Understanding the Importance of Leakage Rates to the GHG Footprint of Natural Gas Production

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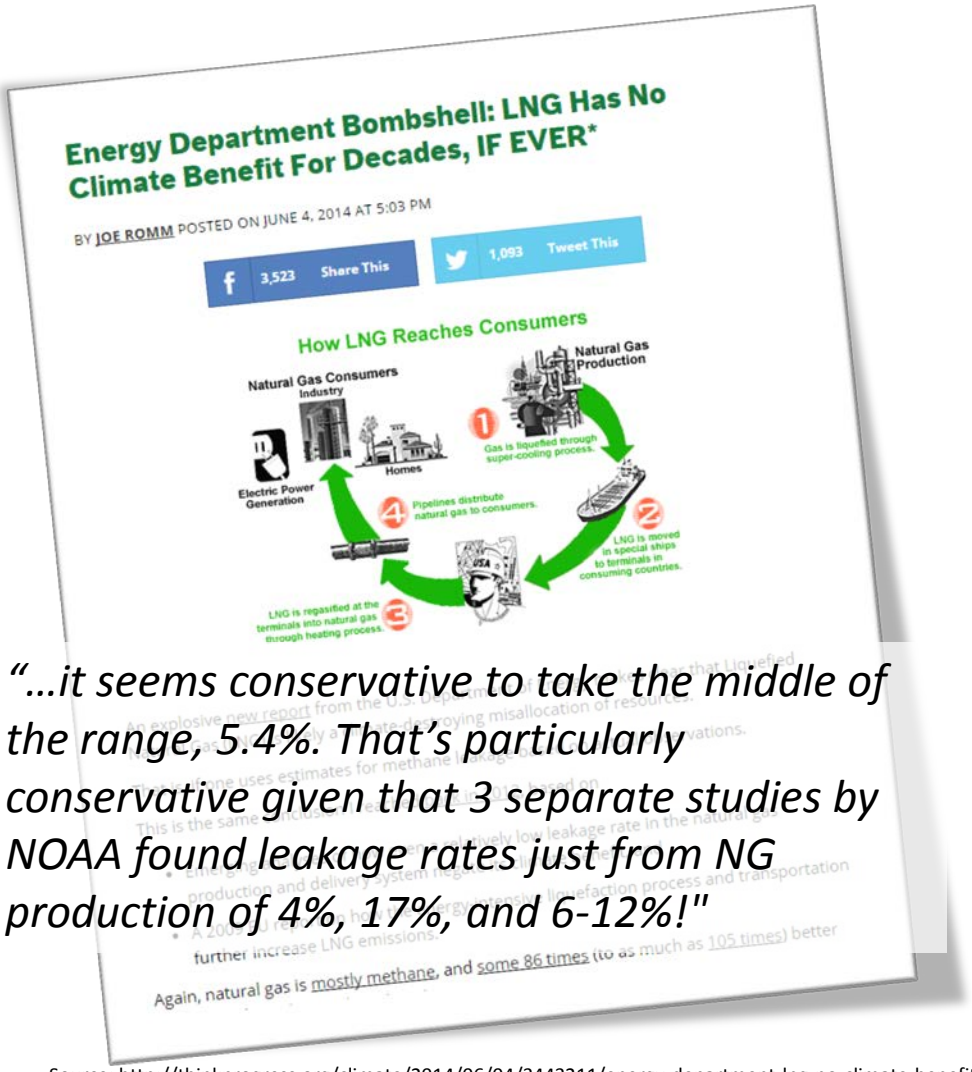
Natural gas (NG) leakage is misunderstood from a life cycle perspective



Energy Department Bombshell: LNG Has No Climate Benefit For Decades, IF EVER*

BY JOE ROMM POSTED ON JUNE 4, 2014 AT 5:03 PM

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How LNG Reaches Consumers

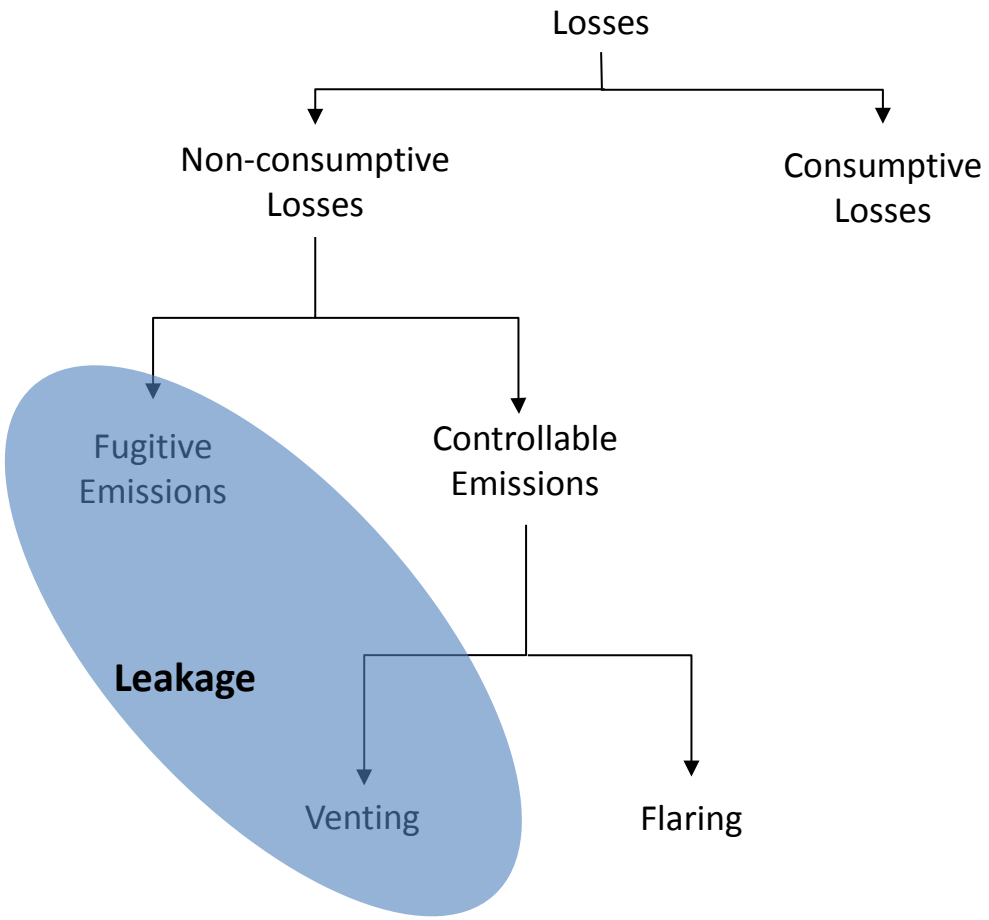
"…it seems conservative to take the middle of the range, 5.4%. That's particularly conservative given that 3 separate studies by NOAA found leakage rates just from NG production of 4%, 17%, and 6-12%!"

Again, natural gas is mostly methane, and some 86 times (to as much as 105 times) better

Source: http://thinkprogress.org/climate/2014/06/04/3443211/energy-department-lng-no-climate-benefits/

- Upstream methane (CH_4) is a significant contributor to NG life cycle greenhouse gas (GHG) emissions
- NG leakage rates are often compared without considering boundaries and representativeness

NG leakage is a subset of total NG losses



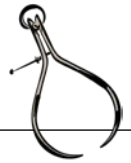
- We define losses as non-consumptive and consumptive losses
- NG is *leaked*, *flared*, and *used* by the supply chain
- Flaring is preferable to venting because of relative GWPs of CO_2 and methane
- Process heaters and compressors compose consumptive losses

Using a single model, we can demonstrate how boundaries affect rates

Boundary	Upstream Leakage (g CH_4) Extraction	Processing	Transmission	Distribution	NG Exiting Boundary (g)	Loss Rate	Leakage Rate
Cradle-to-Extraction	4.7				1,086	0.5%	0.43%
Cradle-to-Processing	4.7	+ 2.6			1,020	6.6%	0.71%
Cradle-to-Transmission	4.7	+ 2.6	+ 5.2		1,005	7.9%	1.24%
Cradle-to-Distribution	4.7	+ 2.6	+ 5.2	+ 4.5	1,000	8.4%	1.70%
Processing Only (GtG)		2.6			1,020	6.1%	0.25%
Transmission Only (GtG)			5.2		1,005	1.5%	0.52%
Distribution Only (GtG)				4.5	1,000	0.5%	0.45%
	Numerator				*Denominator*		

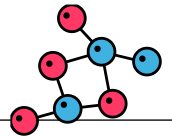
- In this context, boundaries are the processes included in a life cycle (without respect to spatial or temporal representativeness)
- Based on our model, boundary shifts alone can cause large changes in rates
  - Loss rates can range from 0.5% to 8.4% (17x)
  - Leakage rates can range from 0.25% to 1.7% (7x)

Ultimately we want same results from all methods



Measure

Model



Top down

- **"High level" measurements**
- **Data are apportioned according system output**

Example: NOAA Denver-Julesburg Basin research (Pétron et al. , 2012)

- **Calculations of sector inputs/outputs**
- **Calculations are apportioned according overall system activity**

Example: EPA GHG inventory (EPA, 2014)

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Bottom up

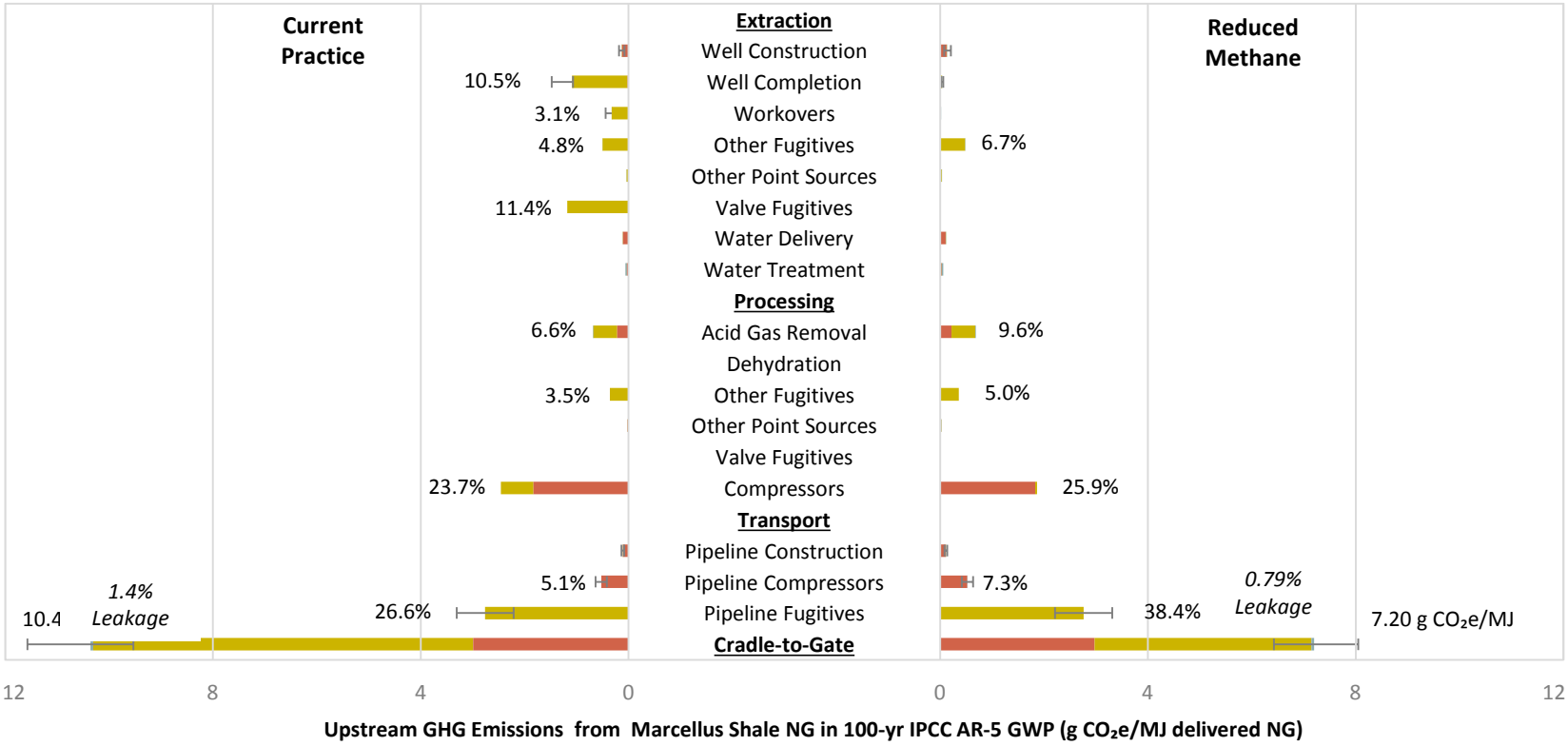
- **Equipment-level measurements**
- **Data are compiled to represent a system**

Example: UT/EDF CH_4 research (Allen et al., 2013)

- **Engineering principles, emission factors, and other relationships are used to build equipment-level unit processes**
- **Unit processes are assembled into a network that represents a system**

Example: NETL upstream NG model

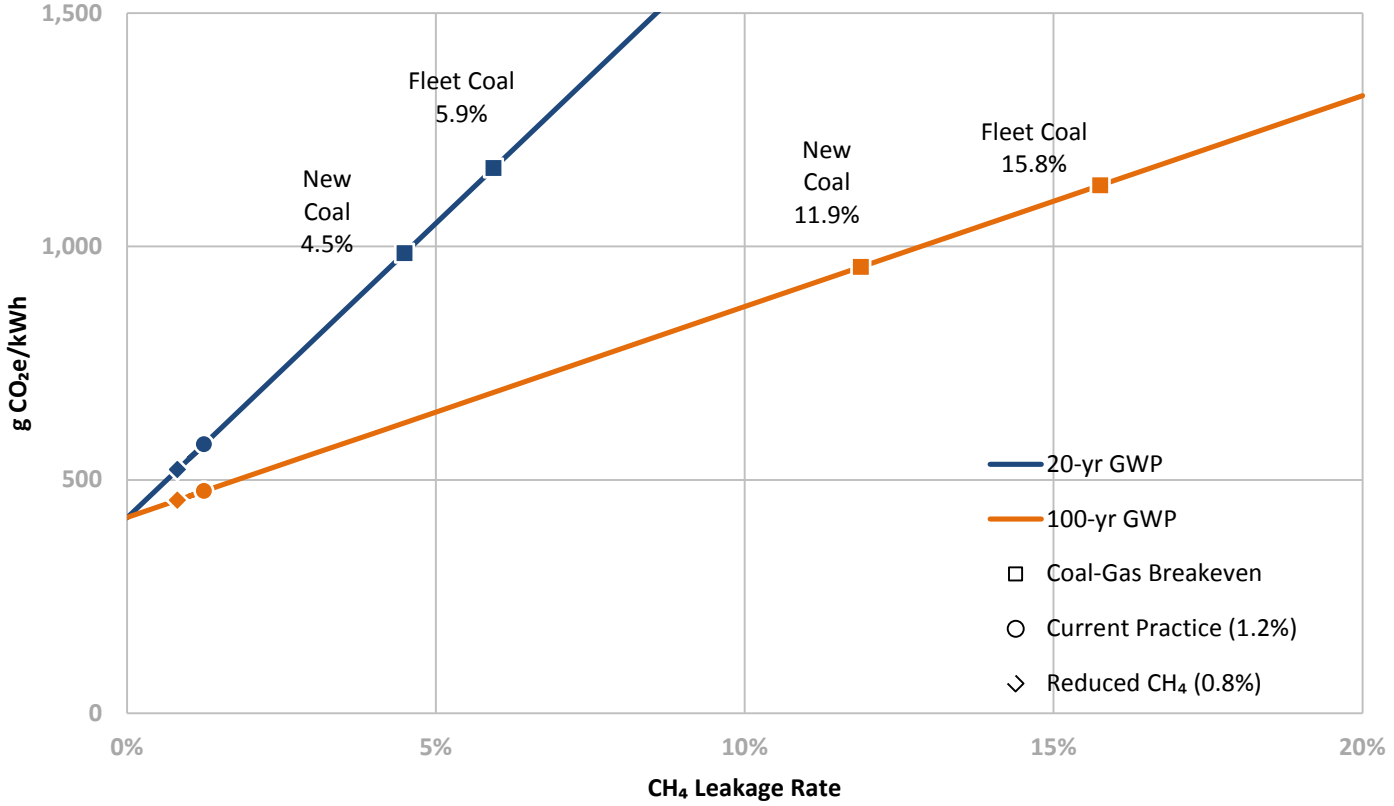
Bottom up modeling allows us to point to contributors and identify opportunities



Upstream GHG Emissions from Marcellus Shale NG in 100-yr IPCC AR-5 GWP (g CO_2e/MJ delivered NG)

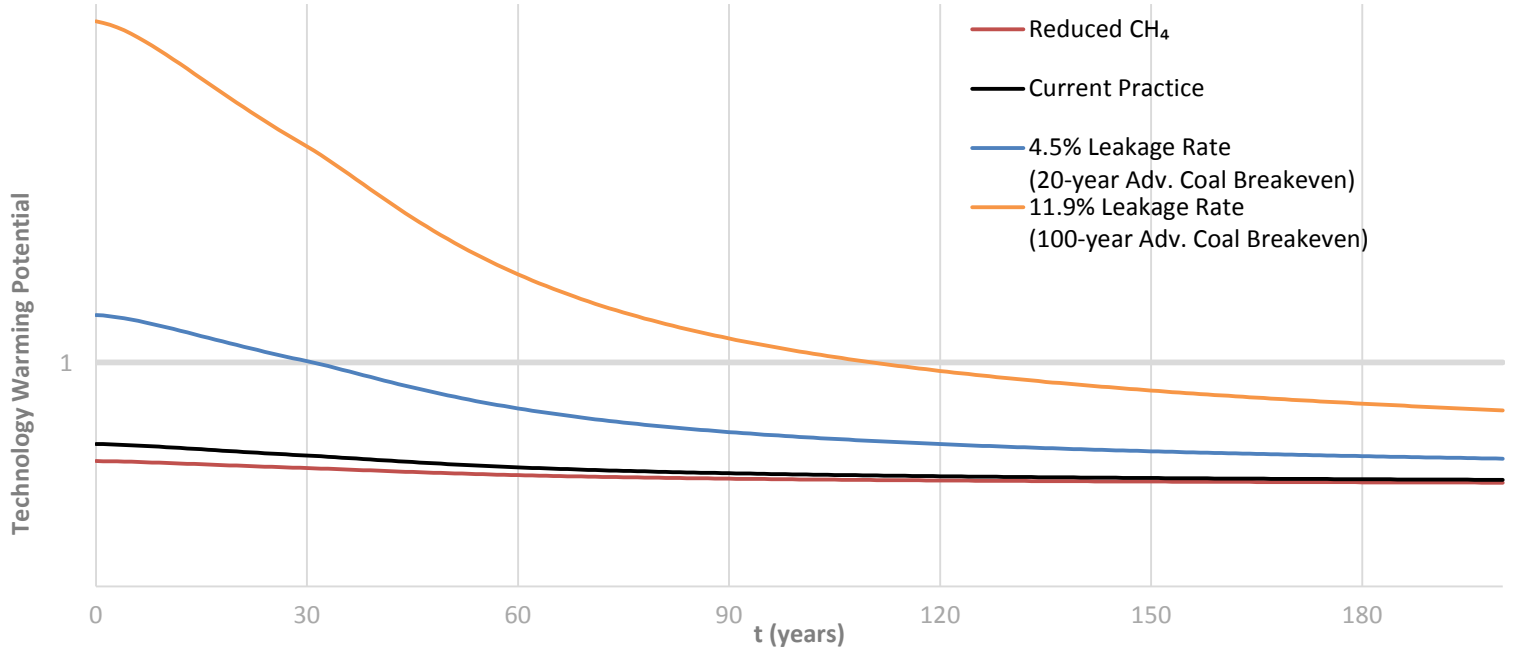
- Reduced methane scenario is based on NSPS rules and uses best practices to reduce completion, valve, and compressor emissions at extraction and processing
- Best practices for natural gas extraction and processing can reduce GHG emissions from new or modified Marcellus Shale wells by 29%

Life cycle of delivered electricity is an equivalent basis for comparing natural gas and coal



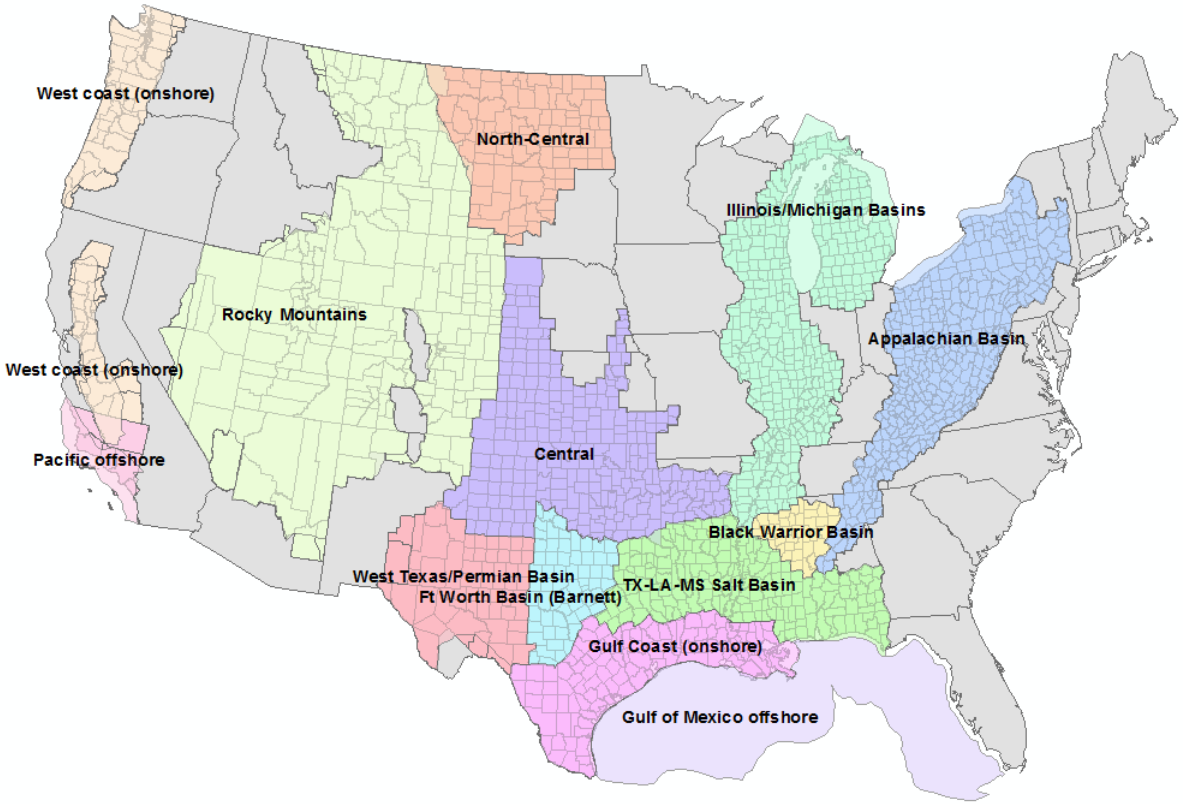
- Our calculated leakage rates are well below the breakeven leakage rates
- Results are sensitive to GWP timeframe

Technology warming potential (TWP) calculates radiative forcing each year



- TWP method developed by EDF as a way to compare life cycle GHGs of different applications without selecting a specific time frame (Alvarez, 2012)
- Intersections between natural gas scenarios and horizontal line (y=1) show number of years at which natural gas and coal systems have same cumulative radiative forcing

Data improvements are one step toward reconciling our models with top down measurements



- Regional variation in fugitive emissions and natural gas compositions
- Potential emissions from completions/workovers based on regional production curves
- Potential emissions from liquids unloading based on well pressure, tubing diameter, hours per episode, and lift technology

Summary

- Conclusions about natural gas leakage are often confounded by boundary inconsistencies and representativeness
- Bottom-up modeling approach has allowed NETL to respond to questions about natural gas leakage
- Reconciliation between top-down and bottom-up models is possible, but requires research
- Data improvements will further increase the accuracy and representativeness of NETL's results

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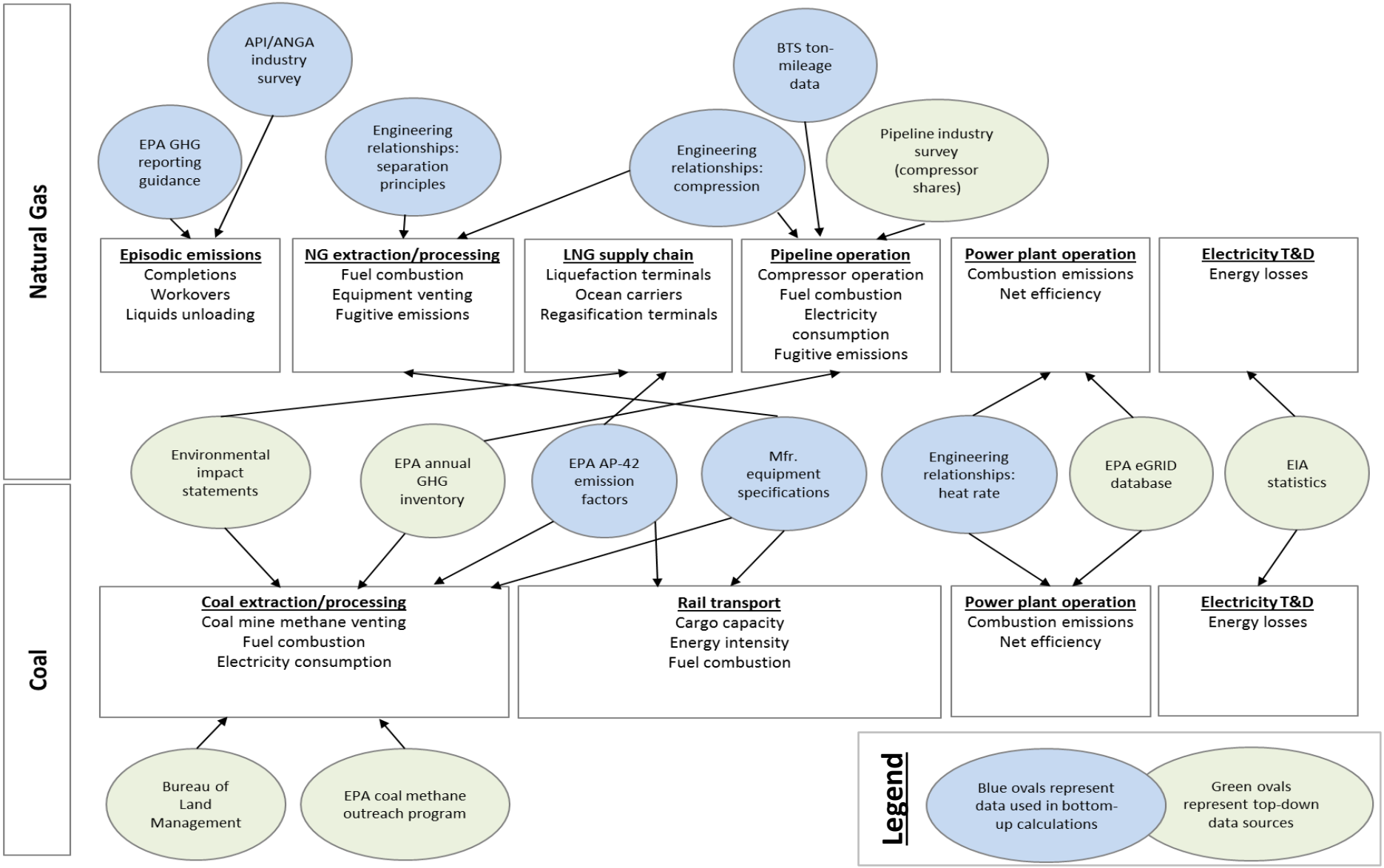
Our models use a variety of data sources



Supporting Material: Extraction Parameters

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			

Supporting Material: Processing and Transport Parameters

Property (Units)	Onshore	Associated	Off-shore	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)	0.04						
CO_2 Absorbed (lb. CO_2/Mcf)	0.56						
H_2S Absorbed (lb. H_2S/Mcf)	0.21						
NMVOC Absorbed (lb. NMVOC/Mcf)	6.59						
Glycol Dehydrator Unit							
Flaring Rate (%)	100%						
Water Removed (lb. H_2O/Mcf)	0.045						
CH_4 Emission Rate (lb. CH_4/Mcf)	0.0003						
Valves & Other Sources of Emissions							
Flaring Rate (%)	100%						
Valve Emissions, Fugitive (lb. CH_4/Mcf)	0.0003						
Other Sources, Point Source (lb. CH_4/Mcf)	0.02						
Other Sources, Fugitive (lb. CH_4/Mcf)	0.03						
Natural Gas Compression at Gas Plant							
Compressor, Gas-Powered Reciprocating (%)	100%	100%		100%	75%	100%	100%
Compressor, Gas-Powered Centrifugal (%)			100%				
Compressor, Electric Centrifugal (%)					25%		
Natural Gas Emissions on Transmission Infrastructure							
Pipeline Transport Distance (mi.)	604 (483 - 725)						
Pipeline Emissions, Fugitive (lb. CH_4/Mcf-mi.)	0.0003						
Natural Gas Compression on Transmission Infrastructure							
Distance Between Compressors (mi.)	75						
Compressor, Gas-powered Reciprocating (%)	78%						
Compressor, Gas-powered Centrifugal (%)	19%						
Compressor, Electrical, Centrifugal (%)	3%						

Supporting Material: Use of New Source Peformance Standards (NSPS) to estimate GHG reductions from a reduced methane scenario

- **Reduced emission completions (RECs) for unconventional wells**
  - Can reduce unconventional completion emissions by 95% [1]
  - New completion and workover emission factor = 9,000*(100% - 95%)
    = 450 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% [1]
  - 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% [1]
  - 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 [2]
  - Low bleed controllers have leak rates less than 6 scf/hr and are used by offshore gas wells [2]
  - New emission factor for onshore conventional and unconventional valves = existing emission factor for offshore valves = 0.0001 lb CH_4/Mcf

[1] *EPA, 2012. Oil and Natural Gas Sector: New Source Performance Standards and National Emission Standards for Hazardous Air Pollutants Reviews; Final Rule. 40 CFR Parts 60 and 63. Federal Register, Vol. 77, No. 159. National Archives and Records Administration. Retrieved October 8, 2013 from http://www.gpo.gov/fdsys/pkg/FR-2012-08-16/pdf/2012-16806.pdf*

[2] *EPA, 2006. Options for Reducing Methane Emissions from Pneumatic Devices in the Natural Gas Industry. Environmental Protection Agency. Retrieved October 8, 2013 from http://www.epa.gov/gasstar/documents/ll_pneumatics.pdf*

Supporting Material: 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.
    - Natural gas used at the production site includes (1) the volume returned to reservoirs in cycling, repressuring of oil reservoirs, and conservation operations; and (2) gas vented and flared
    - Processing losses incudes (1) nonhydrocarbon gases (e.g., water vapor, carbon dioxide, helium, hydrogen sulfide, and nitrogen) removed from the gas stream; and (2) gas converted to liquid form, such as lease condensate and plant liquids

[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*