Implications of Shale Gas Development for Climate Change

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Context

• This presentation is part of larger workshop on the risks of shale gas development, covering issues relating to water, air, health, ecology, community, climate, and other impacts.

• This presentation focuses only on the greenhouse gas impacts of shale gas development.

• Comprehensive analysis should consider the array of risks relative to other energy sources, as well as the benefits of shale gas development.
What questions are at play?

• Greenhouse gas (GHG) accounting
  – **Aggregate level.** What are the total lifecycle GHG emissions of natural gas use, including both combustion and upstream non-combustion emissions?
  – **Sectoral technology level.** What are the relative GHG impacts of technologies that use natural gas for electricity generation, transportation, and buildings, compared to competing technologies?

• Decisions by producers, policymakers, equipment manufacturers, and corporate and individual purchasers
  – Which technologies are advantageous to promote/develop/market/purchase taking into account GHG impacts?
  – What issues need to be addressed to improve the GHG profile of technologies based on natural gas?
  – How does natural gas abundance change the baseline outlook for GHG emissions and domestic and international policy responses?
Overview

• U.S. natural gas use and shale gas development

• Understanding the potential implications of increased natural gas use on the climate

• Aggregate effects on U.S. energy and economy

• Non-combustion GHG emissions from natural gas

• Sectoral impacts: electricity, residential and commercial buildings, transportation, and industry

• International implications

• Policy interactions and implications
Relevant existing evidence

• Baseline statistics
  – Emissions accounting (EPA, industry, academia, NGOs)
  – Energy data (U.S. Energy Information Administration (EIA), industry)

• Technology lifecycle analysis
  – Various studies (source list at close of presentation)

• Energy modeling projections
  – EIA Annual Energy Outlook 2013
    • Reference case: current policies
    • High oil and gas resource case (note also increases oil)
    • Low oil and gas resource case (note also decreases oil)
    • New Policies case
    • Golden Age of Gas case
  – Other modeling studies
U.S. natural gas use and shale gas development
U.S. natural gas production, distribution, and use

trillion cubic feet in 2011

Natural gas was about 26% of total CO$_2$ and CH$_4$ emissions from U.S. fossil energy in 2011.

Shale gas is a globally distributed and abundant resource

North America has thus far been the focus for shale gas production


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U.S. shale gas production has surged and is expected to grow further.

Historical U.S. natural gas production in trillion cubic feet per year, with projections for 2012 and beyond. The chart shows a significant increase in production, particularly from shale gas, with expected growth in the near future.


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Current and projected U.S. natural gas prices have declined

Henry Hub spot price
2010 dollars per million Btu

Understanding the potential implications of increased natural gas use on the climate
Natural gas abundance has both direct and indirect effects on GHG emissions and climate

Increased natural gas resources and production

Lower natural gas prices

Lower overall energy prices

Increased overall energy consumption (+)

Fuel substitution

Increased natural gas consumption (+)

Decreased coal consumption (-)

Decreased oil consumption (-)

Decreased renewables & nuclear consumption (-)

CO₂

CH₄

Net climate impact ( +/- ?)

Decreased renewables & nuclear consumption (-)

Decreased oil consumption (-)

Decreased coal consumption (-)

Increased overall energy consumption (+)

Net climate impact ( +/- ?)

Decreased overall energy consumption (-)

Policy
Aggregate effects on U.S. energy economy
Natural gas is an important energy source, but is only 13% of all U.S. energy expenditures and 1% of GDP

Effects related to fuel substitution are likely to dominate effects on aggregate energy demand

• Aggregate energy demand is driven primarily by
  – Population growth
  – Overall economic growth and stage of economic development
  – Composition of GDP (e.g., share of services, manufacturing)

• Price changes have much bigger effects on fuel substitution than overall energy demand
  – Economists summarize this responsiveness through demand elasticities measuring the % increase in consumption with respect to a % decrease in price
  – EIA modeling, e.g., which embodies numerous such relationships has:
    • very low elasticity of aggregate energy demand with respect to natural gas price changes (<0.1)
    • low-moderate elasticity of natural gas demand with respect to natural gas prices in the residential/commercial (<0.3) and industrial sectors (<0.5)
    • quite elastic demand for natural gas for electricity generation (1.5 - 2.5)
Greater U.S. shale gas leads to lower gas prices, more energy use, slightly higher GDP, and slightly lower GHG emissions in EIA projections

<table>
<thead>
<tr>
<th>Scenario (for 2040)</th>
<th>Natural gas price (2011) at Henry Hub</th>
<th>Total energy use Quadrillion Btu</th>
<th>GDP Trillion $2005</th>
<th>Cumulative emissions (2010-2040^*) billion tonnes CO(_{2})e</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>7.83 $/mmBtu&lt;br&gt;108</td>
<td>108</td>
<td>$27.3</td>
<td>179</td>
</tr>
<tr>
<td>High oil/gas resource</td>
<td>-45%&lt;br&gt;+3%</td>
<td>+1%</td>
<td>-0.4%</td>
<td></td>
</tr>
<tr>
<td>Low oil/gas resource</td>
<td>+32%&lt;br&gt;-1%</td>
<td>-0.1%</td>
<td>-0.8%</td>
<td></td>
</tr>
</tbody>
</table>

Percent difference relative to Reference case

Notes: *CO\(_{2}\)e emissions computed by augmenting EIA CO\(_{2}\) emission estimates for coal, oil, and natural gas by 3.3%, 1.5%, and 12.7% respectively to account for non-combustion CO\(_{2}\) and CH\(_{4}\) emissions, based on EPA Greenhouse Gas Inventory 2013.
Non-combustion GHG emissions from natural gas
87% of greenhouse gas emissions from natural gas occur during the combustion phase.

Non-combustion emissions from natural gas are variable, but have fallen in the past several years.


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Upstream non-combustion GHG emissions have fallen per unit of natural gas production

EPA estimates of methane emissions from natural gas systems have changed over time


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Non-combustion GHG emission estimates for shale gas are not consistently lower or higher than conventional gas

Electricity sector
Most estimates have 40%-50% lower lifecycle GHG emissions for electricity from natural gas than coal

Life-cycle emissions for power generation
Ratio of CO\textsubscript{2}e emission estimates for electricity generation from natural gas relative to coal

Higher per kWh emissions than coal
Lower per kWh emissions than coal

Data source: Listed authors. Notes: 100-year global warming potential (GWP) used unless otherwise indicated. *Howarth does not account for differences in combustion efficiency of coal versus gas.
U.S. electric-sector CO₂ emissions have declined 16% since 2005 due to fuel switching.

Data source: U.S. Energy Information Administration.
Greater shale gas leads to lower prices, fuel switching to gas, and lower electricity GHG emissions in EIA projections

<table>
<thead>
<tr>
<th>Scenario (for 2040)</th>
<th>Natural gas prices (delivered for elec.)</th>
<th>Average electricity prices</th>
<th>Electricity consumption</th>
<th>Natural gas consumption for electricity</th>
<th>Coal consumption for electricity</th>
<th>Nuclear and renewables consumption</th>
<th>Cumulative electricity CO₂e emissions* 2010-2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>8.55 $/mmBtu</td>
<td>10.8 ¢/kWh</td>
<td>5,200 GWh</td>
<td>1,600 GWh</td>
<td>1,800 GWh</td>
<td>1,800 GWh</td>
<td>71 billion tonnes</td>
</tr>
</tbody>
</table>

Percent and absolute difference relative to Reference case

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Natural gas prices</th>
<th>Average electricity prices</th>
<th>Electricity consumption</th>
<th>Natural gas consumption for electricity</th>
<th>Coal consumption for electricity</th>
<th>Nuclear and renewables consumption</th>
<th>Cumulative electricity CO₂e emissions* 2010-2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>High oil and gas</td>
<td>-39%</td>
<td>-14%</td>
<td>+4.2% (+200 GWh)</td>
<td>+49% (+800 GWh)</td>
<td>-21% (-400 GWh)</td>
<td>-9% (-200 GWh)</td>
<td>-5%</td>
</tr>
<tr>
<td>Low oil and gas</td>
<td>+26%</td>
<td>+7%</td>
<td>-2.4% (-100 GWh)</td>
<td>-34% (-500 GWh)</td>
<td>+4% (+100 GWh)</td>
<td>+19% (+300 GWh)</td>
<td>+0.2%</td>
</tr>
</tbody>
</table>

Data source: U.S. Energy Information Administration, 2013 Annual Energy Outlook. Notes: *CO₂e emissions computed by augmenting EIA CO₂ emission estimates for coal, oil, and natural gas by 3.3%, 1.5%, and 12.7% respectively to account for non-combustion CO₂ and CH₄ emissions, based on EPA Greenhouse Gas Inventory 2013.
Residential and commercial buildings sector
Natural gas space and water heating tends to have significantly lower GHG emissions than electricity

- **Space heating***
  - Natural gas boilers are about 50% less GHG-intensive (CO$_2$ and CH$_4$) than electric heat from natural gas electricity
  - Natural gas-powered heat pumps could further reduce emissions
  - Lower-GHG electricity would improve the electric heat footprint

- **Water heating**
  - Natural gas water heating systems in 46 out of 50 states are less CO$_2$ intensive than electric heating systems
  - In most states, natural gas water heating systems are ~60% less CO$_2$ intensive than electric heating systems
  - Variation occurs between states due to electricity fuel mix
  - Lower-GHG electricity would improve the electric water heating footprint

Greater shale gas leads to lower prices, more energy use, and lower GHG emissions in EIA residential and commercial projections

<table>
<thead>
<tr>
<th>Scenario (for 2040)</th>
<th>Natural gas prices (avg. res/comm price)</th>
<th>Electricity prices (avg. res/comm price)</th>
<th>Aggregate res/comm energy* consumption</th>
<th>Natural gas consumption for res/comm</th>
<th>Electricity* consumption for res/comm</th>
<th>Cumulative res/comm CO₂e emissions** 2010-2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>15.13 $/mmBtu</td>
<td>11.7 ¢/kWh</td>
<td>21.8 QBtu</td>
<td>7.9 QBtu</td>
<td>11.8 QBtu</td>
<td>67 billion tonnes</td>
</tr>
<tr>
<td>Percent and absolute difference relative to Reference case:</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High oil and gas</td>
<td>-22%</td>
<td>-13%</td>
<td>+5% (+1.1 QBtu)</td>
<td>+7% (+0.6 QBtu)</td>
<td>+4% (+0.5 QBtu)</td>
<td>-3%</td>
</tr>
<tr>
<td>Low oil and gas</td>
<td>+18%</td>
<td>+7%</td>
<td>-3% (-0.6 QBtu)</td>
<td>-4% (-0.3 QBtu)</td>
<td>-2% (-0.2 QBtu)</td>
<td>-0.2%</td>
</tr>
</tbody>
</table>

Data source: U.S. Energy Information Administration, 2013 Annual Energy Outlook. Notes: *Does not include electricity-related losses. **CO₂e emissions computed by augmenting EIA CO₂ emission estimates for coal, oil, and natural gas by 3.3%, 1.5%, and 12.7% respectively to account for non-combustion CO₂ and CH₄ emissions, based on EPA Greenhouse Gas Inventory 2013.
Transportation sector
Natural gas passenger vehicles reduce emissions by 10%-30% relative to gasoline

Life cycle emissions for passenger vehicles ratio of CO₂e emission estimates for CNG relative to gasoline vehicles

Data source: Listed authors.
Climate benefits from natural-gas powered heavy vehicles are less clear

Life cycle emissions for transit buses
Ratio of CO$_2$e emission estimates for natural gas buses relative to diesel

Data source: Listed authors.

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Industrial sector
Greater shale gas leads to more industrial energy use and slightly higher GHG emissions in EIA projections

<table>
<thead>
<tr>
<th>Scenario (for 2040)</th>
<th>Industrial natural gas prices</th>
<th>Aggregate industrial energy* consumption</th>
<th>Natural gas consumption by industry</th>
<th>Coal consumption by industry</th>
<th>Electricity* consumption by industry</th>
<th>Cumulative industrial CO$_2$e emissions** 2010-2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>9.09 $/mmBtu</td>
<td>28.7 QBtu</td>
<td>10.4 QBtu</td>
<td>1.6 QBtu</td>
<td>3.9 QBtu</td>
<td>52 billion tonnes</td>
</tr>
<tr>
<td>High oil and gas</td>
<td>-39% (+2.1 QBtu)</td>
<td>+7% (+1.8 QBtu)</td>
<td>+18% (-0.05 QBtu)</td>
<td>-3% (+0.1 QBtu)</td>
<td>+2%</td>
<td>+0.3%</td>
</tr>
<tr>
<td>Low oil and gas</td>
<td>+28% (-1.1 QBtu)</td>
<td>-4% (-0.9 QBtu)</td>
<td>-8% (-0.1 QBtu)</td>
<td>-5% (-0.02 QBtu)</td>
<td>-1%</td>
<td>-1.4%</td>
</tr>
</tbody>
</table>

Percent and absolute difference relative to reference scenario

*Does not include electricity-related losses. **CO$_2$e emissions computed by augmenting EIA CO$_2$ emission estimates for coal, oil, and natural gas by 3.3%, 1.5%, and 12.7% respectively to account for non-combustion CO$_2$ and CH$_4$ emissions, based on EPA Greenhouse Gas Inventory 2013.

International implications
Projections for global natural gas use are rising

primary global natural gas demand
billion cubic meters

5,500

3,000

3,500

4,000

4,500

5,000

2010 2015 2020 2025 2030 2035

3% lower CO₂ emissions than 2011 New Policies scenario in 2035

2011 “Golden Age of Gas” scenario

2012 “New Policies” scenario

2011 “New Policies” scenario

U.S. coal exports have increased, but represent a fairly small share of global trade

Greater shale gas resources lead to lower U.S. coal production and negligible effects on coal exports in EIA projections.

LNG tends to have higher GHGs than domestic natural gas for electricity, but still lower than coal.

Life cycle emissions for electricity generation.

Ratio of CO\textsubscript{2}e emission estimates for electricity from natural gas relative to coal.

Lower emissions per kWh than coal.

Higher emissions per kWh than coal.

Data source: Listed authors.
Policy interactions and implications
How does abundant natural gas interact with and affect climate/energy policy?

• Lower natural gas prices make the cost of some policies lower and other policies higher
  – lowering the cost of options with relatively low GHG intensity will tend to make achievement of climate goals less costly
    • e.g., in current baseline scenarios no new US coal power is built in part due to low natural gas prices; as a result, regulations that would regulate new coal plant GHG emissions have no apparent impact
    • e.g., under an emissions constraint, lower natural prices lower the cost of meeting emission targets and (by design) do not affect emissions (e.g., EIA AEO 2013, Jacoby et al. 2011, Brown and Krupnick 2010)
  – in the context of renewable energy standards, however, lower gas prices will tend to increase the incremental cost of maintaining those standards

• With substantial long-term GHG reductions, natural gas would need to incorporate carbon capture and storage at reasonable cost to continue as a competitive option
Concluding thoughts

• The GHG emissions intensity of natural gas has fallen; further reductions in non-combustion emissions and improved combustion efficiency could further this trend
  – upstream emission estimates have fluctuated, but not sufficiently to alter the main conclusions

• Thus far, shale gas has lead to decreased GHG emissions by lowering prices and displacing more coal than renewables/nuclear

• Using current lifecycle GHG estimates, natural gas tends to lower GHG emissions relative to coal electric power, gasoline personal vehicles, and electricity for space/water heating

• Natural gas abundance alone will probably not have a substantial effect on future GHG emissions; policy is the key factor
  – but could influence relevant policy in ways that have a substantial effect
Sources


Sources


For more information

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