

26th World Gas Conference

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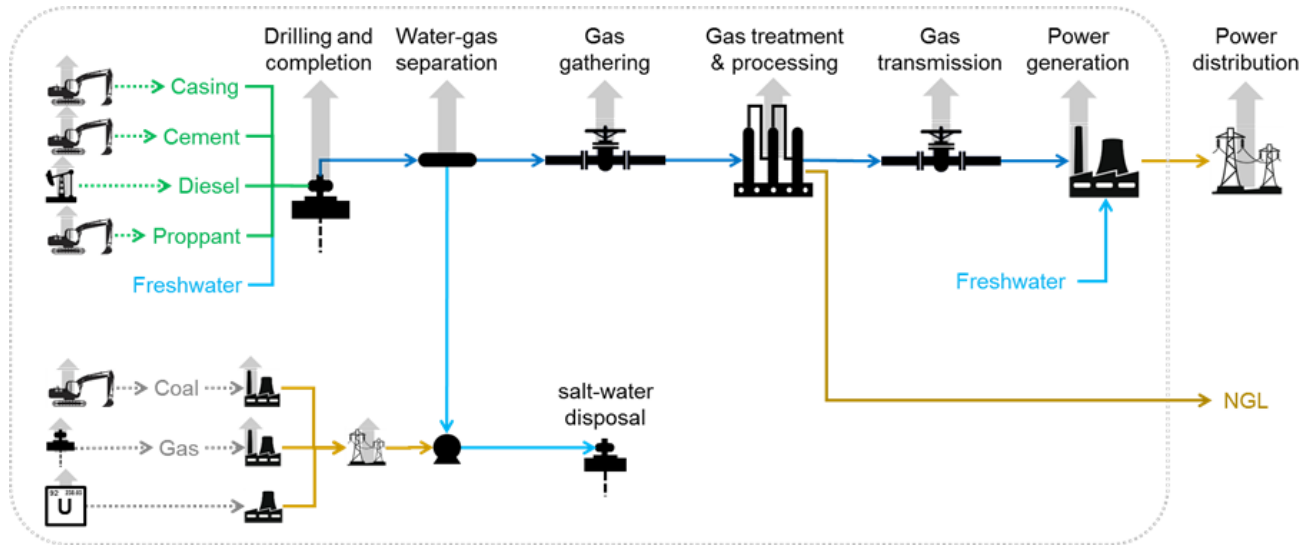
ENVIRONMENTAL LIFE CYCLE ASSESSMENT OF NORTH AMERICAN SHALE GASES

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Life Cycle Assessment

- Objective: Assess impacts associated with power generated from shale gas (“well to wire”)
 - Greenhouse Gas Emissions, kg CO₂eq/MJe (IPCC AR5 GWP, 100-year)
 - Freshwater consumption, L H₂O/MJe



- Impacts of power generation must be assessed on a common basis (MJ of electricity)

Data Sources

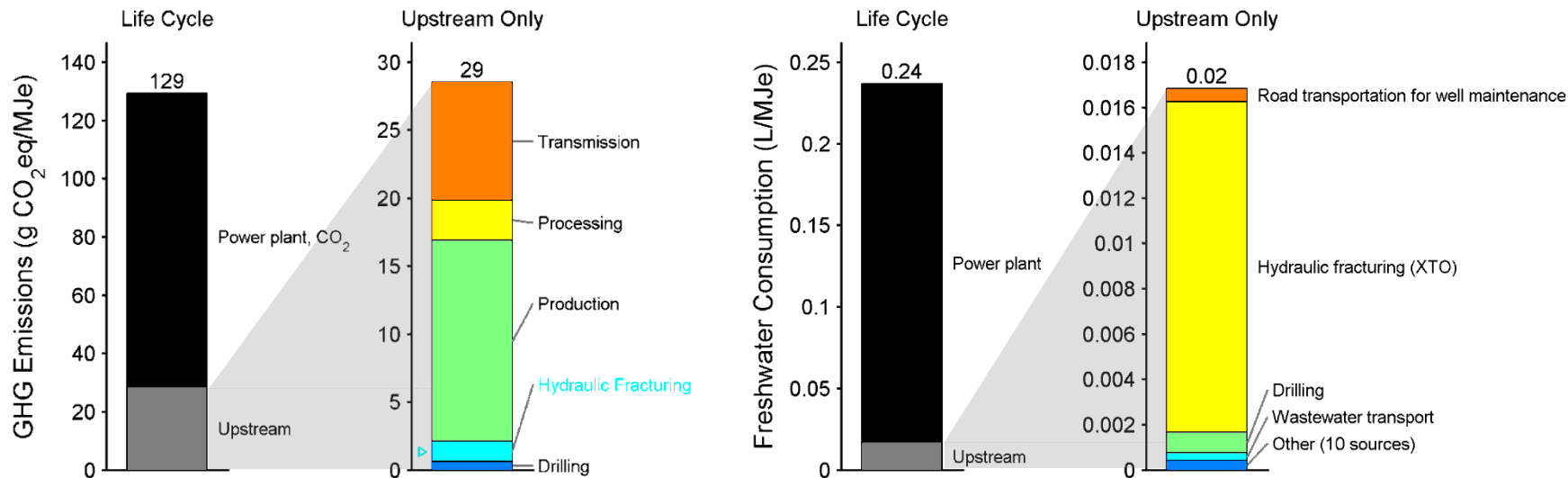
- Shale Gas
 - We used internal data from XTO Energy (an ExxonMobil affiliate) to assess impacts of upstream operations (e.g. hydraulic fracturing)
 - U.S. EPA estimates of fugitive emissions* were utilized when ExxonMobil data were not available (e.g. chemical injection pumps)
 - EPA estimates have been validated by the findings of the University of Texas/EDF study of fugitive emissions from oil and gas
 - Power plant efficiency: 50.2% (HHV basis)
- Coal:
 - We employ the results of the LCA of coal power published by the U.S. Department of Energy (National Energy Technology Laboratory)†
 - Power plant efficiency: 36.8% (HHV basis)

* Source: U.S. Environmental Protection Agency (EPA-600/R-96-080a)

† Source: U.S. Department of Energy (DOE/NETL-2012/1566)

Life Cycle Impacts – Marcellus

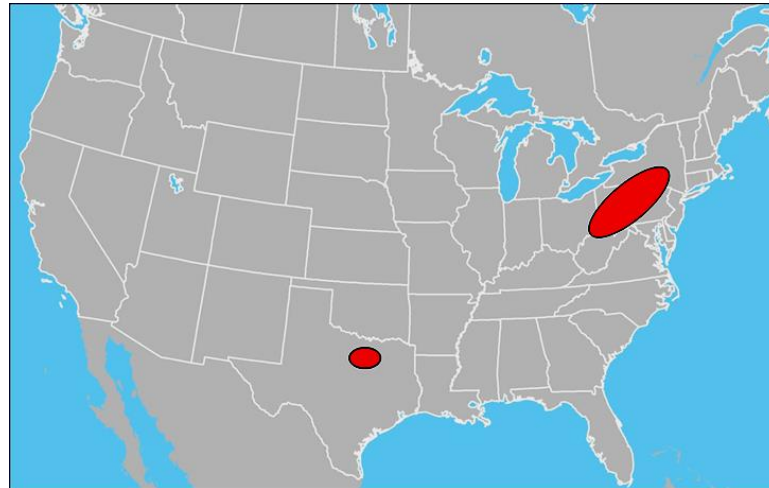
- Marcellus shale gas has half the GHG emissions, water consumption of coal
 - Coal power*: 288 g CO₂eq/MJ_e power generated, 0.47 L/MJ_e power generated
- Hydraulic fracturing emissions are minor compared with other sources
 - 0.66% of life cycle GHG, 6.3% of life cycle freshwater



* Source: U.S. Department of Energy (DOE/NETL-2012/1566)

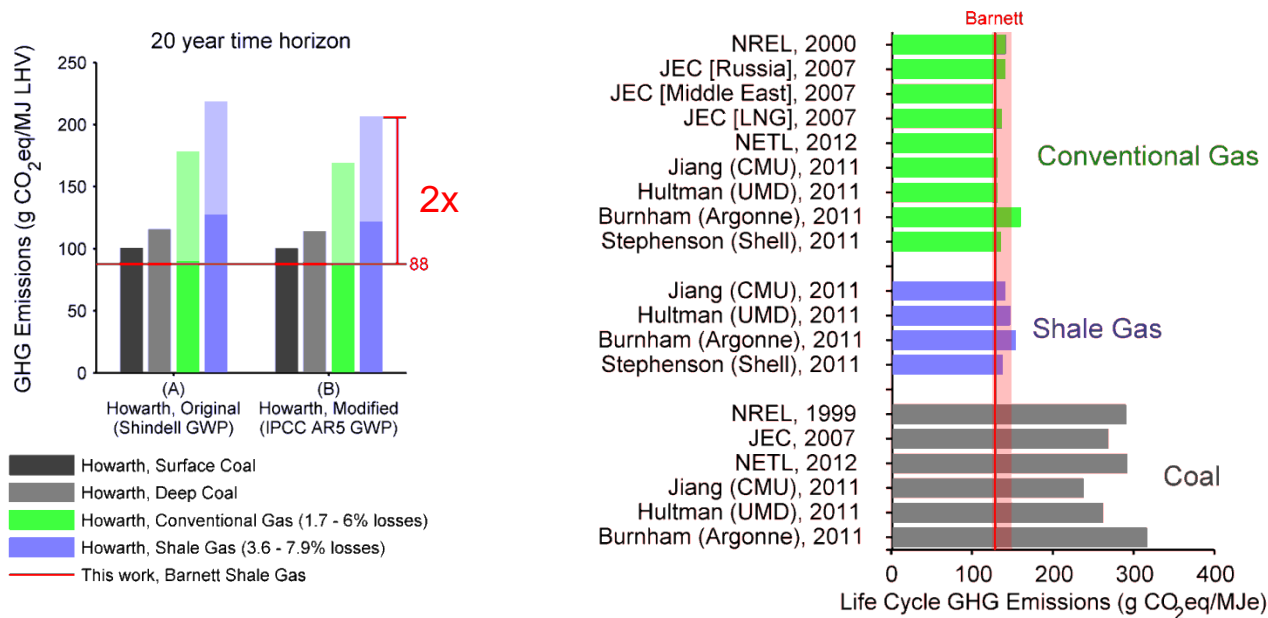
Life Cycle Impacts – North American Shale Gases

	Barnett		Marcellus		Coal
	Rich	Lean	Rich	Lean	
GHG Emissions (g CO ₂ eq/MJ _e)	130	134	129	128	288
Fraction of Gross Methane Emitted	1.7%	1.6%	1.5%	1.4%	
Freshwater Consumption (L/MJ _e)	0.24	0.24	0.24	0.24	0.47



Comparison with other studies

- Our findings are consistent with the rest of the peer-reviewed literature
- One study overstates GHG emissions by **2x** for a 20-year horizon
 - Normalizes GHG emissions with respect to fuel LHV
 - Does not account for efficiencies of coal and gas power plants



Summary

- Life Cycle Environmental Impacts
 - GHG emissions associated with power from shale gas are half those of coal power
 - Shale gas consumes half as much freshwater as coal
 - No significant difference between GHG from shale gas and conventional gas
- More than 98% of extracted methane is used as fuel
 - 87% at power plant (largest source of GHG emissions)
 - ~11% at engines & turbines that drive compression (2nd largest source)
- Life Cycle Freshwater Consumption
 - More than 90% occurs at the power plant (closed loop cooling)
 - Hydraulic fracturing constitutes 6 - 8% of life cycle water consumption
- Key Factors Influencing the Environmental Footprint
 - Power plant efficiency
 - Ultimate recovery (Bcf/well)