The climate and health effects of a USA switch from coal to gas

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IAEE NYC: June 17, 2014
The rise of natural gas

- Increased gas generation
- Gas dominates new builds

Drivers:
- Economics
- Regulations on criteria pollutants ($\text{NO}_x$, $\text{SO}_2$, PM)
  - MATS, CAIR, CSPAR

Sources: EIA, PJM
Our thought experiment

• **What would happen** if all U.S. coal plants were shut off in 2016, and were replaced with new gas plants or zero-emission plants?
• An **upper bound** on pollution reduction benefits
• We quantify:
  – Changes in GHG & criteria pollutant emissions
    • CO₂, CH₄, SO₂, NOₓ, PM₂.₅, PM₁₀
  – Effect on public health and warming
    • CH₄ global temperature potential (GTP₂₀⁰₆₈) = 68 ± 75%
    • Sensitivity to fugitive CH₄ emission rates of 0% - 7%
  – Costs
Baseline scenario

- Coal generation is flat
- Gas generation doubles
- $\text{CO}_2$ rises
- $\text{CH}_4$ rises, but uncertain
- Criteria pollutants flat after 2016

Solid line: EIA Reference Case
Shaded area: EIA high gas/low gas resource cases

*MATS* standard goes into effect

*EIA Annual Energy Outlook, 2014*
Methods

- **Baseline emissions:** Identify emissions from coal plants, 2016 – 2040
- **Emission reductions:** Calculate emissions if same coal generation came from gas or zero-emission plants
- **Sensitivity to fugitive CH\(_4\):** Vary rate of fugitive CH\(_4\) emissions from 0% - 7%
- **Warming effects:** Use climate models to estimate warming effects
- **Effect on health:** Monetize reductions in health damages (APEEP)
### Emission rates

<table>
<thead>
<tr>
<th>Plant Type</th>
<th>CO₂</th>
<th>NOₓ</th>
<th>SO₂</th>
<th>CH₄</th>
<th>PM₂.₅</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal - 2016</td>
<td>910</td>
<td>0.69</td>
<td>0.72</td>
<td>0.01</td>
<td>0.14</td>
</tr>
<tr>
<td>A): High-efficiency gas</td>
<td>300</td>
<td>0.09</td>
<td>0.02</td>
<td>0.008</td>
<td>0.06</td>
</tr>
<tr>
<td>B): Average gas</td>
<td>450</td>
<td>0.17</td>
<td>0.02</td>
<td>0.009</td>
<td>0.06</td>
</tr>
<tr>
<td>C): Zero emission plants</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Change in U.S. power sector emissions

- Constant across years 2016 – 2040
- 3% fugitive CH$_4$ rate
Change in warming from U.S. power sector

Solid line: EIA Reference Case, GTP20_{CH_4} = 68, 3% fugitive CH_4
Shaded area: EIA high gas/low gas cases, GTP20_{CH_4} = 68 ± 75%, 0-7% fugitive CH_4
## Percent change in warming, 2040

<table>
<thead>
<tr>
<th>Scenario</th>
<th>0%</th>
<th>3%</th>
<th>5%</th>
<th>7%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switch to high-efficiency gas</td>
<td>-47%</td>
<td>-17%</td>
<td>-5%</td>
<td>+5%</td>
</tr>
<tr>
<td></td>
<td>(-38%, -3%)</td>
<td>(-33%, +11%)</td>
<td></td>
<td>(-28%, +21%)</td>
</tr>
<tr>
<td>Switch to average gas gas</td>
<td>-35%</td>
<td>+1%</td>
<td>+16%</td>
<td>+28%</td>
</tr>
<tr>
<td></td>
<td>(-24%, +18%)</td>
<td>(-18%, +36%)</td>
<td></td>
<td>(-12%, +49%)</td>
</tr>
<tr>
<td>Switch to zero-emission plants</td>
<td>-70%</td>
<td>-53%</td>
<td>-45%</td>
<td>-40%</td>
</tr>
<tr>
<td></td>
<td>(-64%, -44%)</td>
<td>(-61%, -36%)</td>
<td></td>
<td>(-59%, -30%)</td>
</tr>
</tbody>
</table>

**Assumptions:** EIA Reference Case, GTP20\(_{CH4}\) = 68

**In parenthesis:** EIA high gas/low gas cases, GTP20\(_{CH4}\) = 68 ± 75%
Monetized criteria pollutant health benefits: ~$20-$25B annually

- $6M value of statistical life
- Calculated with APEEP model*
- >75% due to reductions in SO$_2$
- Annual capital cost: $35 - $65 billion**

** Assuming capital cost of $1,000 - $1,300/kW, facility life of 20 years, and blended cost of capital of 7% - 12%
Health benefits from criteria pollution

- $10 billion
- $7 billion

2016 damages from coal plants, EIA Reference Case
2016 damages from average gas replacement plants
Coal retrofits may be a more cost effective way to reduce SO$_2$

<table>
<thead>
<tr>
<th>SO$_2$ control technology</th>
<th>Capital cost ($/kW)</th>
<th>Fixed O&amp;M ($/MW-yr)</th>
<th>Variable O&amp;M ($/MWh)</th>
<th>Fuel cost ($/MWh)</th>
<th>SO$_2$ reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Build new NGCC</td>
<td>$1,000 - $1,300</td>
<td>$5,500 - $6,200</td>
<td>$2 - $3.5</td>
<td>$24 - $25</td>
<td>99%</td>
</tr>
<tr>
<td>Flue gas desulfurization (FGD)</td>
<td>$500</td>
<td>$8,100</td>
<td>$1.8</td>
<td>$15 - $20</td>
<td>98%</td>
</tr>
<tr>
<td>Direct sorbent injection (DSI)</td>
<td>$40</td>
<td>$590</td>
<td>$7.9</td>
<td>$15 - $20</td>
<td>50%</td>
</tr>
</tbody>
</table>

- Retrofit costs for a 500 MW plant; costs higher for small plants
- PJM: Plants <400 MW & >40 years old at high risk of retirement
  - 25% of PJM’s 80 GW of coal

Lazard, Levelized Cost of Energy Analysis – Version 6.0
PJM. Coal Capacity at Risk of Retirement in PJM
Summary

• Switching to gas is a viable path to 30% CO$_2$ reductions

• However, the net effect on warming is unclear due to fugitive methane emissions.

• Health benefits are large, and currently not adequately monetized
Thank you!

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100-year warming potential

A: High-efficiency gas

B: Average gas

C: Zero-emission plants

Quantified with MAGICC6 climate model*

Methane’s warming potential

- **Global Temperature Potential (GTP):** “*change in global mean surface temperature at a chosen point in time in response to an emission pulse relative to that of CO₂*”*

- $GTP_{CO₂} = 1$
- $GTP_{20CH₄} = 68 \pm 75\%$
- $GTP_{100CH₄} = 15\pm 75\%$

$$\Delta T_i = \sum_{i=1}^{I} \sum_{n=1}^{N} GTP_i(n) \times AGTP_{CO₂} (n) \times M_i(n)$$

Change in warming from U.S. power sector

Sensitivity to EIA reference case

3% fugitive CH4 rate, GTP20_{CH4} = 68 ± 75%
U.S. coal plants

As of 2009:
- 560 plants
- 380 GW (1/3 of U.S. total)
- 45% of U.S. generation
- Avg age: 41 years

eGRID 2009
Some think of gas as a ‘bridge fuel’

• “The Obama Administration has promoted […] actions to promote fuel switching from oil and coal to natural gas or renewables” – President’s Climate Action Plan, June 2013

• “What I would argue is that the way to look at it […] as kind of a bridge to a very low carbon future – is that it affords us a little bit more time to develop the technologies, to lower the costs of the alternative technologies, to get the market penetration of these new technologies.” -Secretary Moniz, May 2013