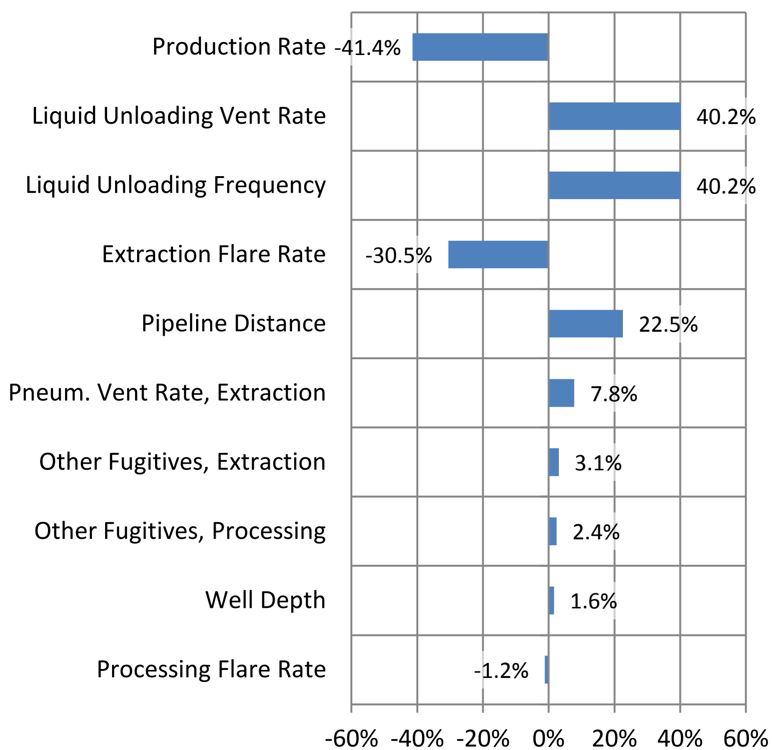




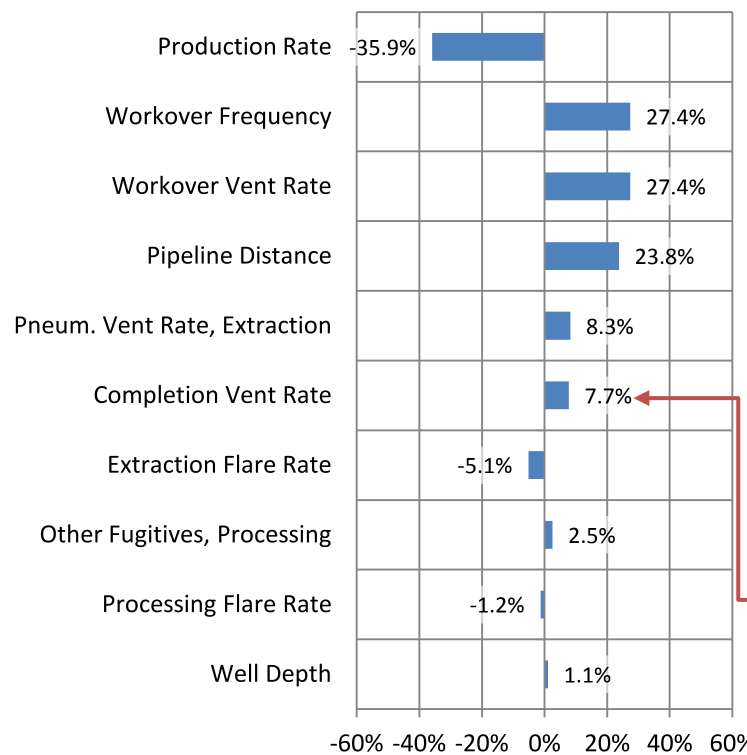
- Liquid unloading is a key episodic emission for onshore conventional natural gas; completion and workovers are key episodic emissions for unconventional natural gas
- Compressors (processing and pipeline) are a significant source of CO_2
- Hydrofracking water delivery and treatment is 2.1% of upstream GHG from Marcellus Shale natural gas

Production rate is the top driver of GHG sensitivity, followed by episodic emissions and pipeline distance

Onshore Natural Gas Extraction and Transport



Marcellus Shale Natural Gas Extraction and Transport



These graphs show all sensitivities relative to a 100% increase in the input parameter.

A positive percent change indicates a direct relationship.

A negative percent change indicates an inverse relationship.

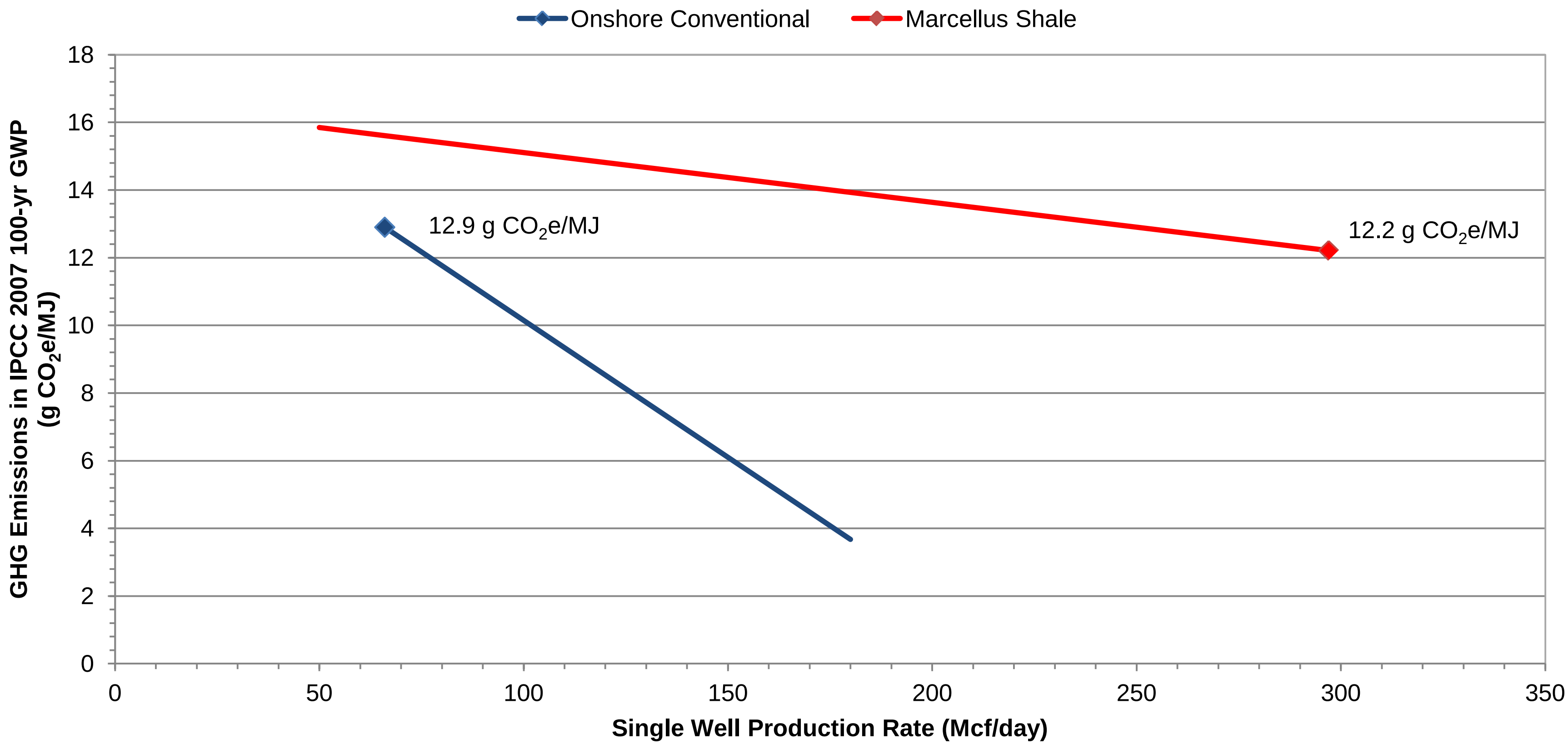
For example, a 100% increase in completion vent rate causes a 7.7% increase in upstream GHG emissions for Marcellus Shale natural gas.

- Production rate is a key factor in apportionment of environmental burdens
- Emission factors for episodic emissions are a greater driver of GHG emissions than emission factors for routine operations
- Market forces may prevent a reduction in average pipeline distances, but it is possible to reduce pipeline emissions

Production rates for onshore conventional wells are variable, while Marcellus performance is uncertain

- **What's a typical well for onshore conv. production?**
  - 479,000 conventional onshore wells in the U.S.
  - With respect to *well count*, the average well produces 70 Mcf/day
  - With respect to contribution to *total production*, the average well produces ~500 Mcf/day
- **There's no historical data for Marcellus production**
  - Current data support estimated ultimate recoveries of 3.2 BCF/well life
  - Recent USGS data suggest that ultimate recoveries could be closer to 2.0 BCF/well life

All natural gas types show an inverse relationship between production rate and upstream GHG emissions

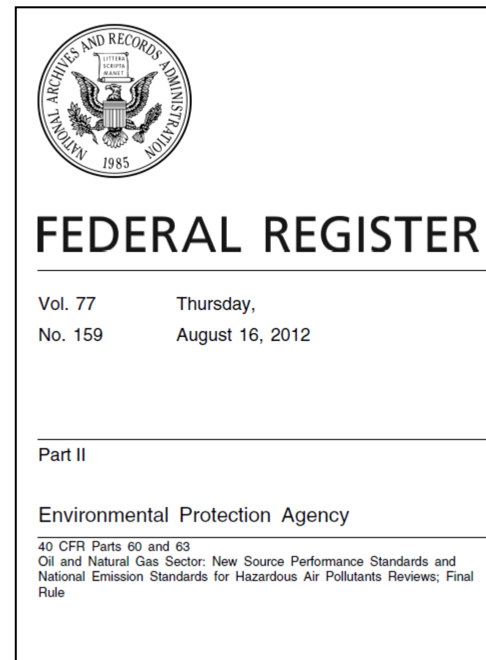


- The retirement of older wells will improve the overall GHG profile of conventional onshore natural gas
- Lower-than-expected production from Marcellus Shale will increase the GHG profile of Marcellus Shale natural gas

How will new regulations and voluntary emission reductions change the environmental profile of natural gas?

EPA New Source Performance Standards (NSPS) regulate VOC emissions from the oil and gas sector

- **Final NSPS rule established August 16, 2012**
- **Methane is key VOC from natural gas extraction and processing**
- **NSPS regulates emissions from:**
  - Well completions and workovers
  - Centrifugal compressors
  - Reciprocating compressors
  - Storage tanks
  - Pneumatic controllers
- **NSPS does not regulate emissions from:**
  - Liquid unloading from conventional wells
  - Compressors used for pipeline transmission


FEDERAL REGISTER

Vol. 77 Thursday,
No. 159 August 16, 2012

Part II

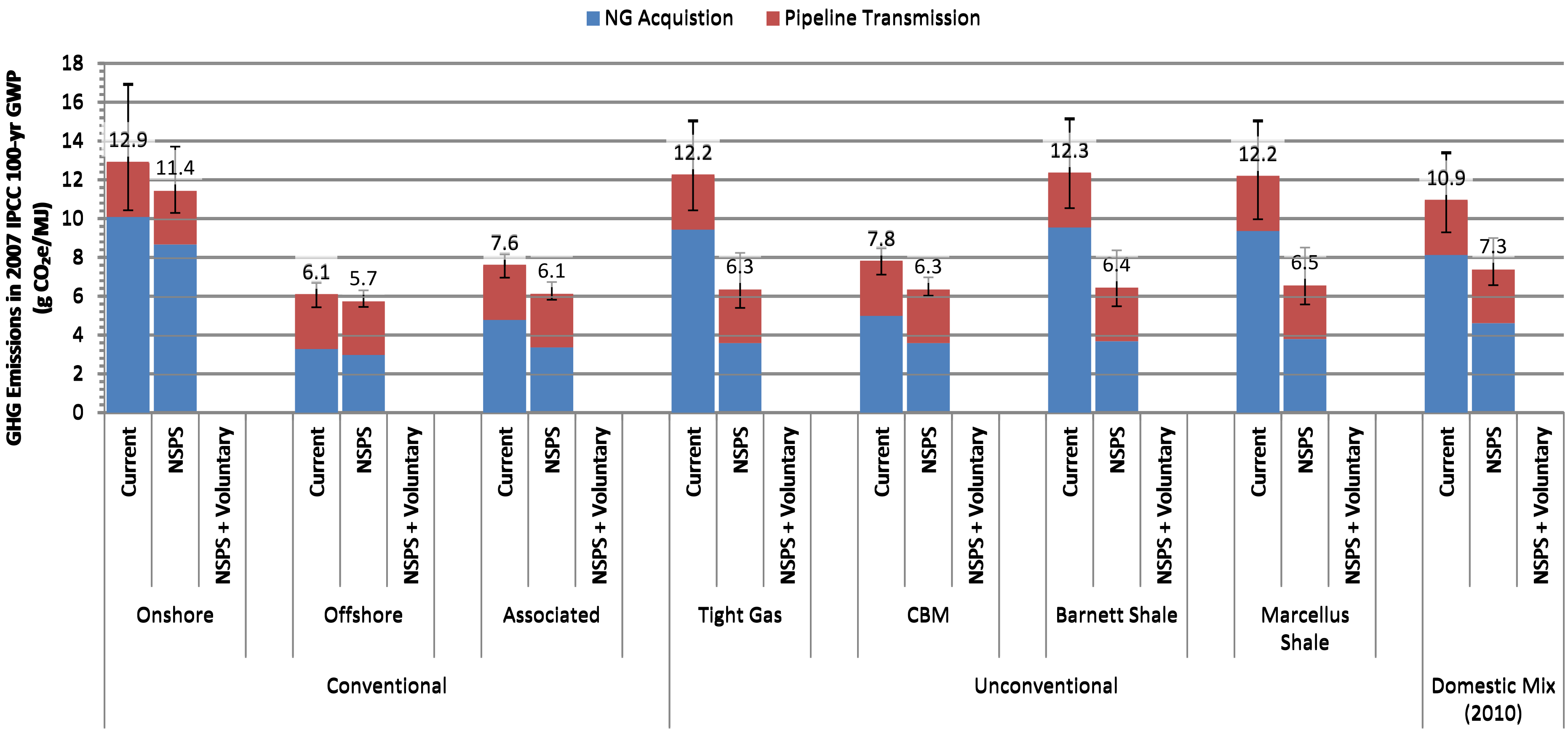
Environmental Protection Agency

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

NETL's parameterized modeling approach can estimate the GHG changes caused by NSPS

- **Reduced emission completions (RECs) for unconventional wells**
  - Can reduce unconventional completion emissions by 95% (NSPS, 2012)
  - New completion and workover emission factor = 9,175*(100% - 95%)
    = 459 Mcf natural gas/episode
  - A higher extraction flaring rate is also expected for RECs, so increase unconventional flaring rate from 15% to 51%
- **Replacement of compressor wet seals with dry seals**
  - Can reduce centrifugal compressor CH_4 emissions 95% (NSPS, 2012)
  - New emission factor for centrifugal compressors (at processing site)
    = 0.0069 kg CH_4/kg natural gas compressed * (100% - 95%)
    = 0.00035 kg CH_4/kg natural gas compressed
- **Routine replacement of compressor rod packings**
  - Can reduce reciprocating compressor CH_4 emissions 95% (NSPS, 2012)
  - New emission factor for reciprocating compressors (at processing site)
    = 0.0306 kg CH_4/kg natural gas combusted * (100% - 95%)
    = 0.00153 kg CH_4/kg natural gas combusted
- **Replacement of pneumatic controllers**
  - High bleed controllers have leak rates of 6 - 42 scf/hr (EPA, 2006b)
  - Low bleed controllers have leak rates less than 6 scf/hr and are used by offshore gas wells (EPA, 2006b)
  - New emission factor for onshore conventional and unconventional valves = existing emission factor for offshore valves = 0.0001 lb CH_4/Mcf

NSPS can reduce emissions from all natural gas sources, but brings greatest improvements to unconventional sources



- NSPS reduces GHG emissions of the domestic mix by 33 percent
- Greatest reductions are driven by reduced emission completions (RECs)
- NSPS overlooks the opportunity for liquid unloading emission reductions and does not address pipeline emissions

Some important emission sources are not addressed by NSPS or are outside the scope of NSPS

- **NSPS does not propose reductions in emission factors for liquids unloading from conventional wells**
  - New options for liquid unloading can reduce NG emissions at least 500 Mcf/yr per well (EPA, 2011b)
  - New liquid unloading emission factor

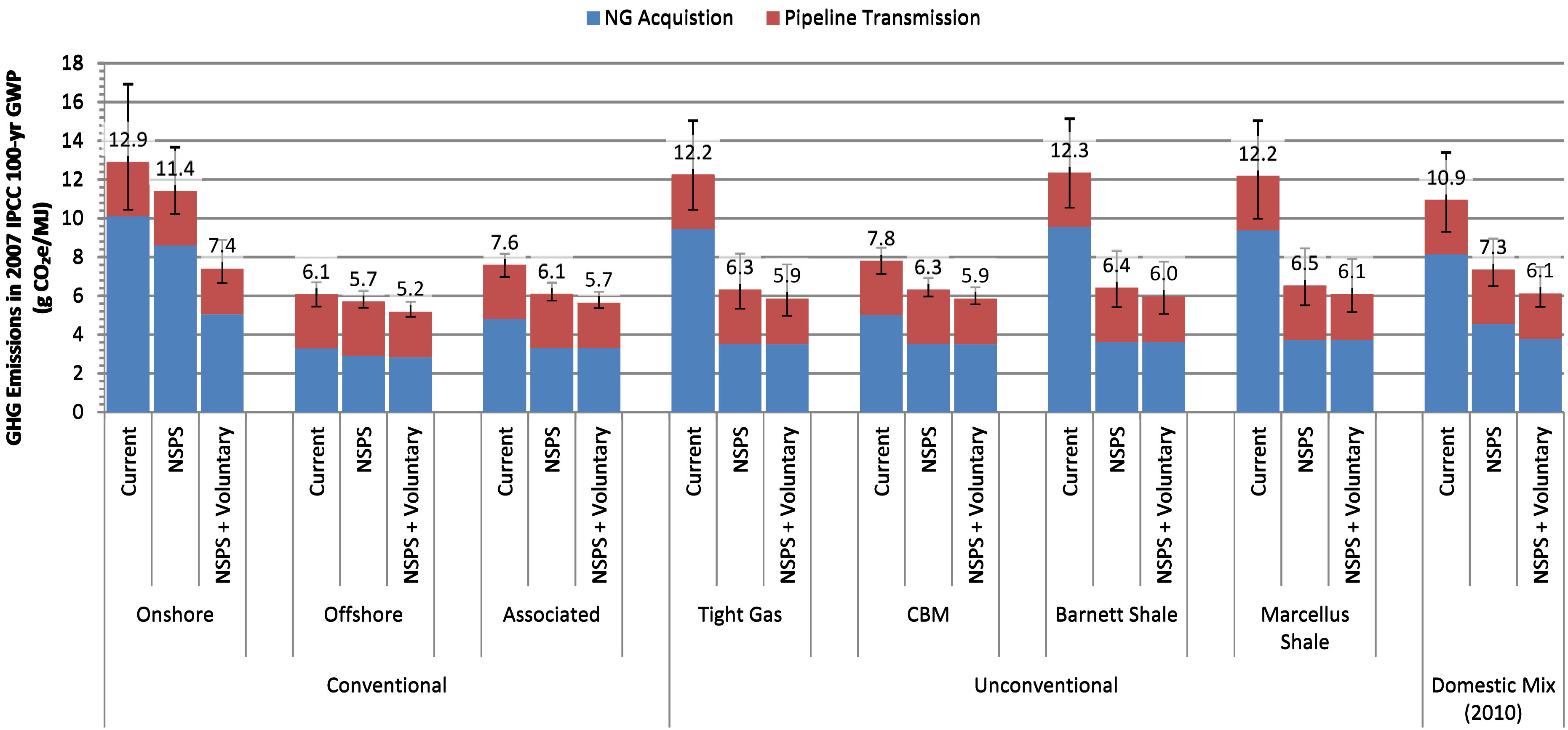
    = 23.5 Mcf/episode - (500 Mcf/yr)/(31 episodes/yr)

    = 7.4 Mcf natural gas/episode
- **NSPS boundaries stop after the gas processing plant and do not include natural gas pipeline transmission**
  - Natural gas transmission pipelines could replace centrifugal compressor wet seals with dry seals
  - Centrifugal compressors are 19 percent of transmission pipeline compressors
  - New pipeline emission factor

    = 5.37E-06 kg CH_4/kg-km * ((100% - 95%) * 19% + 81%)

    = 4.40E-06 kg CH_4/kg-km

Voluntary emission reductions, in addition to NSPS regulations, could further reduce upstream emissions



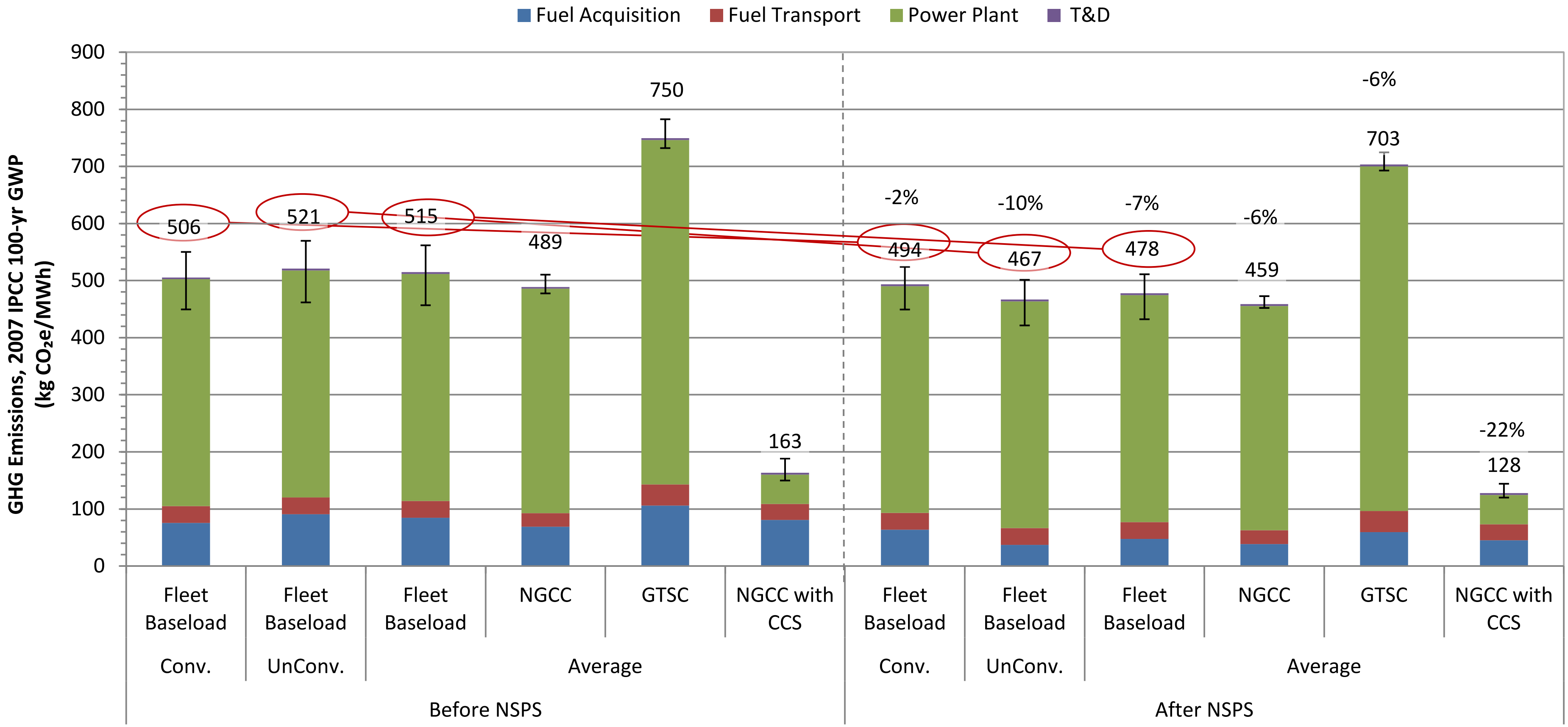
- Voluntary actions lead to an additional 16% reduction in the upstream GHG emissions of domestic natural gas (from 7.3 to 6.1 CO_2e/MJ)
- Total GHG emission reductions from NSPS and voluntary action are 43% (from 10.9 to 6.1 CO_2e/MJ)

Conclusions

- LCA is a valuable tool for identifying opportunities for improvement in a supply chain
- Methane emissions from natural gas acquisition and delivery can be reduced with existing, cost-effective technologies
- Greatest opportunities for upstream GHG emission reductions are the development of productive wells, capture of episodic emissions, and prevention of pipeline emissions
- Some emission reductions will be achieved through regulations, while others will be voluntary
- If new wells are not developed and methane capture technologies are not implemented, the average GHG profile of natural gas will increase

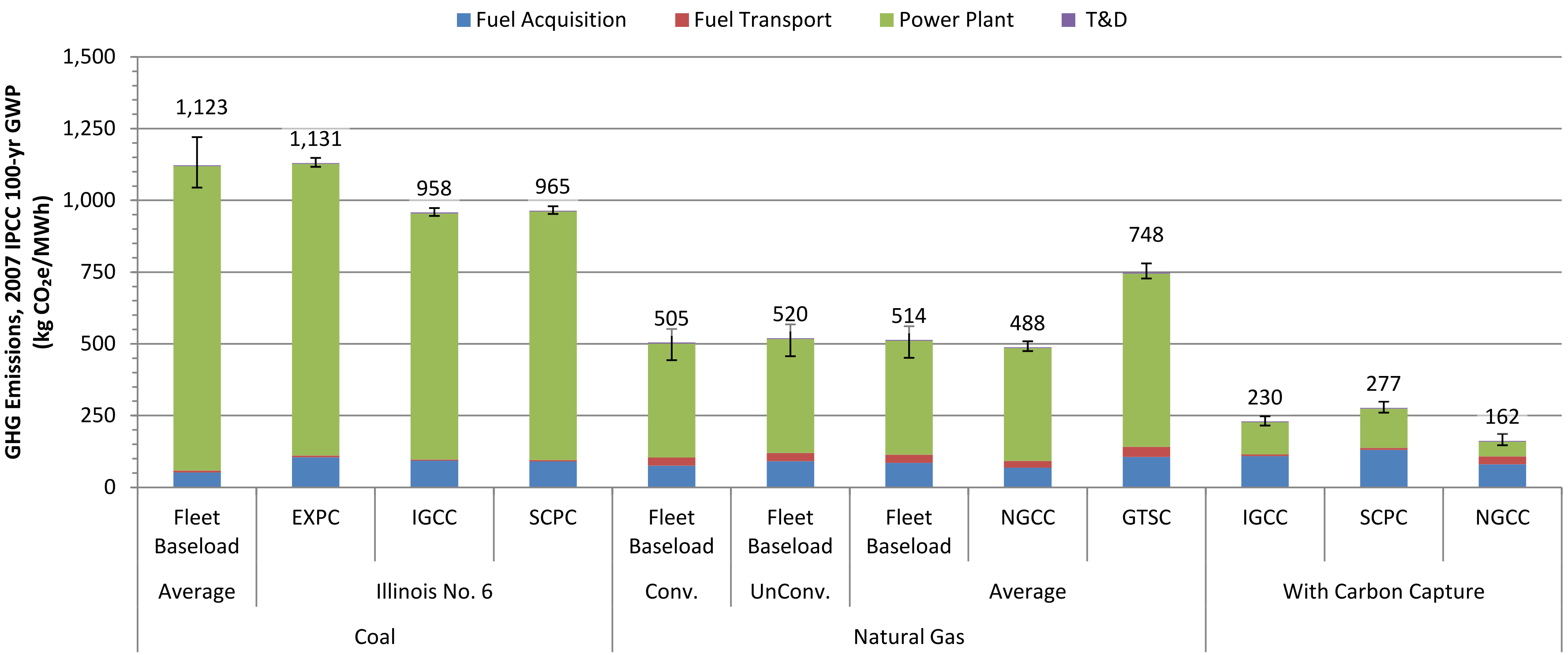
What about the rest of the life cycle?

There are opportunities for improving the upstream profile of natural gas, but combustion dominates the GHG profile



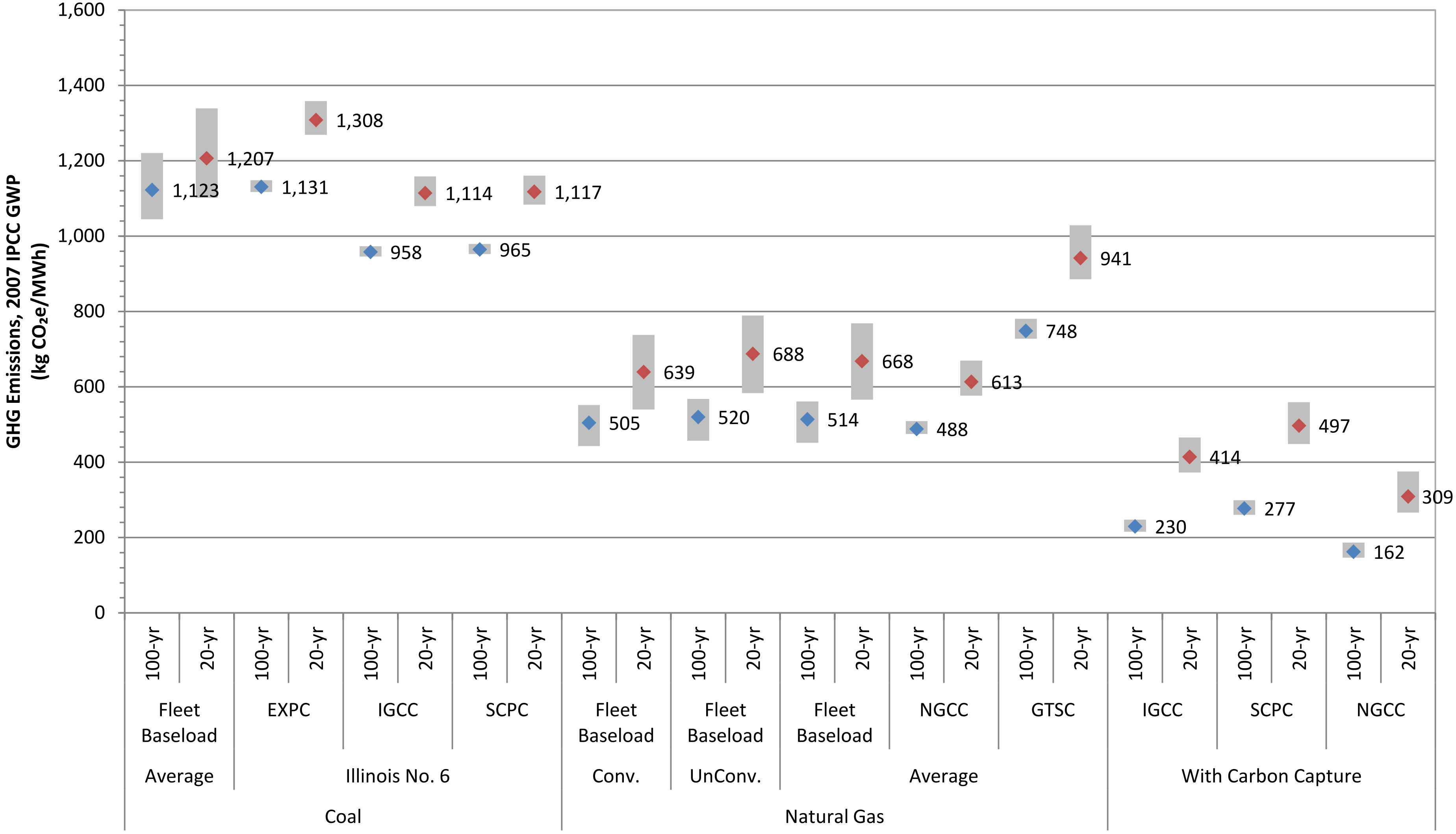
- **NSPS reductions to fleet baseload power:**
  - 12 kg CO_2e/MWh when using conventional natural gas (2% reduction)
  - 54 kg CO_2e/MWh when using unconventional natural gas (10% reduction)
  - 37 kg CO_2e/MWh when using domestic mix of natural gas (7% reduction)

On a life cycle basis for electricity, the power plant generates more GHG emissions than fuel acquisition and transport



- On a 100-yr IPCC GWP basis, natural gas power has a lower impact than coal power
- Because of their similar roles, the fairest comparison is the domestic mix of coal through an average baseload coal power plant vs. the domestic mix of natural gas run through an average baseload natural gas plant (1,123 vs. 514 kg CO_2e/MWh)
- Fuel acquisition and transport is 22% of life cycle GHG emissions from average NG fleet baseload – it is only 5.2% of life cycle GHG emissions from average coal fleet baseload

GHG results are more sensitive for natural gas than for coal when changing from 100- to 20-year GWPs



Bottom Line: Combustion Emissions Still Matter Most

- **Upstream emission reductions are a near term opportunity, but CO_2 from combustion remains the largest contributor to the GHG emissions from natural gas power**
  - Best case regulatory approaches reduce life cycle GHG emissions of baseload natural gas power by only 7%
  - Difficult to improve upon efficiency of combined cycle power plants
  - After upstream GHG reductions have been made, CO_2 capture, utilization and storage (CCUS) will be the next step toward reductions in the life cycle GHGs from natural gas power

References

Baker-Hughes. (2012). North America Rotary Rig Counts: Baker Hughes Incorporated.

Dennis, S. M. (2005). Improved Estimates of Ton-Miles. *Journal of Transportation and Statistics,* Volume 8, Number 1. U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics.

EIA. (2010). United States Distribution of Wells by Production. U.S. Energy Information Administration Retrieved July 19, 2011, from http://www.eia.gov/pub/oil_gas/petrosystem/us_table.html

EIA. (2011). Natural Gas Gross Withdrawals and Production. U.S. Energy Information Administration Retrieved April 5, 2011, from http://www.eia.doe.gov/dnav/ng/ng_prod_sum_a_EPG0_VRN_mmcf_a.htm

EIA. (2012a). AEO2012 Early Release Overview. (DOE/EIA-0383ER(2012)). Washington, DC: U.S. Energy Information Administration Retrieved April 17, 2012, from http://www.eia.gov/forecasts/aeo/er/early_intensity.cfmEIA. (2011d). Weekly Natural Gas Storage Report: U.S. Department of Energy, Energy Information Administration.

Engelder, T. (2009, August). Marcellus 2008: Report Card on the Breakout Year for Gas Production in the Appalachian Basin. *Fort Worth Basin Oil and Gas Magazine,* 18-22.

EPA. (1995). *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources*. (AP-42). Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards Retrieved May 18, 2010, from http://www.epa.gov/ttnchie1/ap42

EPA. (2006b). *Options for Reducing Methane Emissions from Pneumatic Devices in the Natural Gas Industry.* U.S. Environmental Protection Agency. Washington, D.C. Retrieved August 22, 2012 from http://www.epa.gov/gasstar/documents/ll_pneumatics.pdf

EPA. (2006c). *Convert Gas Pneumatic Controls To Instrument Air.* U.S. Environmental Protection Agency. Washington, D.C. Retrieved August 17, 2012 from http://www.epa.gov/gasstar/documents/ll_instrument_air.pdf

EPA. (2006b). *Convert Gas Pneumatic Controls To Instrument Air.* U.S. Environmental Protection Agency. Washington, D.C. Retrieved August 17, 2012 from http://www.epa.gov/gasstar/documents/ll_instrument_air.pdf

EPA. (2010). Emissions & Generation Resource Integrated Database (eGrid). from United States Environmental Protection Agency http://www.epa.gov/cleanenergy/energy-resources/egrid/

EPA. (2011). *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009*. (EPA 430-R-11-005). Washington, D.C. Environmental Protection Agency, Retrieved August 23, 2011, from http://epa.gov/climatechange/emissions/usinventoryreport.html

EPA. (2011b). *Reduced Emissions Completions for Hydraulically Fractured Natural Gas Wells.* U.S. Environmental Protection Agency. Washington, D.C. Retrieved August 17, 2012 from http://www.epa.gov/gasstar/documents/reduced_emissions_completions.pdf

EPA. (2011c). *Options for Removing Accumulated Fluid and Improving Flow in Gas Wells* . U.S. Environmental Protection Agency. Washington, D.C. Retrieved August 17, 2012 from http://www.epa.gov/gasstar/documents/ll_options.pdf

FERC. (2010). Federal Energy Regulatory Commission: Form 2/2A - Major and Non-major Natural Gas Pipeline Annual Report: Data (Current and Historical) Retrieved August 23, 2011, from http://www.ferc.gov/docs-filing/forms/form-2/data.asp

Hedman, B. (2008). Waste Energy Recovery Opportunities for Interstate Natural Gas Pipelines. Interstate Natural Gas Association of America Retrieved July 25, 2011, from http://www.ingaa.org/File.aspx?id=6210

NETL. (2010a). Cost and Performance Baseline for Fossil Energy Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity (Revision 2 ed.): U.S. Department of Energy, National Energy Technology Laboratory.

Pierce, B., Colman, J., & Demas, A. (2011). USGS Releases New Assessment of Gas Resources in the Marcellus Shale, Appalachian Basin. USGS. Retrieved May 18, 2012, from http://www.usgs.gov/newsroom/article.asp?ID=2893

Contact Information

Office of Fossil Energy

www.fe.doe.gov

NETL

www.netl.doe.gov

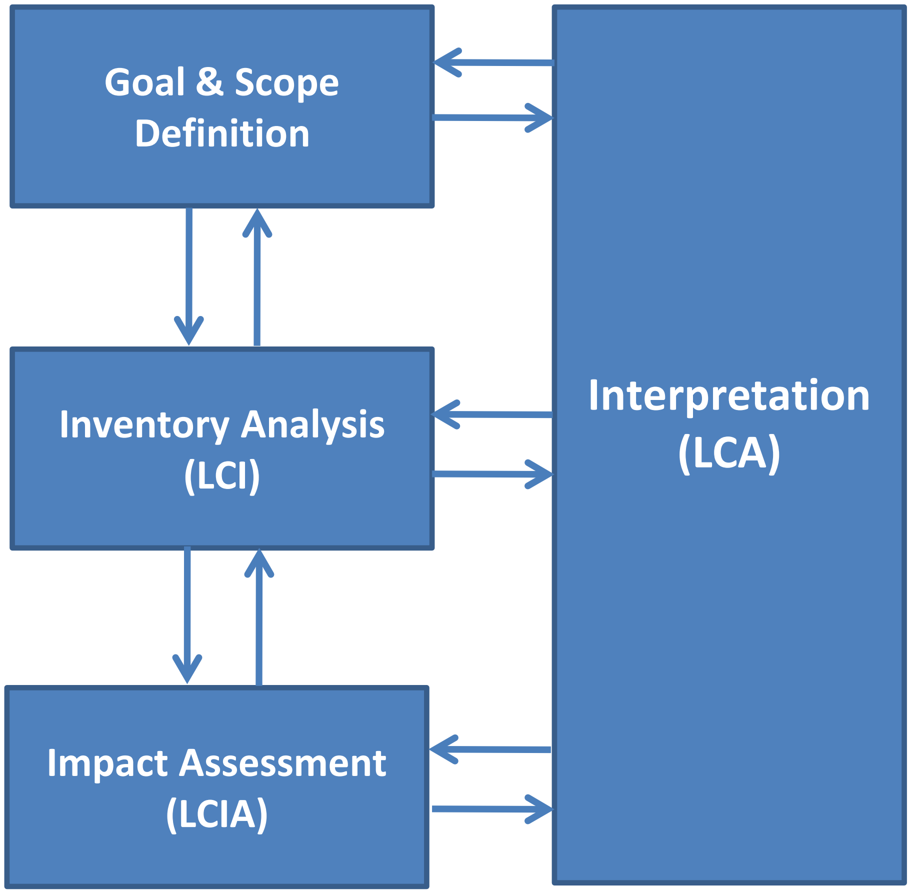
Timothy J. Skone, P.E.
Senior Environmental Engineer
Office of Strategic Energy Analysis and Planning
(412) 386-4495
timothy.skone@netl.doe.gov

Robert James, Ph.D.
General Engineer
Office of Strategic Energy Analysis and Planning
(304) 285-4309
robert.james@netl.doe.gov

Joe Marriott, Ph.D.
Lead Associate
Booz Allen Hamilton
(412) 386-7557
joseph.marriott@contr.netl.doe.gov

James Littlefield
Associate
Booz Allen Hamilton
(412) 386-7560
james.littlefield@contr.netl.doe.gov

Supporting Material: Life Cycle Analysis Approach

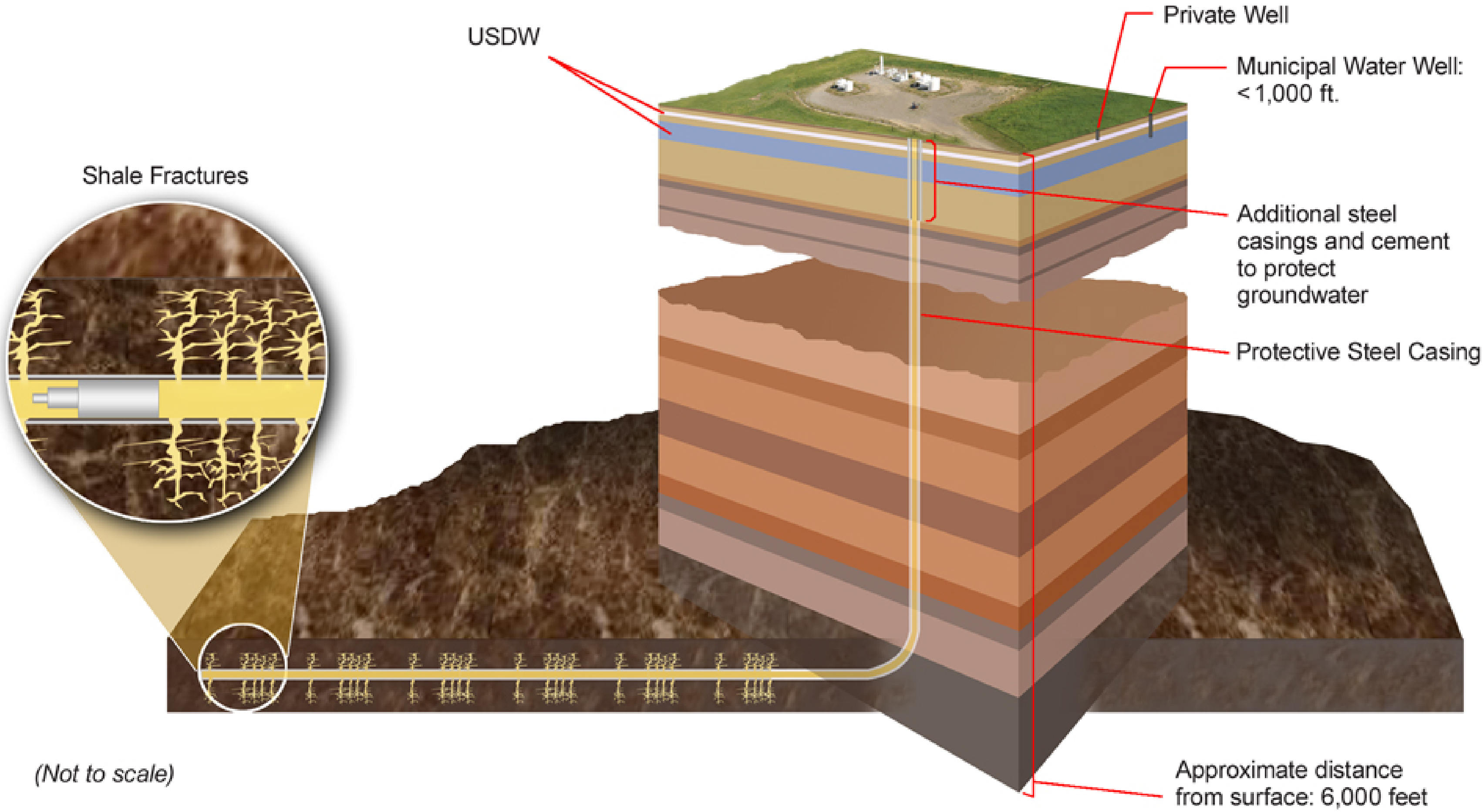


Source: ISO 14040:2006, Figure 1 – Stages of an LCA (reproduced)

International Organization for Standardization (ISO) for LCA

- ISO 14040:2006 Environmental Management – Life Cycle Assessment – Principles and Framework
- ISO 14044 Environmental Management – Life Cycle Assessment – Requirements and Guidelines
- ISO/TR 14047:2003 Environmental Management – Life Cycle Impact Assessment – Examples of Applications of ISO 14042
- ISO/TS 14048:2002 Environmental Management – Life Cycle Assessment – Data Documentation Format

A Deeper Look at Unconventional Natural Gas Extraction via Horizontal Well, Hydraulic Fracturing (*the Barnett Shale Model*)



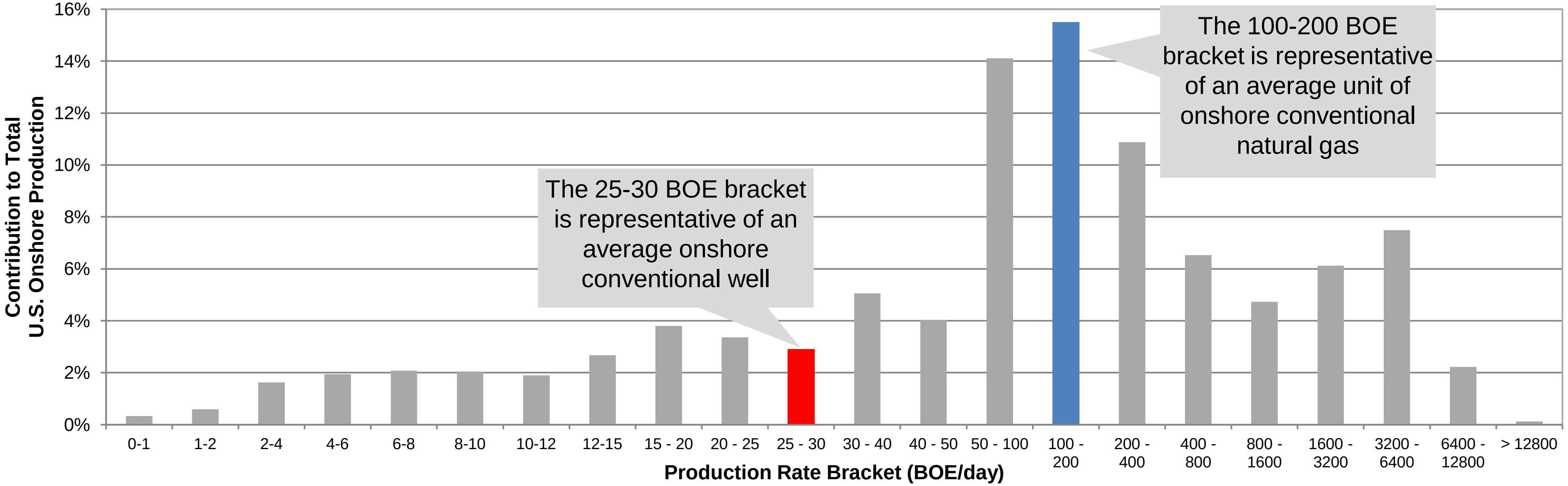
Source: NETL, *Shale Gas: Applying Technology to Solve America's Energy Challenge*, January 2011

Supporting Material: NETL's model also parameterizes NG processing

Property (Units)	Onshore	Associated	Offshore	Tight Gas	Barnett Shale	Marcellus Shale	CBM
Acid Gas Removal (AGR) and CO_2 Removal Unit							
Flaring Rate (%)	100%						
CH_4 Absorbed (lb CH_4/Mcf natural gas)	0.04						
CO_2 Absorbed (lb CO_2/Mcf natural gas)	0.56						
H_2S Absorbed (lb H_2S/Mcf natural gas)	0.21						
NMVOC Absorbed (lb NMVOC/Mcf natural gas)	6.59						
Glycol Dehydrator Unit							
Flaring Rate (%)	100%						
Water Removed (lb H_2O/Mcf natural gas)	0.045						
CH_4 Emission Rate (lb CH_4/Mcf natural gas)	0.0003						
Valves & Other Sources of Emissions							
Flaring Rate (%)	100%						
Valve Emissions, Fugitive (lb CH_4/Mcf natural gas)	0.0003						
Other Sources, Point Source (lb CH_4/Mcf natural gas)	0.02						
Other Sources, Fugitive (lb CH_4/Mcf natural gas)	0.03						
Natural Gas Compression at Gas Plant							
Compressor, Gas-powered Reciprocating (%)	100%	100%		100%	75%	100%	100%
Compressor, Gas-powered Centrifugal (%)			100%				
Compressor, Electrical, Centrifugal (%)					25%		

- Unit processes for acid gas removal, dehydration, and other emissions are parameterized with respect to gas properties, but current data do no allow differentiation among natural gas sources
- Co-product allocation is used to account for the two products (natural gas and NMVOC) of acid gas removal
- Offshore platforms require centrifugal compressors, but reciprocating compressors are most likely technology for other sources of natural gas
- Barnett shale uses electrically-powered, centrifugal compressors when extraction and processing is near a city

Supporting Detail: Onshore conventional wells exhibit the most variability in production rates



Source: EIA, 2010 (United States Distribution of Wells by Production)

- *Low* production rate brackets have a *high* well count; *high* production rate brackets have a *low* well count
- As old wells are retired, the average production rate will be more representative of the higher production rate brackets

- Historical data not available for Marcellus Shale
- Current estimated ultimate recoveries (EUR) for Marcellus Shale wells are 3.2 BCF, but could be closer to 2 BCF (Pierce et al., 2012)

Supporting Material: In contrast to the unit processes for extraction and processing, pipeline transport is based on national data

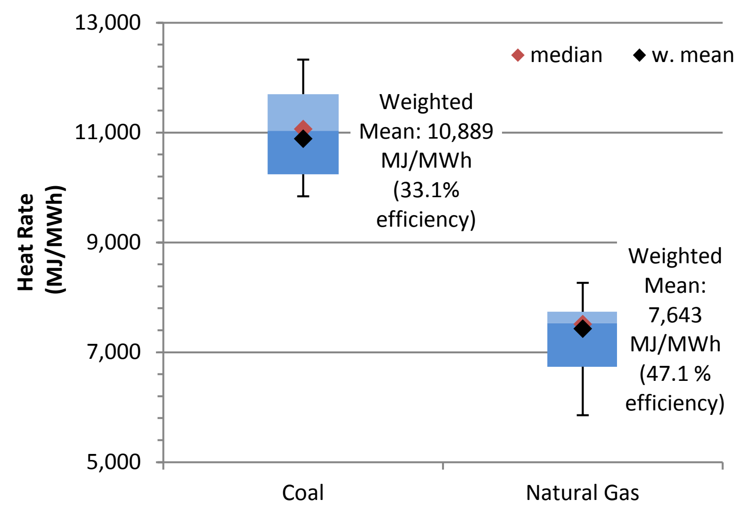
- **National methane emissions from natural gas pipeline transmission (EPA, 2011)**
  - $E_{methane}$ = 2.12 billion kg CH_4/yr
- **National natural gas consumption (EIA, 2011)**
  - $NG_{consumption}$ = 21.8 MMBtu/yr
- **Methane emission factor from pipeline operations**
  - National ton-miles of natural gas transmission (Dennis, 2005 and EPA, 2011)
  - Fuel consumed by pipeline companies (FERC, 2010)
  - Methane emission factor for natural gas combustion in reciprocating compressors and gas turbines used by centrifugal compressors (EPA, 1995)
  - Percent split between pipeline compressor types (Hedman, 2008)
  - $EF_{methane}$ = 9.97E-05 kg CH_4/MMBtu-km

$$d = \frac{E_{methane}}{NG_{consumption} * EF_{methane}} = 971\ km$$

Supporting Material: Natural Gas Power Performance

Power Plant Characteristic	NGCC	NGCC/ccs	GTSC	Fleet Baseload
Net Power, MWe	555	474	360	N/A
Net Plant Efficiency (HHV), %	50.2%	42.8%	30.0%	47.1%
Net Plant Heat Rate (HHV), MJ/MWh	7,172	8,406	11,983	7,643
Consumables				
Natural Gas Feed Flow, kg/hr	75,901	75,901	75,901	N/A
Raw Water Consumption, m^3/min	6.9	11.3	4.4	N/A
Air Emissions, kg/MWh				
Carbon Dioxide	362	46.3	560	379
Methane	7.40E-06	8.61E-06	N/A	N/A
Nitrous Oxide	2.06E-06	2.39E-06	N/A	N/A
Carbon Monoxide	2.70E-04	3.14E-04	4.59E-01	N/A
Nitrogen Oxides	2.80E-02	3.25E-02	4.24E-02	N/A
Sulfur Dioxide	1.93E-06	2.24E-06	N/A	N/A

- Performance of NGCC power plants (with and without CCS) is detailed in NETL's bituminous baseline (NETL, 2010a)
- GTSC performance is adapted from baseline by considering energy & material flows pertinent to gas turbine only
- Characteristic of U.S. natural gas (and coal) average baseload are based on eGRID (EPA, 2010) data



Supporting Detail: Converting inventory of GHGs to 20-year GWP emphasizes the importance of CH_4 losses to upstream GHG results