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Comparing Coal and Natural Gas

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Introduction

A comparison of coal, natural gas and alternative energies is important for the hydraulic fracturing boom because it endeavors to remove bias and help the public form opinions unaffected by advertising. In the debate of whether to pursue shale gas resources, it is known that natural gas combusts cleaner than coal, but production emissions are not always considered. An analysis of coal and natural gas from production through use allows the reader to see the big picture of how natural gas will impact the future compared to coal. This comparison strives to address whether natural gas is a transitional fuel to a low carbon economy as industry says, and if it will be used as such.

It is important to provide the public with information beyond industry advertising and environmental group opinions to make educated decisions about what they want to happen in their communities. An educated voting base can also more efficiently interact with politicians to seek legislation and regulation representative of communities' needs.

Comparing coal, natural gas and alternative energies is important for Lehigh students because the Marcellus Shale in Pennsylvania is a fracking hotspot. While fracking is not occurring in the Lehigh Valley, air and water quality issues can spread from other areas. Lehigh students should consider whether they should pressure the university to divest from companies supporting fracking. Most importantly, Lehigh students are future employees of many industries; business students will determine what to finance and engineering students will foster advancements to make the fracking process more efficient and protect the environment, or they will push toward alternative energies.

For a comparison of coal, natural gas and the potential impact on a move to renewable energy, we will look at scientific uncertainty, methane emissions, the use of these fuels in power plants, the change in U.S. and global emissions, and how coal, gas and renewable energy development are dependent on each other.

In the midst of industry lobbying and advertisements it can be difficult to discover the truth. Such is the case with the comparison of coal, natural gas and alternative energies. There is a substantial amount of scientific uncertainty on how much impact shale gas will have on the environment when compared to coal. There are limited verified, publicly available and peer-reviewed data to make an in-depth analysis of life-cycle emissions for shale gas. Data used in many of the studies previously conducted on this topic are "subject to high levels of uncertainty and may change significantly over time as industry develops" (Broderick et al., 2011, p. 49-50).

Methane Emissions

Life-cycle analysis of shale gas is complicated by the debate of how methane emissions should be measured. Methane emissions are measured in carbon dioxide equivalents, or the warming potential over time that a greenhouse gas has compared to the warming potential of carbon dioxide. Carbon dioxide can reside in the atmosphere for almost a century after it is released, but methane has a residence time of about 10 years.

While methane is in the atmosphere for less time, researchers say a ton of methane traps up to 25 times more heat than a ton of carbon dioxide (Revkin & Krauss, 2009). As a result, controversy arises. When the Environmental Protection Agency (EPA) calculated the average concentration of methane in the Earth's atmosphere over a period of 100 years, it determined that one ton of methane in the atmosphere is the same as 21 tons of carbon dioxide. However, other scientists argue that because of methane's shorter residence time in the atmosphere, its impact should be calculated over the span of 20 years rather than 100. Robert Howarth, a professor of ecology and environmental biology at Cornell University, calculated that when a 20-year period is used in calculations instead of 100 years, one ton of methane is the same as 72 tons of carbon dioxide (Lustgarten, 2011b).

In 2009, the EPA concluded that the amount of methane released by routine operations at gas wells was 12 times its original estimates of nine billion cubic feet (Revkin & Krauss, 2009). According to an article in ProPublica, a non-profit independent investigative journalism organization, these greenhouse gas emissions are comparable to annual emissions from "35 million automobiles" (Lustgarten, 2011b; 2011a). Using EPA's revised estimates, methane levels from fracking in the Marcellus Shale are 9,000 times higher than previously reported levels (Lustgarten, 2011b). Current total methane emissions from the gas industry are 261 million metric tons (Lustgarten, 2011a). The World Bank estimates that gas-drilling emissions are at least one-fifth of human-caused methane residing in the atmosphere (Lustgarten, 2011b).

Howarth (2011) estimated the life-cycle emissions of an average shale gas well are 3.6 to 7.9 percent of the total lifetime production of that well (p. 685). The total emissions of shale gas are 20 to 50 percent higher than that of coal, based on the quantity of energy available during combustion over 20 years. Meanwhile, when analyzed over a period of 100 years, the total emissions of shale gas and coal are comparable, Howarth stated (p. 686). J.D. Hughes of the Post-Carbon Institute, a non-profit think tank in California, tried to reconcile Howarth's findings with other studies in an Institute 2011 report because Howarth's life-cycle analysis did not include the efficiency of final use of the fuel. When the efficiency of fuel use is taken into account, natural gas gains some advantage over coal when used to generate electricity because of power plant efficiencies (p. 686). Hughes found that shale gas does have higher total emissions than coal if the well's lifetime production is less than 1.5 billion cubic feet, using the 20-year global warming factor value for methane. However, if the well produces more than 1.5 billion cubic feet or if the 100-year factor is used, then shale gas has lower total emissions than coal (Klemow & Fetcher, 2011).

Coal versus Natural Gas in Power Plants

Natural gas can provide twice the energy that coal does per unit weight, and natural gas produces around half of the carbon dioxide produced by coal per unit of power (Cathles et al., 2012, p. 531; Clark, 2013). Coal combustion emits 93 tons of carbon dioxide equivalents per terajoule of electricity, while natural gas produces 57 tons of carbon dioxide equivalents per terajoule (Broderick et al., 2011, p. 109). A terajoule is the same amount of solar energy that reaches an area of 1.5 football fields in one day. Natural gas is

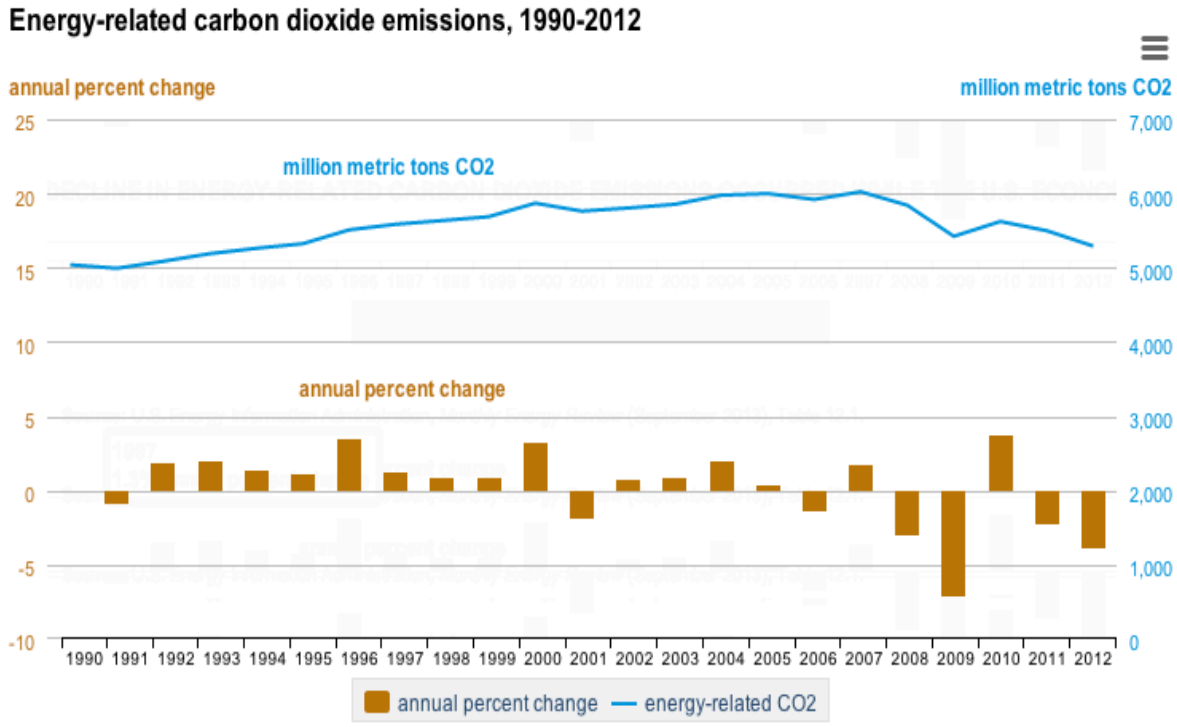
also considered to be a cleaner fuel than coal because it does not produce sulfur, mercury, ash, and particulates that are harmful to the environment and human health (Cathles et al., 2012, p. 526). Hayhoe et al. (2002) shows that substituting gas for coal using a 100-year span instead of a 20-year span does reduce global warming potential. "They consider the warming effects of decreasing [sulfur dioxide] and black carbon emissions as coal burning is reduced, as well as the warming effects of [carbon dioxide] and [methane] emissions" (as cited in Cathles et al., 2012, p. 527).

When the full life-cycle greenhouse gas emissions are analyzed, including the production and combustion emissions, the advantage of natural gas is maintained only when burned in modern and efficient power plants. A coal-fired power plant has a thermal efficiency on average of 33 percent, while a gas-fired plant ranges in efficiency from 40 to 60 percent (IEA, 2012, p. 6; as cited in Broderick et al., 2011, p. 63). Before the EPA revised its emissions estimate, the average gas-fired power plant was about 32 percent cleaner than coal-fired power plants, according to Paulina Jaramillo, an assistant professor of engineering and public policy at Carnegie Mellon University. However, about half of the 1,600 U.S. gas-fired power plants "operate at the lowest end of the efficiency spectrum." Currently, the median U.S. gas-powered plant is just 40 percent cleaner than coal, while the 800 inefficient gas-fired plants offer only a 25 percent advantage, according to calculations by ProPublica based on Jaramillo's formulas.

As the advantages of natural gas versus coal become smaller with revised emissions estimates, the political push for a move to natural gas becomes weaker. Power utilities are apprehensive to invest in a fuel that may lose the government's support in the long run. "Billions of dollars of taxpayer and industry investment in new infrastructure, drilling and planning could be spent for limited gain" (Lustgarten, 2011b).

Is Natural Gas the Bridge to a Low Carbon Future?

Energy Information Administration projections suggest that the substitution of shale gas as a transitional fuel to a low carbon economy cannot be assumed in the United States. The increase in shale gas drilling and use has been complemented "by a reduction in the proportion of coal-based electricity generation, although absolute consumption of coal has not altered significantly" (as cited in Broderick et al., 2011, p. 38). Switches from coal to natural gas in the United States have accounted for about half of the 3.8 percent decrease in energy-related emissions in 2012 to a level last seen in the 1990s (Mufson, 2013). From a peak in 2007, total emissions have fallen 8 percent (Grose, 2013). The International Energy Agency warned that this drop in emissions might not continue because gas prices were unusually low in 2012, below $2 per million BTU, due to a glut of shale gas on the market caused by a lack of storage facilities and increased gas production (Mufson, 2013; Plumer, 2013). Carbon dioxide emissions for the U.S. energy sector have already increased 2.6 percent in the first half of 2013 compared to 2012, according to preliminary data. The Energy Information Administration expects the increase to continue (Plumer, 2013).

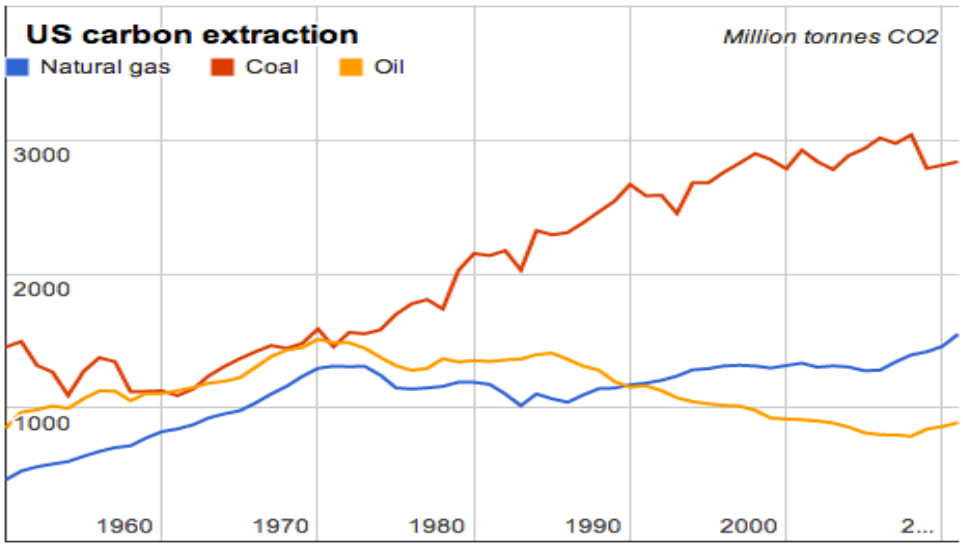


eia **Source:** U.S. Energy Information Administration, *Monthly Energy Review* (September 2013), Table 12.1.

Note: All data in this analysis refers to the Monthly Energy Review of September, 2013 unless otherwise indicated. Because of slightly differing coverage and data vintage, absolute values and percent changes may differ slightly with other Energy Information Administration (EIA) publications.

To date there has been no sign that shale gas has substituted for coal use globally. The U.S. boom in shale gas is currently primarily domestic because there are few natural gas export facilities, while there is plenty of capacity to ship coal abroad (Clark, 2013). U.S. use of coal fell by 11 percent in 2012 and domestic coal production fell by 7 percent. U.S. coal exports rose 17 percent to a new record since 2011, 12 percent higher than the previous maximum reached in 1981 (Grose, 2013). The U.S. net export of coal has tripled from 2007 to 2010, and will continue to grow as exports are increased to Asian markets (as cited in Broderick et al., 2011, p. 38). It is estimated that half of the U.S.' reported reduction of carbon emissions could be reversed from a global perspective because other countries will burn the exported coal (Grose, 2013). This increase in coal exports is tied to a 1.4 percent increase of 2012 global carbon dioxide emissions from energy, according to the International Energy Agency (Mufson, 2013).

Is coal production decreasing enough to counterbalance the shale gas boom in production? Looking at the amount of carbon extracted from the earth instead of emissions, it shows that there has been no decline, but an upward trend in the amount of carbon that the U.S. is mining. "Despite or because of the shale gas revolution, 'American carbon' is flowing into the global economy and atmosphere faster than ever" (Clark, 2013).



from Clark, D. (2013, August 5). The rise and rise of American carbon. The Guardian. Retrieved November 13, 2013, from http://www.theguardian.com/environment/2013/aug/05/us-emissions-extraction-fracking

"At the global level no new major energy source has stopped the existing sources from expanding." Even as the energy mix changes, energy use and carbon emissions show exponential growth. Each new energy source increases access to and demand for preexisting sources of energy. The shale gas boom has not drastically impacted U.S. carbon production or global emissions because new energy sources are typically added to existing sources (Clark, 2013). "Switching from coal to gas only saves carbon if the coal stays in the ground," said John Broderick, a Knowledge Exchange Fellow at Manchester University (Grose, 2013). We must focus on regulating the flow of carbon out of the ground to the atmosphere instead of believing that renewable energy or shale gas will reduce emissions by themselves (Clark, 2013).

If a new generation of gas-fired power plants is brought online they will carry on and encourage a fossil fuel energy future. However, gas-fired power plants produce carbon emissions for decades, which renewable energy options would not. Gas-fired power plants brought online in the next 10 years can remain on the grid for 25 to 40 years (Harvey 2011). Issues with shale gas arise when it is deemed a transitional fuel to a low carbon economy. "The problem is you build a gas plant for 40 years. That's a long bridge," said James Rogers, the CEO of Duke Energy. "What if, with revelations around methane emissions, it turns out to be only a 10 or 20 percent reduction of carbon from coal? If that's true, gas is not the panacea" (Lustgarten, 2011b).

Where Do We Go From Here?

Power utilities face a dilemma; they must build new power plants to meet the increasing energy demand and anticipate the future political climate and emissions regulations. (Lustgarten, 2011b). Standard & Poor's, a ratings agency, says that two-thirds of U.S. coal-fired power plants are older than 30 years and must be retired or retrofitted with new emission controls. Old and small facilities are candidates for retirement and new, larger operations will be modernized (Silverstein, 2013). Power utilities have the option of building a new gas-fired plant with a
$2 billion price tag, or wait for carbon emission controls, such as Carbon Capture and Storage (CCS) technology, to be brought to market cheaply for coal-fired plants (Lustgarten, 2011b).

Scientists say the U.S. must cut emissions in half by 2050; therefore, the European Gas Forum's analysis assumes that all gas-fired power plants will have CCS technology in place after 2030. However, this technology has never been used at the commercial scale, because it is still too expensive to install. Therefore, running costs are also not known and carbon storage problems have not been solved (Harvey, 2011). The technology is at least 15 years away from the market. If it works on the commercial scale, emissions could be cut by 90 percent, said Nick Akins, president of American Electric Power (Lustgarten, 2011b). However, the efficiency of the power plant will be reduced by 25 percent if it uses CCS technology (Sahagian, 2013).

Peter Atherton, an energy analyst at the UK company Liberum Capital, said companies face the prospect of building plants that will run at 20 percent of their capacity for the majority of their lives to meet carbon budgets. These plants could be kept on standby and only used during winter peak of energy needs, or to supplement the intermittency of renewable energy (Harvey, 2013; 2011). CCS also adds to the cost of electricity production beyond the decrease in efficiency, because it requires additional energy input for the transportation and storage of the captured carbon dioxide, raising the net quantity of production emissions for gas or coal, and more fuel is needed to attain the same electricity output (Broderick et al., 2011, p. 73).

Natural Gas or Renewable Energy?

Andrew Raingold, executive director of the Aldersgate Group, said: "This investment would be better made in real zero-carbon technologies that would provide more effective long-term options for decarbonizing electricity" (Broderick et al., 2011, p. 119). Most low-carbon technologies have their costs fall substantially once they are installed and operational, compared to natural gas which will be vulnerable to market volatility (Hickman, 2013). "Any money and investment that is going to gas is money that is not going to renewables," said Brook Riley, a staff person for Friends of the Earth, an environmental group. Gordon Edge, the director of policy for Renewable UK, said "We must be careful not to lock ourselves into dependence on a finite fuel which, while it is less carbon intensive than coal, is nevertheless much more carbon intensive than any renewable" (Harvey, 2011).

The International Energy Agency said that if nothing is done before 2020, changing emissions will be difficult because of the quantity of carbon in the atmosphere and the established energy infrastructure. As the energy industry is responsible for two-thirds of greenhouse gas emissions, it must spearhead change toward lower emission levels (Mufson, 2013). Green advocates believe that natural gas investment will crowd out investment in renewable energy until major overhauls in infrastructure are needed once again (Harvey, 2011). The infrastructure investment required to exploit natural gas puts the world in danger of a dependency on natural gas (Broderick et al., 2011, p. 119).

If climate policy remains unchanged in the U.S. and measures to control emissions remain weak, natural gas will lower gas and electricity prices while total energy use will be higher in 2050. These lower prices will stimulate economic growth, increasing total emissions by 13 percent as growth of renewable energy is slowed and development of CCS technology will be delayed. Natural gas "is so attractive that it threatens other energy sources we ultimately will need," according to Henry Jacoby, an economist from MIT. "We've got to keep our eye on the long term" (Inman, 2012).

James Bradbury, a policy analyst from the World Resources Institute, said "Given current U.S. policies, abundant and relatively cheap natural gas puts all other energy sources at a competitive disadvantage. It is particularly important for decision-makers to…usher in more renewable energy by creating incentives to help this industry thrive." Policies would need to promote innovation and investment in electric grids (Inman, 2012).

In my opinion, more regulation is needed at the federal level to standardize industry operations, what equipment is used, what site remediation is required, and what testing is required before and after drilling. Natural gas should not be relied on heavily, so that an immediate investment in renewable energy sources can be made. Energy policy must be long-term, because even when carbon dioxide emissions are lowered, current levels will remain in the atmosphere causing warming effects until these emissions degrade. We must be proactive instead of reactive in these regards.

Interview with Jason Hanna

Mr. Hanna graduated from Millersville University in 1995 with a bachelor's degree in Engineering Geology and from Pennsylvania State University in 2002 with a master's degree in Environmental Pollution Control. He has been working at Langan Engineering for 11 years where he focuses on pollution characterization and cleanup, and site redevelopment. He is also a member of the Marcellus Shale Coalition. This interview has been paraphrased.

Q: What do you typically work on at Langan Engineering?

A: A host of environmental services, including site assessments, site characterization, and site cleanups according to state and federal standards. We also support design and permitting for compliance with regulations for gas and oil companies.

Q: What would be the ideal well pad location for a natural gas company?

A: Ideally you would want flat land that minimizes the potential for erosion. If you can, you do not want to avoid impacts to natural resources such as wetlands and waterways. At Langan, we identify the natural resources the gas company should avoid and we design to avoid or minimize impacts to these resources, which also simplifies the permitting processes.

Q: You also work on the designs for natural gas pipelines. What is normally covered in those designs?

A: We complete desktop routing using GIS, or picking the path, for the pipeline. We identify and design to avoid natural resources, such as wetlands and waterways. We design erosion and sediment controls that keep the soil from eroding into nearby streams, and we complete the earthwork analyses and design site restoration. We specialize in performing geotechnical investigations for when a pipeline needs to go under a complex structure, like a river or highway system.

Q: I know that you are involved with the natural gas designs. Does Langan conduct any projects with the coal industry?

A: In western Pennsylvania seepage of acid water from coal mines is really a problem. Currently many responsible parties are treating it actively, mixing it with lime to lower the acidity, settling out the solids from the water and then disposing of the leftover sludge. At a couple sites, we are converting this active process to a passive one by removing the pumping and electricity. After studying the hydrology of the site, we build passive mine water treatment systems so that the system is gravity fed. It is lower maintenance, more sustainable and greener. Acid mine drainage is also being considered for reuse in fracking. The issue is the sulfate levels and solids dissolved in the water. When injected into the Marcellus Shale where there are high levels of barium in the formation, the sulfate in the water combines with it to form barium sulfate that precipitates out as a solid. This actually clogs the formation when you are trying to open it for gas to flow. So there is a lot of research going on to address this issue.

Q: Do you personally think that decreasing advantages of natural gas over coal will impact the political push for shale gas?

A: I do not think that it will change anything politically. Politicians are focused on job creation and the economy rather than the environment. The environment just is not the most important thing to most politicians. Shale gas is job creation here in the U.S., homegrown. It is not just natural gas production; it is also natural gas liquids and ethane, which is used to make ethylene for plastics manufacturing. The next big question is do we build plastics manufacturing here or do we export the ethylene we are producing from shale liquids to other countries where plastics manufacturing is already established.

Q: Do you personally think that the move to natural gas is going to limit the move to renewables?

A: What's surprising when you look at the funding sources for renewables is that the development and research for renewables is largely funded by the big oil companies. I personally think there will not be fewer incentives and subsidies from the government for renewables. We should not be offsetting the progress of renewables, and we should be using money from gas development to fund renewable research. Natural gas is better than coal, and can be used as a bridge fuel. "If we could be operating completely on solar and wind we would." Everyone is still just as anxious to get to renewables.

For More Information

- "Natural Gas May Be Easier On Climate Than Coal, Despite Methane Leaks" (NPR) http://www.npr.org/2013/09/16/223122924/despite-leaks-during-production-natural-gas-still-better-than-coal
- "Coal vs. Natural Gas: It's Complicated" (Houston Chronicle) http://www.chron.com/business/energy/article/Coal-vs-natural-gas-It-s-complicated-3897251.php
- "Coal vs. Natural Gas Power Plants, with Lincoln Pratson" (Duke University Energy Initiative) http://www.youtube.com/watch?v=ZzUcn01-KIg
- "Shale Gas vs. Coal" (Steffen Jenner and Alberto Lamadrid) http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2025627
- "Is Natural Gas 'Clean'?" (New York Times) http://opinionator.blogs.nytimes.com/2013/09/24/is-natural-gas-clean/?_r=0
- "Coal vs. Natural Gas Quiz" (National Geographic) http://science.nationalgeographic.com/science/coal-vs-natural-gas-quiz/

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