Coal 2040: The Future of Coal

A research paper presented by the 2013 Class of Tomorrow's Leadership Council, sponsored by the American Coal Council. This paper is intended to provide a forward-looking perspective on the benefits and use of coal now and into 2040.

Coal – a simple shiny black rock, which represents America’s largest single source of energy, has been getting a lot of attention lately. Is coal dead? This is a question that has been in the headlines often over the past couple of years, and it is a question that needs to be approached with sound reasoning and solid facts. Coal is expected to continue its important role in U.S. electricity generation; however, there are many challenges and uncertainties that could affect future outcomes.

Coal is abundant, reliable and affordable and has been the backbone of American prosperity by keeping utility bills low, and industry progressing. Coal has a proven track record of supplying our country with the power it needs, and doing it cleaner than ever before. It has gotten us to where we are today, and can take us into the future. Our ability to continue growing our economy depends on affordable, reliable power – and this can only be guaranteed by including coal as part of the energy mix.

This paper will explore numerous aspects of coal, including: the evolution of coal; past, present, and future market projections for coal utilization; current misconceptions about coal; opportunities and challenges in the coal market; the outlook for FutureGen, poly-generation and other technologies; and will demonstrate why coal is so important, why it is here to stay and why it is a critical component of a successful and diversified energy portfolio.
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Coal - A Distinguished History

Coal is the most plentiful fuel in the fossil family and it has the longest and, perhaps, the most varied history. It is simply a highly compressed plant-based fuel that is plentiful enough to drive most of the industrial growth around the world.

[Coal has a distinguished past – in fact, you can’t tell the history of America without telling the history of coal. Throughout history, coal has been used for just about everything including heating, cooking, steamship and rail transportation, forging tools, making weapons, steel and industrial production, and of course, for electric generation. Starting as early as the 1300’s, the Hopi Indians in the U.S. Southwest used coal for cooking, heating and to bake the pottery they made from clay. Coal was later rediscovered in the United States by explorers in 1673.

However, it was in the early 1800’s when coal’s potential was truly discovered, and the Industrial Revolution played a major role in expanding the use of coal. At the heart of the Industrial Revolution was the use of energy, and the energy that powered the mills, the railroads, the steam engines and the factories was coal.

In the second half of the 1800s, more uses for coal were found. During the Civil War, weapons factories were beginning to use coal. By 1875, coke (which is made from coal) replaced charcoal as the primary fuel for iron blast furnaces to make iron and steel, which was a breakthrough in building materials. The burning of coal to generate electricity is a relative newcomer in the long history of this fossil fuel. It was in the 1880s when coal was first used to generate electricity for homes and factories.]

1 Department of Energy: http://fossil.energy.gov/education/energylessons/coal/coal_history.html
Coal has been the leading fuel source for electric generation since 1949, as shown in the U.S. Energy Information Administration graph below. Even with the recent dip in net electric generation from coal sources, it still remains well above any other source.

It’s only natural that it’s the leading source of electricity demand in the United States, as reflected above, because America sits on the largest coal reserve in the world. It’s estimated the U.S. has access to 260 billion tons while we consume nearly 900 million tons per year. At this rate, our economy would be able supply America for the next 290 years.\(^2\)

Today coal provides 41% of the world’s electricity needs.\(^3\) It is the second source of primary energy in the world after oil, and the first source of electricity generation.

![Total World Electricity Generation by Fuel (2009)](chart)

**Misconceptions**

There are countless misconceptions today about coal, and unfortunately they can get blown out of proportion by special interest groups who have engaged in a prolonged campaign of public relations and litigation to put pressure on the industry in the hopes of closing coal-fueled power plants across the United States.Outlined below are three common misconceptions about coal and the factual information supporting why they are, in fact, misconceptions.

**Misconception #1**

*Can’t we just substitute wind and solar power for coal?*

With coal making up nearly 40% of the electricity generated domestically\(^4\), it would be a stretch and very expensive to cover that gap with other sources, including natural gas, solar, and wind. Some people may be surprised to know that wind and solar together generated only 3.5% of

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\(^3\) International Energy Agency: [www.iea.org](http://www.iea.org)

\(^4\) International Energy Agency: [www.iea.org](http://www.iea.org)
total U.S. net generation in 2012.\(^5\) These figures show the relative amount of coal-based generation this country uses versus other energy sources, and give an indication of the sheer scale and cost of what it would take to replace coal with wind.

**Net Generation for All Sectors, Monthly**

![Graph showing net generation for all sectors, monthly.](image)

The other challenge that we face is the fact that wind cannot act as a baseload energy supply. Wind has approximately a 34% capacity factor\(^6\) because it is not a constant resource - it doesn't blow 100% of the time. Ideally you would need some means of storing excess wind power so it can be used to smooth out spikes and lulls in generation caused by changing wind patterns and speeds. At present, there are not any proven or commercially viable storage technologies. Without an option or means to store massive amounts of power, utilities need to maintain a constant and permanent source for back up generation to guarantee power supply at all times. “In today’s reality, that firming power means coal or natural gas. This means that utilities have to build and maintain almost double the generation capacity they would need if they were simply building coal, nuclear, gas, or hydro. That reality leads to massive expansions in the cost of providing electricity, which means your electric bill has to grow to cover those costs.”\(^7\)

A 2005 report by E.ON Netz – one of the largest suppliers of wind energy in the world – stated that wind generation could only replace traditional power stations to a “limited extent.” They

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\(^6\) EIA Annual Energy Outlook, 2013: [www.eia.gov/forecasts/aeo/pdf/0383%282013%29.pdf](http://www.eia.gov/forecasts/aeo/pdf/0383%282013%29.pdf)

\(^7\) American Coal Council Coal Myths and Facts: [http://www.americancoalcouncil.org/?page=coalfacts](http://www.americancoalcouncil.org/?page=coalfacts)
argued that since wind power has a “limited load factor even when technically available” utilities need to maintain permanently online backup generation “with capacities equal to 90% of the installed wind power capacity … to guarantee power supply at all times.” In the same report, they stated that “wind power feed-in can only be forecast to a limited degree” and that further use of wind energy would require massive investments in new transmission infrastructure to avoid electrical grid congestion and system failures. Describing their experience with wind generation, they stated that periods of extreme cold and high summer heat correspond to “stable high-pressure weather systems,” (translation: the wind doesn't tend to blow when energy demand is at its greatest). This assertion was proved out during the 2006 California heat wave. From July 13 to 23, 2,500 MW of installed wind capacity was unable to provide more than 325 MW – a 13% or lower capacity factor.

Adding to these difficulties is the fact that one of the key reasons for the push to replace coal with wind is to reduce emissions. It is coming to light that renewable portfolio standards may have had serious negative unintended consequences in Colorado, Texas, and other areas around the world. A study conducted by Bentek Energy, LLC, titled "Wind, Coal and Gas in Colorado: How Less Became More" demonstrated that mandating the use of wind generation forced coal and natural gas generating units to operate in an inefficient manner due to cycling the baseload units. This process called "cycling," is when those units are forced to ramp up and cut back on generation rapidly in response to wind's variable nature. Coal-fueled power plants are designed to run most efficiently at stable rates and are not well-suited to accommodate the load variability imposed by the integration with wind generation. Cycling causes coal-fueled power plants to operate less efficiently, and reduces the effectiveness of their environmental control equipment, which together drive up emissions. Ironically, using wind energy in such a way that it forces utilities to cycle their coal generation often results in greater SO2, NOX and CO2 emissions than would have occurred if less wind energy were generated and coal generation was not cycled. In many instances over a four year study period, this cycling actually added to the air pollution problem by causing increases in emissions of CO2, NOX, and SOX. Other studies and utilities are arriving at similar conclusions.

There's no doubt that wind energy will continue to be a valuable segment of our generation mix. However, the reality is that wind is a high-cost option, by its nature it is limited in the amount of generation it can provide, and mandating its use can actually cause an increase in overall emissions.

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9 http://www.energycentral.com/articles/article/1332
10 Department of Energy: www.doe.gov
Misconception #2
Today’s Climate Change (temperature and significant weather events) is unusual, and is the result of coal-fired power plants.

“The Earth is always searching for a balance that it can never fully achieve because of the design of the system. We rotate around the Sun on an axis that tilts, with more land in the Northern Hemisphere than Southern Hemisphere”. This is a quote by Joe Bastardi, Chief Forecaster with WeatherBELL Analytics.

Throughout history, there have always been periods of warming and cooling. Long before civilization, there was far more extreme climate change than today. In the past 1.6 million years there have been at least 33 glacial advances and interglacial warm periods where temperatures soared above that which we experience now.11

[Climatologists argue that the Modern Warming, the rise in global temperatures over the last 130 years, is abnormal in Earth’s history. They then conclude that human contribution to a trace gas in our atmosphere, carbon dioxide, must have caused this rise. But a closer look at temperatures shows that the rise in Earth’s average temperature over the last 130 years has been only about 1.3 degrees Fahrenheit or 0.7 degrees Celsius. In Chicago, temperatures typically swing from about -5°F on the coldest winter day to about 95°F on the hottest summer day, about 100 degrees in a single year. Compared to the annual swing in daily Chicago temperatures, the one degree rise in global temperatures during the Modern Warming has been tiny.

So have past temperatures been constant, as the Climatologists claim? Most geologists know that the sites of London, New York, and Chicago, along with much of the Northern Hemisphere, were buried in ice 20,000 years ago during the last ice age. Global temperatures changed as much as 7°-12°C as Earth moved from glacial to interglacial periods in geologic history.

In addition to the ice ages, a vast body of additional evidence shows that Earth’s temperatures are always changing. While the database of modern thermometer measurements only stretches back 130 years, proxy data allows a look at more distant past temperatures. Measurements of oxygen isotope proxies from ice cores in Greenland show periodic warm and cool periods including the Medieval Warm Period and the Little Ice Age, when temperatures were both warmer and cooler than today’s temperatures. Natural climate change is not only real, but continuous.]12

A graph showing this long history of warming and cooling periods is shown below:

[Diagram showing temperature changes over thousands of years.]

Additionally, a look at history shows that current weather events are neither more frequent than past events nor more violent than weather of the past. Dr. Ryan Maue of Florida State University uses satellite data to monitor global tropical storm activity on an around-the-clock basis. He compiles the measured maximum wind speed for all major storms into a metric called ACE (Accumulated Cyclone Energy). In 2011, Dr. Maue reported that global tropical cyclone accumulated energy had fallen by half from 2005 levels and set a new record low, lower than the previous record low set in 1977. Dr. Maue’s data shows that, during a period of rising atmospheric carbon dioxide, there is no trend of increasing tropical storm frequency or strength.

Tornados are another type of significant weather event that tend to be attributed to man-made global warming. However, it should be noted that there was almost a complete lack of tornados in the United States in 2012. It is true that the total number of tornados recorded has been increasing, but this is due to better radar detection techniques and many of these funnel clouds never touch the ground. A graph of data from the National Climatic Data Center shows that the number of strong tornados peaked in the 1970s and has been declining for the last 30 years. There is no trend evidence to show that storms are getting stronger or more frequent due to man-made greenhouse gas emissions or other causes.\(^\text{13}\)

\(^{13}\) Steve Goreham, 2012, ‘The Mad, Mad, Mad World of Climatism’
Misconception #3

*We would be much better off if we didn’t burn coal.*

There are numerous facets to the coal industry including: mining, transportation, utilities, industry, manufacturing, and much more. Coal makes a substantial contribution to improving the livelihoods of many. We benefit from this resource on a daily basis probably without even knowing it. It plays a significant role in heating and cooling our homes, powering our phones and electronic gadgets, keeping our lights on, and powering the industries that manufacture steel, cement and all the other goods and materials that we count on. It even powers electric vehicles when they are charging. Businesses and healthcare facilities depend on the dependable, reliable and affordable energy that coal provides.

In addition to its direct role as an energy resource, coal plays a significant global role in sustainable development. This is especially true in developing countries where coal mining makes a major contribution to national economies allowing them to grow stronger and address the challenges of poverty and development. These challenges also include widening access to affordable energy supplies. Today there are 1.3 billion people across the globe without access
Affordable, secure and reliable electricity supply enables economic development, which is a prerequisite for poverty alleviation. Coal is the only thing that has the ability to provide the scale to meet this need. The use of coal is under pressure, but it is critical that we keep electricity affordable. The vast majority of Americans depend on low-cost electricity, and if rates were to increase, some people would probably have to go without. Modern life would be unimaginable without access to affordable energy.

Looking Forward

Coal is currently responsible for 37.4% of all the electricity generated in the United States, more than any other source of energy. Also, the U.S. Energy Information Administration projects coal will remain the dominant fuel for electricity generation in our country at least through 2040.

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14 World Coal Association: www.worldcoal.org/coal-society/
Opportunities and Challenges in the Coal Market

Looking beyond the current economic state and perception of the industry towards the next 30 years, coal is, in fact, the world’s fastest growing major fuel; representing 56% share of global energy since 1969. It is on track to continue to pass oil by 2030 as the largest energy source. A shocking number of 3.6 billion people have no or only partial access to electricity in the world. Asia represents 90% of 4.2 billion tons of coal demand growth from 2010 to 2035, making coal’s importance remain.\(^\text{16}\)

More opportunities for coal on a global level include China’s urbanization. This will help drive enormous energy use, as steel and generation build-out on coasts will encourage greater imports. India’s domestic coal production consistently falls below targets, and they struggle to meet demand, resulting in many blackouts and revealing the necessity for improved grid and coal imports.\(^\text{17}\) Once natural gas gets into the global market, we will see price stability as it relates to coal. The Department of Energy has approved 20 export terminals for gas. The U.S. needs to double export terminal capacities to get into thermal coal trade market,\(^\text{18}\) something that is being looked at seriously by the coal industry. According to IEO2011, much of the increase in demand for energy in non-OECD Asia, particularly in the electric power and industrial sectors, is met with coal. With coal-fueled power plants satisfying a substantial portion of China’s total power generation requirements throughout the period to 2040, the increase in electricity demand in the sector can be viewed as a probable increase in demand for coal.\(^\text{19}\)

The future opportunities for coal are clearly to be taken seriously. Japan is the second largest steel producer in the world, after China, and it continues to import coking coal for its steelmaking plants through 2040. China remains a net coal importer through 2040, surpassing Japan in 2015 as world’s largest importer of coal.\(^\text{20}\) China’s increase in imports, and the fact world steel is expected to increase 35% by 2020, will make coal a viable player on a global level still.

The U.S. holds 30% of global coal reserves, and has numerous opportunities to expand both exports and domestic uses.\(^\text{21}\) Ambre, for example, is establishing a U.S. coal export business with the first two international contracted customers in place (increasing from 14.8mt in 2018 to 30.3mt by 2020). This potential to grow in export markets will continue. As of June 2013, there are currently three export terminals, four permits submitted for new terminals, and two that will be submitted in the near future.\(^\text{22}\) With the largest coal reserves in the country, increasing coal production in Montana by way of export terminals would yield an economic boom and bonanza in terms of new jobs, economic growth, and an expanded tax base.\(^\text{23}\) The U.S. Coal industry is gearing up to be a steady, large scale supplier of coal to world energy markets. This growth into

\(^{16}\) Jacob Williams, VP Global Energy Analytics, ACC June 2013
\(^{17}\) Jacob Williams, VP Global Energy Analytics, ACC June 2013
\(^{18}\) Andy Miller, Ernst and Young, ACC June 2013
\(^{19}\) EIA Annual Energy Outlook, 2013: www.eia.gov/forecasts/aeo/pdf/0383%282013%29.pdf
\(^{20}\) EIA Annual Energy Outlook, 2013: www.eia.gov/forecasts/aeo/pdf/0383%282013%29.pdf
\(^{21}\) Andy Blumenfield, VP Analysis and Strategy, Arch Coal, ACC June 2013
\(^{22}\) Dan Speck, COO Ambre Energy, ACC June 2013
\(^{23}\) Chuck Denowh, Alliance for Northwest Jobs and Exports
world export markets could help to counter decreasing domestic demand. Planned port expansion could allow U.S. exports to more than double by mid-decade from the 107mn short tons exported in 2011. This could be a major expansion opportunity for the coal industry, especially since PRB coal meets China’s new coal restrictions. Despite having its own reserves, China’s coal is high in ash, sulfur, and low quality. China uses over three billion tons per year; which could potentially run resources low and open the door for reliance on imports.

In terms of coking coal, Australia, U.S., and Canada rank as the top three exporters and are projected to remain the top 3 through 2035. However, the lack of a large West Coast export terminal hampers the U.S. access to Asian-Pacific export markets. Alternatively, Powder River coal producer Arch Coal has secured a deal that will allow it to export coal through Ridley Terminal in British Columbia through 2015. Sustained high international demand and prices and supply constraints in other coal-exporting countries support expectations of larger U.S. export volumes.

Domestically, for a few months in 2012, the United States saw natural gas-fired power plants run more economically than coal plants in some regions. Driven by low natural gas prices, coal and natural gas plants (topping all other forms of electric generation) provided nearly the same share of total electric generation for the first time in history. Natural gas prices have since rebounded relative to 2012 prices. Coal-fueled generation has regained market share in 2013 compared to 2012 in which coal plants only accounted for 38% of total electric generation – lowest share in recent history. The U.S. Energy Information Administration (EIA) projects coal will account for 40% of total U.S. electric generation by 2013. Although coal generation has seen some recovery in 2013, coal-fueled generation has experienced a steady decline in total market share since its high of 53% of 1997. Additionally, due in part from State RPS requirements and federal tax credits, most growth in renewable electricity comes from wind and biomass facilities by 2035. Amidst regulation and policy uncertainty, greater emphasis on renewable energy, and relatively lower natural gas prices, will existing domestic power generation remain a viable market for U.S. coal in 2040?

Coal is facing certain factors that may suggest it has an uphill battle to compete with other energy forms when it comes to domestic power generation, but there’s still quite a bit of hope. Generation from U.S. Nuclear power plants increases by 10% from 2010 to 2035, but the share of total generation declines from 20% to 18% during the period. Escalating construction costs have the largest impact on capital-intensive technologies, which include nuclear, coal, and renewables. The federal tax incentives, state energy programs, and rising prices for fossil fuels, all increase the competitiveness of renewable and nuclear capacity. As discussed, coal’s share in electricity generation will fall in the next 25 years due to increased competition from natural gas and renewable generation, as well as the need to comply with regulations. The CO2

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24 Chris Newman, Argus Media  
25 Andy Blumenfield, VP Analysis and Strategy, Arch Coal, ACC June 2013  
26 EIA Annual Energy Outlook, 2013: www.eia.gov/forecasts/aeo/pdf/0383%282013%29.pdf  
27 EIA Annual Energy Outlook, 2013: www.eia.gov/forecasts/aeo/pdf/0383%282013%29.pdf  
emissions prices and actions to restrict or reduce those emissions will have an impact for the outlook on U.S. coal production as well. Appalachian coal pricing will continue to increase and the region reflecting a higher value coking coal will lead to declining shipments of thermal / steam to domestic markets. This, however, opens up the door for this region to be a major player in the steel industry, due to its coking quality of coal.29

There still is hope. After 2020, OECD coal consumption increases to 46.7 quadrillions BTU in 2035, largely because of an increase in natural gas prices in the United States, which will allow coal to compete more effectively with natural gas in the electricity sector. The future for natural gas looks bleak from the standpoint of volatility; capital investments for new technology may not be viable.30 The illusion that coal is already starting to decline by pointing at mine/plant retirements can be skewed. Many of the retirements are 50 years or older and the production at these facilities is extremely low (<200MW on average).31 The remaining fleet has tremendous room to grow and extreme capabilities to meet new regulations. We are also starting to see U.S. coal markets shifting to low cost basins PRB and ILB.32

Despite anti-coal campaigns from special interest groups and excitement surrounding the recent Climate Change Plan announced by President Obama, coal will remain a viable source for domestic power generation. The abundant resource will continue to play an important role in providing reliable, clean energy in the United States. Coal's market share going forward remains unclear given the many uncertainties that could impact coal generation. A few of the most important factors to consider are fuel price projections (natural gas vs. coal), renewable tax credit extensions, and last but definitely not least, new and future environmental regulations. The EIA recently completed its Annual Energy Outlook for 2013 (AEO2013) and provided an outlook on coal-fueled generation versus other forms of generation, taking into consideration the many uncertainties. In 2040, the AEO2013 projects coal will still remain the number one fuel source for U.S. domestic electricity generation; however, the percentage of generation from coal will steadily decline over the next 30 years to only 35% of total generation in 2040 (vs. 42% in 2011). The EIA looked at several different cases, taking into consideration the many different variables and uncertainties but focused mainly on the Reference Case. Important Reference Case assumptions include the implementation of CAIR following the vacation of CSPR in August 2012, the implementation of MATS (Mercury and Air Toxics Standards) in 2016, Renewable federal subsidies extensions expire as enacted, and U.S. import growth is slower than export growth 2011 – 2040, inferring more domestic product is used for U.S. demand. As shown in the figure below, coal generation continues to grow on average – 0.2% increase per year – over the next 30 years, remaining an integral part of the generation portfolio.

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30 Andy Blumenfield, VP Analysis and Strategy, Arch Coal, ACC June 2013
31 Andy Blumenfield, VP Analysis and Strategy, Arch Coal, ACC June 2013
32 Jacob Williams, VP Global Energy Analytics, ACC June 2013
Electricity Generation by Fuel, 1990 – 2040
Trillion kilowatthours per year

Generation by natural gas and renewables both gain market share over the same time frame, gaining 5% and 3% respectively; however, coal remains on top. Although the reference case serves as a starting point for analysis, as mentioned, there are many uncertainties that could affect coal generation going forward such as fuel price projections, renewable energy, and environmental policy and regulation.

Fuel Price Projections
The AEO2013 Reference case assumes coal generation recaptures some market share lost during the low natural gas period in 2012 as natural gas prices increase faster than coal prices. There are many factors that will impact natural gas and coal prices going forward. The Reference case assumes the U.S. becomes a net exporter of natural gas by 2019 driven by much higher volumes of shale gas production. In conjunction with the cost of new drilling production as lower cost production gas resources become depleted, the Henry Hub spot price is projected to increase to $7.83 per million Btu in 2040 according to the EIA. Natural gas exports are a pressing topic in recent headlines. If the Department of Energy does not inevitably agree to allow companies to increase shipments of natural gas overseas, domestic supply will remain abundant, possibly leading to lower natural gas prices. In addition to exports, economic growth, resource recovery rates, oil prices, and future policy will also impact natural gas prices, and inevitably, its relationship to coal prices.

Coal prices will be impacted by some of the same factors affecting natural gas prices. Economic growth, domestic policy, and export opportunity will all affect coal prices. Other variables include mine productivity, mine resources (labor, equipment, etc.), and coal transportation as it relates to delivered costs. The growth rate of coal prices vs. natural gas prices, based on the assumptions listed, will lead to the relative difference between the two fuel types. Fuel competition varies by region; however, the typical combined-cycle natural gas plant
has the opportunity to displace coal generation at a 1.5 ratio (reaching competitive parity) due to lower generation costs. As shown in the Figure below, high or low fuel costs affect the ratio and overall competitiveness between coal-fueled plants and natural gas combined-cycle plants.

**Ratio of Fuels Costs: Natural Gas Combined-cycle to Coal-fueled Plants, 2008 – 2040**

Average per megawatthour

![Graph showing ratio of fuels costs](image)

**Renewable Energy**

Tax credits and federal / state mandates for renewable energy sources have led to continued increases in new renewable electricity capacity. On January 1, 2013, the American Tax Relief Act of 2012 was extended by Congress which prolonged tax credits to utility renewables.\(^{33}\) In addition, individual state Renewable Portfolio Standard (RPS) programs require utilities to add a certain percentage of renewable energy to their overall generation portfolio. According to the EIA AEO13, 30 states plus the District of Columbia have RPS programs that are “enforceable”. The American Tax Relief Act extension and RPS standards will lead to an increase in renewable generation in out years (2% vs. EIA’s Reference case that does not include the American Tax Relief Act extension); however, the overall impact on coal will be minimal. Coal generation provides an affordable base-load energy supply that renewables are unable to provide due to limited load factors. For example, wind does not blow all the time; capacity factors are between 25 – 30%.\(^{34}\)

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\(^{33}\) EIA Annual Energy Outlook, 2013: [www.eia.gov/forecasts/aeo/pdf/0383%282013%29.pdf](http://www.eia.gov/forecasts/aeo/pdf/0383%282013%29.pdf)

A rising concern with the idea of moving away from coal and attempting to fill its void with renewables is how we will feed our country’s hunger for power when it comes to our data consumption. Nearly 20 years ago only about 1.7% of the U.S. population had access to the Internet. By 2011, almost 78% of the US population had the world digitally at their fingertips via smart phones, computers, personal tablets, etc. With this number of increasing daily, so are the number and size of data centers that store all of our data remotely.

Today, datacenters that feed our nation’s electronical addition, and consume more than 3% of U.S. electricity, and approximately 1.5% to 2% of global electricity, (and are) growing at approximately 12% annually. How can these massive power consumers possibly be powered by unreliable power generation, such as wind?

A problem with wind power is that the output doesn’t correspond with peak data demands. With facilities such as data centers, power has to be available at the same time information flows from these centers. In order for wind farms to sustain power needs, they need to be anchored by fossil fuel power plants, such as coal.

Renewables cannot solely provide the reliability required to support the power grid. Renewable energy will continue to grow and remain an integral part of the overall electricity portfolio, but the current overall threat to coal generation is marginal.

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36 Koomy, Worldwide Electricity Used in Data Centers, 2008: www.koomy.com/research.html
Environmental Policy and Regulation

Future and new regulations surrounding coal generation and production could negatively impact domestic coal-fueled generation. In December 2011, the EPA signed a rule – mercury and air toxic standards (MATS) – setting emission limits for new and existing coal-fueled plants nationwide. The ruling gives existing plants three years to comply under the Clean Air Act. Plants can be granted a fourth year by state authorities, on a plant-by-plant basis, for the installation of technology needed to comply. Assuming generators will request the fourth year for implementation, plants will have until 2016 to comply with MATS. In addition, the U.S. Supreme Court recently announced that it will review the EPA’s Cross-State Air Pollution Rule (CSAPR) previously rejected by an appeals court. CSAPR would replace the existing Clean Air Interstate Rule (CAIR), requiring substantial reductions in sulfur dioxide and nitrogen oxide. Both MATS and CSAPR, if passed, require the addition of controls to comply with emission limits. Taking into consideration other economic factors, generators are faced with the dilemma of determining whether or not existing coal units, not currently equipped with the necessary controls (e.g. scrubbers), should be retired.

The EIA estimates 49 gigawatts of coal-fueled capacity will be retired between 2011 and 2040 (reference case). Despite retirements, projections show coal-fueled generation increasing by an average of 0.2 percent by year between 2011 and 2040 as a result of increases in the utilization of existing coal plants. Many of the announced coal retirements are older, less efficient units with lower capacity factors. As these older units retire, the average capacity utilization of remaining coal-fueled generation will increase. Existing generation will be operated more intensively. EIA also assumes 15 gigawatts of new coal-fueled capacity are added during this time frame. Fuel prices and environmental uncertainty could impact additional retirements and new capacity.

Potential greenhouse gas (GHG) emission policies are another uncertainty for coal generators as it is a top priority of the current administration. President Obama’s recent Climate Change Action Plan calls for carbon emission limits on new and existing power plants. The plan would limit carbon emissions from power plants for the first time in U.S. history. Obama ordered the EPA to determine the guidelines for carbon emissions by June 2015. Following the completion of the order, each state would then be asked to develop and submit a plan to meet these standards. If the plan is successful and implemented per Obama’s aggressive timeline, additional coal retirements would be likely; however, the importance of coal as a reliable and affordable resource cannot and will not be able to go unnoticed.38 39

In addition to both CSAPR/CAIR and MATS, the EPA recently released its Carbon Pollution Standards on September 20, 2013. Newly constructed coal-fueled plants will need to meet a limit of 1,100 pounds of CO2 per MWh to comply with an option of meeting a somewhat tighter limit if generators choose to average emissions for several years. Per EPA, current average CO2 emission rates produced from coal-fueled generation stands at 2,249 pounds per MWh.

38 EIA Annual Energy Outlook, 2013: www.eia.gov/forecasts/aeo/pdf/0383%282013%29.pdf
Below is the heading from EPA’s release of the new standards (seems that this one is their “stock” heading for all releases these days):

“Climate change is one of the most significant public health challenges of our time. By taking commonsense action to limit carbon pollution from new power plants, we can slow the effects of climate change and fulfill our obligation to ensure a safe and healthy environment for our children,” EPA Administrator Gina McCarthy said. “These standards will also spark the innovation we need to build the next generation of power plants, helping grow a more sustainable clean energy economy.”

If we assume that these newly defined standards are upheld, then how do we address the question at hand of how the market will react? Will the mining industry be able to adapt to a new production landscape that bears little resemblance to the one we’ve all grown accustomed to?

We’ve already begun to see how production plans to react to the apparent future of the fossil fuel mix. The fundamentals point more and more emphatically to the lowest cost production basins as the “new” trend going forward. We’ve already seen PRB and ILB chipping away at real estate in the mix as CAPP struggles with what it “wants to be when it grows up”.

Basic supply and demand models will tell us that PRB and ILB continue to consume market share in the domestic generation market (low production cost, friendly freight rates, and maximization of installed scrubbers) while higher cost CAPP (and NAPP) must force themselves into pure metallurgical (domestic and export) and Atlantic basin export players.

From this, we’ve seen “traditional” consumers of Central Appalachian coal transform into users of more evenly blended products across basins and even nearly exclusive users of western and centrally produced product (see Southern Company and TVA). Even PJM stalwarts AEP and FirstEnergy have significantly ramped up consumption of Wyoming, Colorado, and Illinois produced products in the heart of Appalachia.

As illustrated in the EIA charts below, we can see both coal consumption and real price delivered (mmBTU basis) on a steady upward curve projected through 2040. With this limited set of data we have to work with, we’re almost certainly forced to assume that the rise in real delivered price will come at the expense of both producer margins as well at ratepayers.

Pulling together the two main points above with the data at hand, the picture begins to focus even more clearly towards more of the “new” normal we’ve seen in the last few years with lower $/mmBTU coals becoming incrementally higher to the end user with regulation factoring which essentially flattens out into delivered prices we’ve seen CAPP occupy over the last 50 years in order to match up with essentially stagnant costs of generation.
Total Energy – Real Prices Delivered Coal: 2010 – 2040

Total Energy – Coal Consumption: 2010 – 2040
Outlook for New Technologies

Safe, affordable, clean energy has been a topic in the United States for many years, but has gained increasing momentum in recent years. In response to the growing concern over pollutants emitted from coal-fueled utility power plants, the G.W. Bush administration announced the FutureGen project in 2003. The intention was to build the world’s first zero-emissions coal-fueled power plant by combining integrated gasification combined cycle (IGCC) with carbon capture and sequestration (CCS) technologies. With coal being the world’s fastest growing energy source, it could be used as a model for future clean plants around the world.

The project was designed as a public-private partnership between industry and the Department of Energy (DOE) with agreements for cost-share and development cooperation. A coalition of electric utilities and coal companies – called FutureGen Industrial Alliance - was formed in July of 2004 to partner with the DOE.

In late 2005, the Alliance completed Phase 1 of the project and reached a final agreement with the DOE. The DOE was expected to contribute around $700M while the Alliance would contribute around $250M. After bidding and review, a site near Mattoon, IL was selected. The initial FutureGen program envisioned building a new power plant. During this time, prices for
materials and labor increased, which forced concerned parties to re-evaluate the project. By 2008, the cost estimates had increased from $1B to $1.75B and the DOE discontinued its cost-share agreement with the Alliance.

In 2009, the American Recovery and Reinvestment Act allocated around $1B to the FutureGen program and a new agreement was reached with the alliance. In August 2010, the DOE announced FutureGen 2.0. Meredosia, IL was selected as the site for the power plant. The Meredosia Energy Center is currently owned by Ameren Energy Resources. The plan is for the Alliance to replace an existing boiler with oxy-combustion technology. This type of upgrade is referred to as a repowering. The new boiler will send steam to an existing steam turbine generator that will produce electricity. The new oxy-combustion coal-fueled boiler will allow for carbon dioxide capture.

In early 2011, the Alliance announced that Morgan County, IL would be the CCS site for the project. This would require the construction of a 32-mile CO2 pipeline from Meredosia to Morgan County. In February of 2013, the DOE approved the final permitting and design activities for construction to begin in mid-2014. Earlier this year, the Alliance signed a binding agreement with them to purchase the portions of the plant required for completion of the project. Upon construction, the option to purchase will be executed.

As emission regulations tighten, the need for an alternative to traditional pulverized coal burning is earned through oxy-combustion technology. This technology, provided by The Babcock & Wilcox Company and Air Liquide Process and Construction, Inc., burns coal with a mixture of oxygen and CO2 instead of air to produce a concentrated CO2 stream for safe, permanent storage. In addition, the FutureGen plant’s new boiler, air separation unit, CO2 purification and compression unit will deliver 90 percent CO2 capture and take other emissions, such as SOx, NOx, and other emissions, to near-zero levels.

Real-time monitoring of the CO2 stream before it exits the plant will automatically shut-down the pipeline if the CO2 composition does not stay within acceptable limits. Sulfur is converted to gypsum, which has beneficial agricultural use or may be utilized in wallboard manufacture. Particulate matter will be captured, stabilized and safely stored in a permitted landfill. Mercury is taken to a safe disposal facility.
Despite the efficiency of oxy-combustion technology, some CO2 is still generated. The CO2 will be compressed, injected and stored more than one-half mile below the earth's surface into the Mt. Simon sandstone formation. This is far deeper than where drinking water, oil, and gas generally exist. The CO2 storage facility will have various monitoring wells located at the site to monitor the sequestered CO2. The FutureGen Alliance and the Illinois State Geological Survey will review the storage process for safety. The Illinois Environmental Protection Agency will have the regulatory authority to stop injection if required.

Carbon capture and storage (CCS) is a proven technology that has been used in a variety of industrial applications since the 1930s, and it is common industrial practice to safely transport CO2 through thousands of miles of U.S. pipelines. The DOE has seven pilot demonstration CO2 storage sites around the country, including one in Central Illinois. These pilot projects have taught us that CO2 storage is safe and it is time to scale-it-up to commercial size. The Intergovernmental Panel on Climate Change estimates that CO2 can be stored at a geological site for over 1,000 years with a 99% rate of effectiveness; i.e. only leaking 1% of the stored quantity into the atmosphere.

Ensuring that geologic storage of CO2 is performed in a safe manner is a top priority of the FutureGen 2.0 project. Working with academic and scientific organizations, the FutureGen Alliance is developing a comprehensive plan with proven technologies to monitor and validate that the CO2 will be safely and permanently stored.
As part of the project, a 32-mile pipeline from Meredosia to Morgan County will be constructed to transport the CO2. The pipeline will be 10 to 12” in diameter and will be buried deep enough to protect from farming and excavation activities. This pipeline will transport an estimated 1M tons of CO2 annually.

The FutureGen Alliance consulted the Illinois Farm Bureau on an agreement that was signed with the Illinois Department of Agriculture to minimize any agricultural impacts due to pipeline construction. Landowners who live along the pipeline route have been given information about the pipeline.
In most areas, topsoil will be removed first and stored separately along the pipeline trench. Once construction is complete, the land above the pipeline will be restored. Horizontal direction drilling will be used in certain locations due to environmental, land or constructability requirements.

In the rare event that a pipeline were hit and punctured, the decrease in pressure would be immediately detected by pressure monitors in the pipeline. Placement of CO2 in the pipeline would automatically cease and the shut-off valves will engage.

The FutureGen carbon dioxide pipeline design includes a leak detection sensitivity system. If a leak is detected, the mainline block valves (MLBV$s) would shut automatically and virtually instantaneously, isolating the damaged pipeline segment and preventing the flow of carbon dioxide from the power plant and backflow from the injection well. The maximum amount of carbon dioxide that could escape before the leak was stopped would be limited to the amount of carbon dioxide contained within the pipeline between the MLBVs. Based on the design, the maximum distance between MLBVs for the Morgan County site will be 10 miles; a 10-mile pipeline segment will contain a maximum of 18 mmscf of carbon dioxide, which would vent harmlessly into the air. Depending on the pipeline damage scenario, the volume released could be significantly lower.
Current projections indicate that the entire project will be completed and operational by 2017. Under its current timetable, FutureGen would start operating in 2017 and would have enough storage capacity to continue for 20 years.

To date, FutureGen 2.0 has made significant progress. In February 2013, following the successful completion of the first phase, the DOE announced the beginning of Phase II of the project development with a new cooperative agreement between the Alliance and the DOE. This means that FutureGen 2.0 has government support as it moves into Phase III – deployment of the project. U.S. Energy Secretary Steven Chu stated that “The Department of Energy is committed to the demonstration of carbon capture and storage technologies. We believe FutureGen 2.0 is an important step in making economic, commercial scale CCS a reality. The project is an important part of a portfolio of approaches we are pursuing to reduce carbon emissions from existing coal-fueled power plants and perhaps other large, localized carbon emitters.”

The positive potential of a successful IGCC and CCS solution is unquestionable. The technology will reduce the ecological impact and restore the long-term viability of legacy power plants and the infrastructure of coal in the U.S. As the government continues to mandate “carbon change”, FutureGen 2.0 represents a bright hope to our industry. Presently, efforts are underway to complete, design, finalize permits, and close on commercial financing. Upon completion of these tasks and approval of the DOE, construction will begin in 2014 and be operational in 2017. All indications are that FutureGen 2.0 will become a reality.

There are many developments in the industry for uses of coal beyond only electrical generation. One of these developments is polygeneration from coal. As stated in Polygenerations From Coal- Integrated Power, Chemicals and Liquid Fuels, a polygeneration plant is “one that simultaneously produces two or more marketable products.” In a polygeneration process in which coal is used, the coal is first gasified to produce synthesis gas and is then cleaned and cooled. Some of this synthesized gas is then entered into gas turbines of a combined cycle power plant or fuel cells to generate electricity, and the remaining will continue through a shift reactor. At this point the cleaned and shifted synthesized gas is used to produce a product such as electric power, liquid fuels or chemicals. Not only can these products be produced, but other by products can be a benefit to polygeneration such as sulphur, methanol, hydrogen, ammonia, diesel, fertilizers and sulphuric acid. See the figure below as reference for the polygeneration process.⁴⁰

There are multiple benefits to polygeneration, which include, but are not limited to: domestic energy reliability, low emissions, potential for carbon capture, cleaner products produced, flexibility in feedstocks, flexibility to play to the market dependent upon the highest valued product at the time and lower production costs. There are negatives to polygeneration plants such as increased complexity and high capital costs. These two negatives along with the

electric utilities lacking the experience of chemical operations and products are just some of many barriers to entry in the polygeneration marketplace.  

Polygeneration

http://www.chemsystems.com/reports/search/docs/prospectus/MC08_Polygeneration_Coal_Pros.pdf

Coal to Liquids (CTL) also known as Coal Liquefaction is a form of polygeneration in which coal is converted to liquid fuel through polygeneration. There are two methods of Coal Liquefaction: Direct Coal Liquefaction (DCL) and Indirect Coal Liquefaction (ICL). Direct Coal Liquefaction “converts coal to a liquid by dissolving coal in a solvent at high temperature and pressure.” This is a very efficient process of Coal Liquefaction, however it does require the liquid product to further be refined in order to be utilized. DCL was first utilized in Germany as a commercial process. The DCL’s that were in Europe were abandoned when low cost oil from the Middle East was available in the early 1950’s. Since these amendments, DCL’s have not been used on a commercial scale, mainly due to the high costs of both capital and operating.

43 Polygeneration from Coal- Integrated Power, Chemicals and Liquid Fuels
Unlike Direct Coal Liquefaction, Indirect Coal Liquefaction (ICL) requires an additional step in the production. ICL “first gasifies the coal with steam to form a ‘syngas’ (a mixture of hydrogen and carbon monoxide). The sulphur is removed from this gas and the mixture adjusted according to the desired product. The syngas is then condensed over a catalyst – ‘Fischer-Tropsch’ process – to produce high quality, ultra-clean products.”

A primary driver for the development of polygeneration from coal is energy independence. Like the Germans in WWII, other countries are seeking further development of this technology to gain energy independence. Three significant energy commodities derived through polygeneration are electricity, diesel fuel and hydrogen. A single facility capable of producing these commodities has a high price tag relative to traditional production methods. While capital intensive, the ability to produce multiple commodities from one facility adds value. Production flexibility allows the facility to switch from producing one commodity to another or a combination of products. Having the ability to react to market movements can mitigate risk created by lower prices and capitalize on higher prices. Having production diversity in one facility is ideal, but idling equipment to produce another commodity may not be economical. Also, such a facility may not be optimized to produce each product at its lowest cost. For simplicity, separate economic analyses for each commodity compares traditional production methods with proven technology using coal as a feed stock.

This high level economic analysis compares an integrated gasification combined cycle (IGCC) and a conventional natural gas combined cycle (CC). Both technologies utilize two F-class combustion turbines feeding two heat recovery steam generators that supply steam to a steam turbine. This configuration in also commonly referred to as a 2x1 combined cycle. As described above, the equipment upstream of the CTs sets the IGCC apart from the CC. Additionally, it is assumed that carbon capture and sequestration would be required for the IGCC. A plant not equipped with CCS is also included to isolate the cost of the CCS technology. As one would expect, the capital cost of an IGCC is significantly greater than that of an NGCC.

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The table below (Table 1) shows the comparison of capital costs in 2012.

Table 1:

<table>
<thead>
<tr>
<th>Technology</th>
<th>Capital Cost (M$)</th>
<th>Overnight Capital Cost ($/kW)</th>
<th>Fixed O&amp;M ($/kW·yr)</th>
<th>Variable O&amp;M ($/MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Unit IGCC</td>
<td>$2,640</td>
<td>$4,400</td>
<td>$62.25</td>
<td>$7.22</td>
</tr>
<tr>
<td>Single Unit IGCC with CCS</td>
<td>$3,431</td>
<td>$6,599</td>
<td>$72.83</td>
<td>$8.45</td>
</tr>
<tr>
<td>Natural Gas</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional CC</td>
<td>$569</td>
<td>$917</td>
<td>$13.17</td>
<td>$3.60</td>
</tr>
</tbody>
</table>

Source: EIA “Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants”, April 2013

Table 2:

As presented in Table 2 above, the downstream CCS adds significant costs to the IGCC project. Extracting this component does make the IGCC more competitive, but the conventional CC remains more economical on a capital costs basis. The performance of each technology can be measured by how efficiently each technology converts its fuel into electricity. The most common unit of measurement is heat rate (Btu/kWh). Additionally, capacity is included in MW.
Table 3:

<table>
<thead>
<tr>
<th>Technology Performance</th>
<th>Nominal Capacity (MW)</th>
<th>Heat Rate (Btu/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Unit IGCC</td>
<td>600</td>
<td>8,700</td>
</tr>
<tr>
<td>Single Unit IGCC with CCS</td>
<td>520</td>
<td>10,700</td>
</tr>
<tr>
<td>Natural Gas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional CC</td>
<td>620</td>
<td>7,050</td>
</tr>
</tbody>
</table>

Source: www.eia.gov/forecasts/capitalcost/xls/table1.xls

While the capacity of the technologies is similar, the CCS creates significant parasitic load and negatively impacts the heat rate of the unit. Applying a fuel prices show in Table 3, above, to these technologies show the production cost of electricity.

Table 4:

<table>
<thead>
<tr>
<th>Technology Fuel Cost and Production Cost</th>
<th>$/ton</th>
<th>Heating Value (Btu/lb)</th>
<th>$/mmBtu</th>
<th>Cost to Produce 1 MWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Unit IGCC</td>
<td>$45.65</td>
<td>11,800</td>
<td>$1.93</td>
<td>$24.05</td>
</tr>
<tr>
<td>Single Unit IGCC with CCS</td>
<td>$45.65</td>
<td>11,800</td>
<td>$1.93</td>
<td>$29.15</td>
</tr>
<tr>
<td>Natural Gas</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional CC</td>
<td>NA</td>
<td>NA</td>
<td>$3.00</td>
<td>$24.75</td>
</tr>
</tbody>
</table>

Source: www.eia.gov/forecasts/capitalcost/xls/table1.xls

Table 4 assumes the IGCC utilizes an 11,800 (Btu/lb) Illinois Basin Coal and the Conventional CC uses a $3/mmBtu natural gas. While the production cost of electricity is competitive the capital cost remains a hurdle for the IGCC.

Similar to the electricity evaluation, the diesel fuel (Fischer-Tropsch diesel) analysis compares the capital and production cost of a diesel producing facility utilizing coal as a feedstock to a traditional refinery production costs. For this example, the National Energy Technology Laboratory’s, “Production of Zero Sulfur Diesel Fuel from Domestic Coal: Configurational Options to Reduce Environmental Impact” was used. The configuration of the study facility is similar to the IGCC utilizing CCS but with additional equipment to produce diesel fuel. Also, this analysis includes a 1x1 configuration that has one less combustion turbine. Table 5, below, lists a few of the key assumptions used in the study. Please refer to the study for a more complete look.
This December 2011 study showed that the production cost of diesel fuel is ~$2.70/gal utilizing a coal feedstock. This is based on the assumption that the market electricity price is ~$71/MWh. Table 6 demonstrates the sensitivity of production cost to the price of electricity.

**Table 5:**

<table>
<thead>
<tr>
<th></th>
<th>2x1 IGCC</th>
<th>1x1 IGCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal Feed (Tons per Day)</td>
<td>25,349</td>
<td>22,562</td>
</tr>
<tr>
<td>Coal Heating Value As Delivered (Btu/lb)</td>
<td>11,666</td>
<td>11,666</td>
</tr>
<tr>
<td>Coal Cost</td>
<td>$38.18</td>
<td>$38.18</td>
</tr>
<tr>
<td>Coal (Tons/yr)</td>
<td>8,328,968</td>
<td>7,412,258</td>
</tr>
<tr>
<td>Coal ($MM/yr)</td>
<td>$318</td>
<td>$283</td>
</tr>
<tr>
<td>Diesel (bbl per day)</td>
<td>34,303</td>
<td>34,302</td>
</tr>
<tr>
<td>Naphtha (bbl per day)</td>
<td>15,698</td>
<td>15,698</td>
</tr>
<tr>
<td>Export Power (MW)</td>
<td>397.3</td>
<td>109.9</td>
</tr>
<tr>
<td>Export Power Value ($/MWh)</td>
<td>$70.59</td>
<td>$70.59</td>
</tr>
<tr>
<td>Parasitic Power (MW)</td>
<td>585.9</td>
<td>516.9</td>
</tr>
<tr>
<td>O&amp;M ($MM/yr)</td>
<td>$409</td>
<td>$371</td>
</tr>
<tr>
<td>Total Overnight Cost ($MM)</td>
<td>$7,561</td>
<td>$6,781</td>
</tr>
<tr>
<td>Total Overnight Cost ($/DB)</td>
<td>$151,220</td>
<td>$135,640</td>
</tr>
<tr>
<td>Required Selling Price ($/bbl FT diesel)</td>
<td>$117.50</td>
<td>$114.50</td>
</tr>
<tr>
<td>Required Selling Price ($/gal FT diesel)</td>
<td>$2.80</td>
<td>$2.73</td>
</tr>
<tr>
<td>Crude Oil Equivalent ($/bbl petroleum)</td>
<td>$97.90</td>
<td>$95.40</td>
</tr>
</tbody>
</table>

"Production of Zero Sulfur Diesel Fuel from Domestic Coal: Configurational Options to Reduce Environmental Impact" by National Energy Technology Laboratory Dec 2011

**Table 6:**

<table>
<thead>
<tr>
<th>Sensitivity to Electricity Prices (2x1 Conf.)</th>
<th>Base Case</th>
<th>Case 1</th>
<th>Case 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity Prices ($/MWh)</td>
<td>$70.59</td>
<td>$49.41</td>
<td>$91.77</td>
</tr>
<tr>
<td>Required Selling Price ($/bbl FT diesel)</td>
<td>$117.50</td>
<td>$121.80</td>
<td>$113.10</td>
</tr>
<tr>
<td>Crude Oil Equivalent ($/bbl petroleum)</td>
<td>$97.90</td>
<td>$101.48</td>
<td>$90.91</td>
</tr>
</tbody>
</table>

"Production of Zero Sulfur Diesel Fuel from Domestic Coal: Configurational Options to Reduce Environmental Impact" by National Energy Technology Laboratory Dec 2011
This relationship is also shown graphically in the chart below. This chart also compares the Crude oil equivalent ($/bbl). Two lines represent different production costs driven by the price of electricity sales for the facility.

Diesel fuel produced through a polygeneration facility as describe can be economical, but long business case with most likely fail to support such capital investments.

In addition to electricity and diesel fuel, hydrogen can also be derived using a coal feedstock. “Production of High Purity Hydrogen from Domestic Coal,” a study published by the National Energy Technology Laboratory addresses hydrogen production from coal. This study, completed in 2010, evaluates several cases and scenarios. Of those cases, the most commercially competitive case shows the capital and production cost of hydrogen requires selling price of $1.87/kg. This is equivalent to $13.93/mmBtu. Table 7 below shows a comparison of typical fuels against the required selling price derived in the study.

Table 7:

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Heat Content</th>
<th>Price ($/gal)</th>
<th>Price ($/mmBtu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>138,490 Btu/gal</td>
<td>$3.97</td>
<td>$28.70</td>
</tr>
<tr>
<td>Gasoline</td>
<td>123,340 Btu/gal</td>
<td>$3.55</td>
<td>$28.76</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>74,720 Btu/gal</td>
<td>$3.55</td>
<td>$17.99</td>
</tr>
<tr>
<td>Natural Gas</td>
<td></td>
<td></td>
<td>$3.60</td>
</tr>
</tbody>
</table>

"Production of Zero Sulfur Diesel Fuel from Domestic Coal: Configuralional Options to Reduce Environmental Impact" by National Energy Technology Laboratory Dec 2011

"Production of High Purity Hydrogen from Domestic Coal: Assessing the Techno-Economic Impact of Emerging Technologies" by National Energy Technology Laboratory Aug 2010
The $/mmBtu price of hydrogen, when compared to diesel and gasoline, is attractive, but technology and infrastructure are not in place to take advantage of this lower priced fuel.

Coal to Liquids is a great alternative for a country where there is an abundance of coal and low supply of oil and or chemicals. With the current natural gas market and the regulatory uncertainty for the coal industry, the United States is not in a position for CTL’s to be a successful business model. China has been increasing their coal production over the last several years and is increasingly looking for new ways to modernize existing mines by introducing new technologies in the coal industry. According to the EIA “the Chinese government is actively promoting the development of a large coal-to-liquids industry.” Recently the Shenhua Group built the country’s first and largest CTL plant in the Inner Mongolia Autonomous Region. The Shenhua Group produced more than 10 million tons of oil and chemical products in 2012, which included 890,000 tons of oil products, 975,000 tons of synthetic resins, 2.15 million tons of methanol, 4.82 million tons of carbon coke and 1.3 million tons of other chemical products. They have also announced that they plan to produce more than 12 million tons of oil and chemical products in 2013.\(^{45,46,47,48,49}\)

The evolution of energy, commodities we use, and how will we use them is not yet complete and will be forever evolving. From government-imposed regulations on coal to globalization, the world’s hunger for the most efficient energy sources, such as coal, won’t die. America’s coal exports will continue to feed countries crossing the threshold into developed nations and also empower those already at the top.

In the early days of electric power, coal was king. Today, it still serves as the backbone of baseload power generation supply. Its affordable, cleaner-burning and increasingly critical for our nation’s long-term energy security. Other energy sources, however, will remain important pieces of the overall energy portfolio. Similar to people’s individual investment portfolio’s, coal is foundation of energy in this country. We predict the next 30 years we will find a healthy balance between all power sources and the ever-available, low-cost, always reliable coal industry will be a viable asset to power the economy of The United States, along with the rest of the world.

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