Roadmap

• Global energy demand on the rise!
• Why do we care?
• Overview of coal based energy production
• Overview of natural gas based energy production
• Quantifying environmental impact
• Coal vs. Natural Gas-The impacts and improvements
• Final verdict
Global Energy Demand Is Growing!

- Global energy demand grew by 8% from 2008-2012
- Demand projected to increase by 37% by 2040
- Development of renewables is being outpaced by energy demand growth
- How to meet this increasing demand?
  - Coal
  - Natural Gas
Question

Given the choice of either coal or natural gas based power production, which is better?

Let’s take a look!
Environmental Concerns

• Traditional methods of energy production produce greenhouse gases.
  – Global warming
  – Other environmental concerns

• Important issue when comparing energy sources!
Coal Based Energy Production

• “Traditional” fuel for electricity production
• Accounts for ~40% of electricity production nationwide
• Used to produce electricity for public since first “Edison Plant” in NY in 1882.
Typical Coal Power Plant Process

Source: http://www.ascovalve.com/Common/Images/Coal_Plant_Simple.jpg
Impacts of Coal Based Power Production

• Significant water use to remove impurities
• Emission of CO$_2$, SO$_2$, NO$_X$, mercury compounds
• Leaves behind ash requires disposal
Natural Gas Based Energy Production

• Newer technology

• Accounts for ~28% of electricity production in the U.S.
  – But this number is growing!

• Results in significant reduction of GHG emissions at the plant level!

• Can be transported in pipeline → lower energy requirement than coal
Typical Natural Gas Power Plant Process

Impacts of Natural Gas Based Power Production

• Methane leakage in pipelines
• Hydraulic fracturing used to produce natural gas
• Impacts of hydraulic fracturing may outweigh NG benefits as fuel source
Is Natural Gas the Answer?

Estimated emission reductions of natural gas versus coal in electrical generation:

- Carbon dioxide: 50 - 60%
- Carbon monoxide: 90%
- Sulfur dioxide: 99%
- Nitrogen oxide: 80 - 90%
- Particulate matter: 99%
- Mercury: 100%
Background

- Natural gas - ↓ CO₂
- Methane
  - More potent GHG

- CO₂ - ↑ atmospheric lifetime
- CH₄ - ↓ atmospheric lifetime
Quantifying Greenhouse Gas Emissions-
Radiative Forcing:

\[ RF = (\text{incoming solar radiation}) - (\text{outgoing solar radiation}) \]

- Assess climate response of different GHGs
- Instantaneous measure
  - must consider future impacts

Comparison of RF Values of Coal and Natural Gas

- Coal $\text{CO}_2$
- Gas $\text{CO}_2$
- Gas $\text{CH}_4$

**Long-term**
Coal produces 2X $\text{CO}_2$
NGas↑

**Short-term**
Ngas ($\text{CO}_2 + \text{CH}_4$) = Coal
NGas↓

*Berkeley Earth, 2014, 12-14.*
Life Cycle Assessment

- 100 year period
  - Methane
  - CO$_2$
  - Upstream CO$_2$
    - Sale of fossil fuels

*Climatic Change Letters. 2011*
Greener Processes for Energy Conversion

- New processes of converting coal to energy
- New methods of acquiring natural gas
Underground Coal Gasification (UCG)
Integrated Gasification Combined Cycle (IGCC)

http://large.stanford.edu/courses/2012/ph240/mao2/
Comparison of IGCC with and without Carbon Capture and Storage (CCS)

<table>
<thead>
<tr>
<th></th>
<th>IGCC</th>
<th>IGCC+CCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal chemical power input (MW)</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>Gross power output (MW)</td>
<td>513.4</td>
<td>459.3</td>
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<tr>
<td>CO$_2$ capture and compression (MW)</td>
<td>0</td>
<td>32.1</td>
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<tr>
<td>Net power output (MW)</td>
<td>438.8</td>
<td>352.6</td>
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<tr>
<td>Net efficiency (%)</td>
<td>43.88</td>
<td>35.26</td>
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<tr>
<td>CO$_2$ specific emissions (g/kW h)</td>
<td>770.1</td>
<td>95.9</td>
</tr>
</tbody>
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Biomass Conversion into Methane

http://www.upsbatterycenter.com/blog/biochemical-conversion-biomass-energy/
Methane Captured from Landfills

http://epa.gov/climatestudents/solutions/technologies/methane.html
Conclusions

• Coal vs. Natural Gas, which is better?
  – Evidence does not lend itself strongly to either side

• Future work
  – Reduce environmental impact of each approach through technological development

• Recommendation
  – Underground natural gas fed power plant
Works Cited

• https://www.iea.org/Textbase/npsum/WEO2014SUM.pdf
• https://www.encana.com/natural-gas/power-generation.html
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