Natural Gas and the Transformation of the U.S. Energy Sector: Electricity

Life Cycle GHG Emissions of Barnett Shale Gas in 2009

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Yale Center for Environmental Law and Policy
Seminar series: "Emerging Issues in Shale Gas Development."

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About JISEA

JISEA seeks to guide the transformation of the global energy economy through comprehensive, transdisciplinary research focused on the nexus of energy, finance, and society.

JISEA Founding Institutions

- NREL
- University of Colorado-Boulder
- Colorado School of Mines
- Colorado State University
- Massachusetts Institute of Technology
- Stanford University
Background: Study Goals and Sponsors

- JISEA designed this study to address four related topics:
  - Life cycle greenhouse gas (GHG) emissions associated with shale gas compared to conventional natural gas and other fuels used to generate electricity
  - Legal and regulatory frameworks governing unconventional gas development at federal, state, and local levels, and how they are changing in response to industry growth and public concerns
  - Water-related practices of natural gas production companies
  - Electric power futures – Forecasts of demand for natural gas – and other generating options – in the electric sector under a variety of policy and technology developments over the next 20 to 40 years

- Study sponsors: Multi-client sponsor group composed of natural gas producers, utilities, transmission companies, investors, researchers, and environmental NGO
Lifecycle Greenhouse Gas Emissions
2009 Barnett Shale Gas for Electricity

Goal: Develop an estimate using methods independent of previous taking advantage of alternative, high resolution data sets

• Leveraged Texas Commission on Environmental Quality inventories of volatile organic compounds from NG production and processing stages
  – 16,000+ sources
  – Very high industry participation rates
  – Year 2009

• Compiled a quality-screened data set of county-level, extended gas composition analyses of produced (raw) gas
  – Demonstrates wide variability of methane and VOC content within the Barnett Shale play.
Methods for Barnett Shale Estimate

For original estimates:
- Venting/fugitives: Methane and CO$_2$ emissions by ratio of inventory VOC and county-average composition analysis
- Combustion sources: Methane and CO$_2$ emissions by emission factor using inventory activity data

For estimates taken from literature:
- Sources: EPA GHG inventory and other LCAs
- Sensitivity analysis on estimated ultimate recovery of wells and emissions from liquids unloading, well completion and well workover
Barnett Shale life cycle GHG emissions by life cycle phase and GHG

- Most life cycle GHG emissions attributable to generation of electricity from combustion at power plant
- Fuel cycle emissions of both CO₂ and methane are important

* Multiple estimates, in parentheses, pertain to high EUR, base case EUR, and low EUR, respectively. Single estimates pertain to stages without sensitivity to EUR. The error bar is plus or minus the total bar length (life cycle GHG emissions).
Barnett Shale Gas Estimate Compared to Harmonized Literature Estimates for Coal and Conventional Gas


EUR = estimated ultimate recovery
NGCC = natural gas combined cycle
Barnett Shale Gas Estimate Compared to Harmonized Literature Estimates for Coal, Conventional and Shale Gas

Life Cycle GHG Emissions (g CO₂e/kWh)

Key to Box Plot
- Maximum
- 75th percentile
- Median
- 25th percentile
- Minimum

Sources:

EUR = estimated ultimate recovery
NGCC = natural gas combined cycle
GHG Sources from Barnett Shale TCEQ Inventories

- In the Barnett Shale area, many GHG sources are potentially controllable

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Background notes:

- Pneumatics, from the area source inventory, have no count of individual sources
# Loss and leakage of produced gas

<table>
<thead>
<tr>
<th>Completions and Workovers(^b)</th>
<th>Production</th>
<th>Processing</th>
<th>Transmission(^c)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extracted from Ground</td>
<td>100.0%</td>
<td></td>
<td></td>
<td>100.0%</td>
</tr>
<tr>
<td>Fugitive Losses</td>
<td>–</td>
<td>0.1%</td>
<td>0.0%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Potentially Controllable Leakage</td>
<td>0.8%</td>
<td>0.1%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Combusted as Fuel</td>
<td>–</td>
<td>0.9%</td>
<td>3.9%</td>
<td>0.8%</td>
</tr>
<tr>
<td>Delivered to Power Plant</td>
<td></td>
<td></td>
<td></td>
<td>92.9%</td>
</tr>
</tbody>
</table>

\(^a\) reported as volume of natural gas consumed or lost per volume of natural gas produced.
\(^b\) See footnote to Figure 9
\(^c\) From Skone et al. (2011)

- **7.1% fuel cycle loss rate (incl consumed) NG volume per volume of NG produced (at average EUR = 1.42 bcf).**
  - 1.5% NG loss per NG produced
  - 1.3% methane emitted per NG produced
- **EUR sensitivity:**
  - low EUR (0.45 bcf) \(\rightarrow\) 2.8% methane leakage rate; 8.9% loss,
  - high EUR (4.3 bcf) \(\rightarrow\) 0.8% leakage and 6.5% losses.
Barnett Shale Gas Composition Variability

Composition by Mass

2009 Production by Heat Content (Million MMBtu)

County

Comanche (A)  Erath (1)  Eastland (A)  Hill (1)  Montague (1)  Clay (A)  Archer (A)  Jack (10)  Wise (15)  Cooke (1)  Palo Pinto (4)  Stephens (A)  Hood (7)  Parker (19)  Somervell (A)  Bosque (A)  Johnson (8)  Denton (14)  Shackelford (A)  Ellis (A)  Dallas (A)  NATIONAL  Tarrant (7)

a "Other" gas include nitrogen, ethane, and any other non-methane, -VOC, or -carbon dioxide gases reported
b BS-AVERAGE refers to the production-weighted average gas composition in the 22-county Barnett Shale basin
c NATIONAL refers to the national average composition commonly used in the literature (EPA 2011)
### Effect of Alternative Gas Composition – Production and Processing

<table>
<thead>
<tr>
<th></th>
<th>Denton County&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Johnson County&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Tarrant County&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Wise County&lt;sup&gt;a&lt;/sup&gt;</th>
<th>22-County Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Barnett Shale average vs.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>main results</td>
<td>12%</td>
<td>-5%</td>
<td>-33%</td>
<td>29%</td>
<td>1%</td>
</tr>
<tr>
<td><strong>National average vs. main</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>results</td>
<td>15%</td>
<td>-11%</td>
<td>-36%</td>
<td>29%</td>
<td>-3%</td>
</tr>
</tbody>
</table>

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<th>Wise County&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Barnett Shale play average&lt;sup&gt;b&lt;/sup&gt;</th>
<th>National average&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volatile organic compounds</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>content&lt;sup&gt;d&lt;/sup&gt;</td>
<td>18%</td>
<td>19%</td>
<td>6%</td>
<td>23%</td>
<td>16%</td>
<td>18%</td>
</tr>
<tr>
<td>CO&lt;sub&gt;2&lt;/sub&gt; content&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2%</td>
<td>2%</td>
<td>1%</td>
<td>3%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>Methane content&lt;sup&gt;d&lt;/sup&gt;</td>
<td>63%</td>
<td>63%</td>
<td>80%</td>
<td>56%</td>
<td>66%</td>
<td>78%</td>
</tr>
</tbody>
</table>

<sup>a</sup> Only the four top-producing counties in the Barnett Shale play are shown.
<sup>b</sup> Production-weighted average across the 22 counties of the Barnett Shale play
<sup>c</sup> As reported in EPA (2011)
<sup>d</sup> Percentage by mass

These results have implications for developing more accurate GHG emission inventories at sub-national levels and any regulatory system that might seek to identify high emitters within plays.
Life Cycle GHG Emissions from Generation Technologies (estimates published pre-2011)

[Graph showing Life Cycle Greenhouse Gas Emissions from various generation technologies, comparing conventional gas only with renewable and non-renewable sources.]

Source: IPCC SRREN, SPM Figure 8.
GHG Emissions from Production and Processing

- Most emissions from CO\(_2\)
- Much of emissions is potentially controllable, including combustion (e.g., higher efficiency)