THE LOOMING NATURAL GAS TRANSITION IN THE UNITED STATES

CENTER FOR CLIMATE AND ENERGY SOLUTIONS

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Discussion questions

1. **Are renewable energy and natural gas complementary or competitors?**
2. **How will state and local policies, such as renewable energy standards, affect the competitiveness of zero-carbon sources in the coming one to two decades?**
3. **This week, Congressional hearings on a clean energy standard are taking place. How would a national policy like this one impact regional natural gas and zero-carbon energy markets?**
4. **Will low cost natural gas lead to less energy diversity and crowd out nuclear power?**
5. **Would LNG exports affect natural gas prices enough to impact the competitiveness of zero carbon sources in the United States? What would the impact of LNG imports be on the zero carbon energy markets in Europe, Japan, and China?**
6. **How will the increasing use of and infrastructure for natural gas impact biodiesel and biomethane entry into the fuel market?**
7. **How would a price on carbon affect the transition to natural gas?**

HIGHLIGHTS:

- Within one to two decades, natural gas might surpass petroleum as the dominant energy source in the United States.
- A period of price choppiness may occur as U.S. natural gas prices settle to a new equilibrium.
- As a marginal power producer, high natural gas prices trigger high electricity prices that make it easier for renewable energy sources to compete.
- Low natural gas prices encourage the replacement of coal in the power sector.
- The relationship between natural gas and wind is nuanced, as they mitigate each other's worst problems – winds' variability and natural gas' price volatility.
- Renewable forms of natural gas, biogas or biomethane, have a potential domestic supply of over 1 quadrillion British thermal units (Btus) annually.

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energy institute The University of Texas at Austin

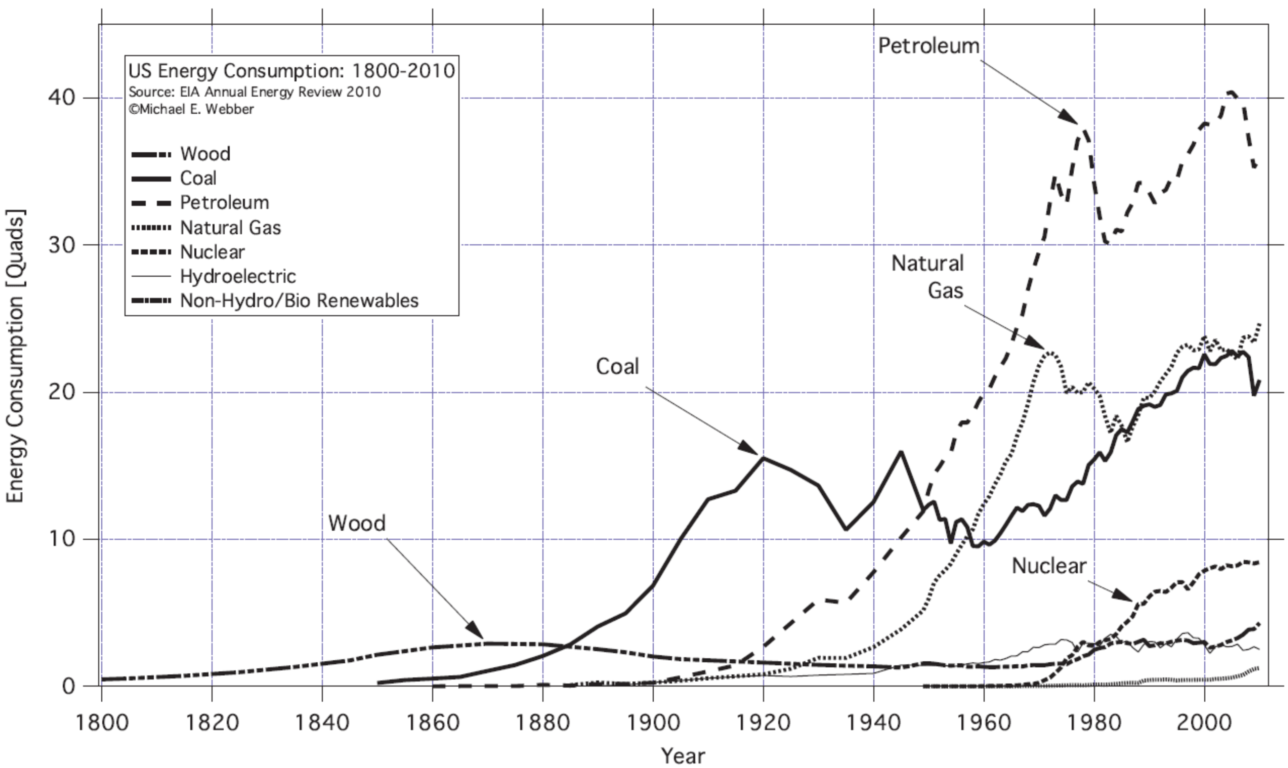
THE UNIVERSITY OF TEXAS AT AUSTIN McCOMBS ENERGY MANAGEMENT AND INNOVATION CENTER

INTRODUCTION

Energy transitions are a way of life. And, it seems that the United States is undergoing another one of those transitions as it seeks lower-carbon, more affordable, domestically-sourced fuels to meet a variety of market and policy objectives. The brief history of energy consumption in the U.S. from 1800 to 2010 is depicted in Figure 1, revealing that we have already experienced several energy transitions. Wood as our dominant fuel in the first half of the 19th century was surpassed by coal starting in 1885.

Coal as our dominant fuel was surpassed by petroleum in 1950. Whether another such a transition is underway is yet to be seen. But, if recent trends continue, then it seems likely that another transition will occur in the coming one to two decades as natural gas overtakes petroleum to be the most popular primary energy source in the U.S. Such a transition will be enabled (or inhibited) by a mixed set of competing price pressures and a complicated relationship with renewables that will trigger an array of market and cultural responses. This article seeks to layout some of the key underlying trends while also identifying some of these different axes of price tensions (or price dichotomies).

FIGURE 1: Total U.S. Energy Consumption, 1800 to 2010



Note: Wood, which was the dominant fuel in the U.S. for the first half of the 19th century, was surpassed by coal starting in 1885. Coal as the dominant fuel was surpassed by petroleum in 1950. Within one to two decades, natural gas might surpass petroleum as the dominant energy provider.

Source: Energy Information Agency 2010[1]

NATURAL GAS COULD BECOME DOMINANT IN THE U.S. WITHIN ONE TO TWO DECADES

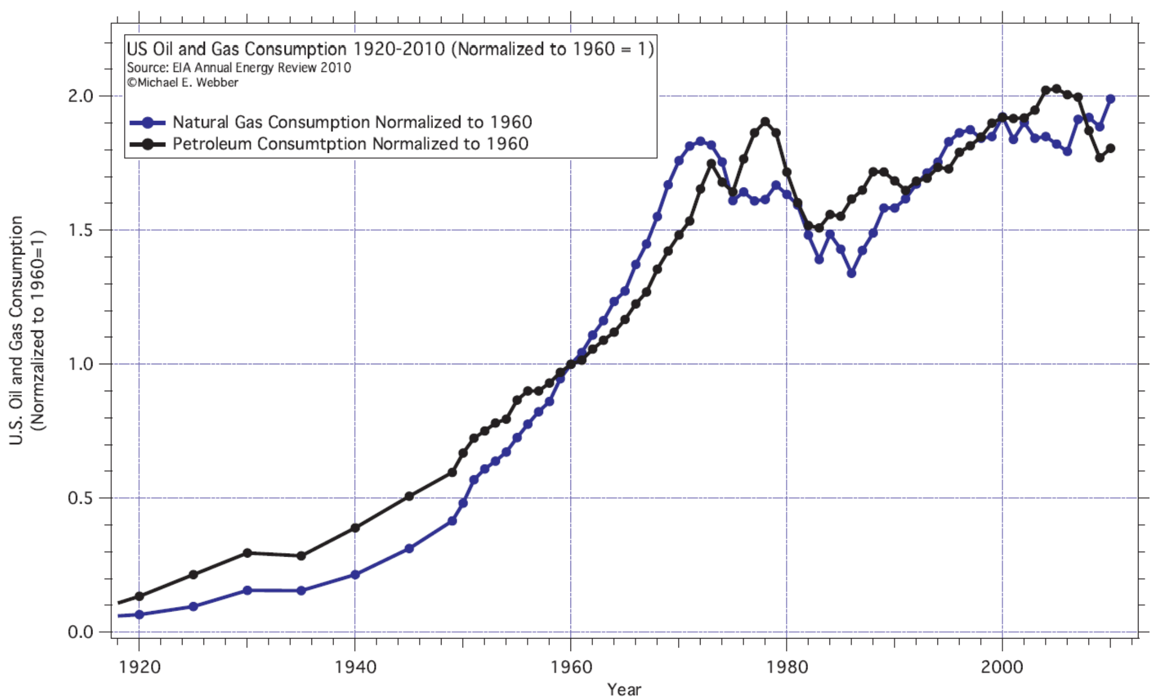
While petroleum still reigns supreme today, within one to two decades, natural gas might surpass it as the dominant energy provider. In fact, recent trends suggest that another transition is already underway. In particular, while petroleum and coal consumption have dropped steadily since 2006, natural gas consumption has increased.

For a century, oil and natural gas consumption trends have tracked each other quite closely. Figure 2 shows normalized U.S. oil and gas consumption from 1920 to 2010 (consumption in 1960 is set to a value of 1.0). These normalized consumption curves illustrate how closely oil and gas have tracked each other up until 2002, at which time their paths diverged: natural gas consumption declined from 2002 to 2006, while petroleum use grew over that time period. Then, they went the other direction: natural gas consumption grew and oil production dropped. That trend continues today, as natural gas pursues an upward path, whereas petroleum is continuing a downward trend.

The growing consumption of natural gas is driven by a few key factors:

1. It has flexible use across many sectors, including direct use on-site for heating and power; use at power plants; use in industry; and growing use in transportation.
2. It has lower emissions (of pollutants and greenhouse gases) per unit of energy than coal and petroleum
3. It is less water-intensive than coal, petroleum, nuclear and biofuels
4. Domestic production meets almost all of the annual U.S. consumption

FIGURE 2: U.S. Oil and Gas Consumption from 1920 to 2010



Note: U.S. oil and gas consumption from 1920 to present day (normalized to a value of 1 in 1960) shows how oil and gas have tracked each other relatively closely until 2002, after which their paths diverge. Since 2006, natural gas consumption has increased while petroleum consumption has decreased.

Source Energy Information Agency 2010[2]

By contrast, the trends for petroleum and coal are moving downwards. Petroleum use is expected to drop as a consequence of price pressures and policy mandates. The price pressures are triggered primarily by the split in energy prices between natural gas and petroleum (discussed in detail below). The mandates include biofuels production targets (which increase the production of an alternative to petroleum) and fuel economy standards (which decrease the demand for liquid transportation fuels). At the same time, coal use is also likely to drop because of projections by the EIA for price doubling over the next 20 years and environmental standards that are expected to tighten the tolerance for emissions of heavy metals, sulfur oxides, nitrogen oxides, particulate matter and CO_2.

Petroleum use might decline 0.9 percent annually from the biofuels mandates themselves. Taking that value as the baseline, and matching it with an annual growth of 0.9 percent in natural gas consumption (which is a conservative estimation based on trends from the last 6 years, plus recent projections for increased use of natural gas by the power and industrial sectors), indicates that natural gas will surpass petroleum in 2032, two decades from now. A steeper projection of 1.8 percent annual declines in petroleum matched with 1.8 percent annual increase in natural gas consumption sees a faster transition, with natural gas surpassing petroleum in less than a decade.

While such diverging rates might seem aggressive, they are a better approximation of the trends over the last six years than the respective 0.9 percent values. An annual decline in petroleum of 1.8 percent is plausible through a combination of biofuels mandates (0.9 percent annual decline), higher fuel economy standards (0.15 percent annual decline), and price competition that causes fuel-switching from petroleum to natural gas in the transportation (heavy-duty, primarily) and industrial sectors (0.75 percent annual decline). Natural gas growth rates of 1.8 percent annually can be achieved by natural gas displacing 25 percent of diesel use (for on-site power generation and transportation) and natural gas combined cycle power plants displacing 25 percent of 1970s–1980s vintage coal-fired power plants by 2022. While this scenario is bullish for natural gas, it is not implausible, especially for the power sector, whose power plants face retirement and stricter air quality standards. Coupling those projections with reductions in per capita energy use of 10 percent (< 1 percent annually) over that same span imply that total energy use would stay the same.

These positive trends for natural gas are not to say it is problem-free. Environmental challenges exist for water, land and air. Water challenges are related to quality (from risks of contamination) and quantity (from competition with local uses and depletion of reservoirs). Land risks include surface disturbance from production activity and induced seismicity from wastewater reinjection. Air risks are primarily derived from leaks on-site, leaks through the distribution system, and flaring at the point of production. Furthermore, while natural gas prices have been relatively affordable and stable in the last few years, natural gas prices have traditionally been very volatile. However, if those economic and environmental risks are managed properly, then these positive trends are entirely possible.

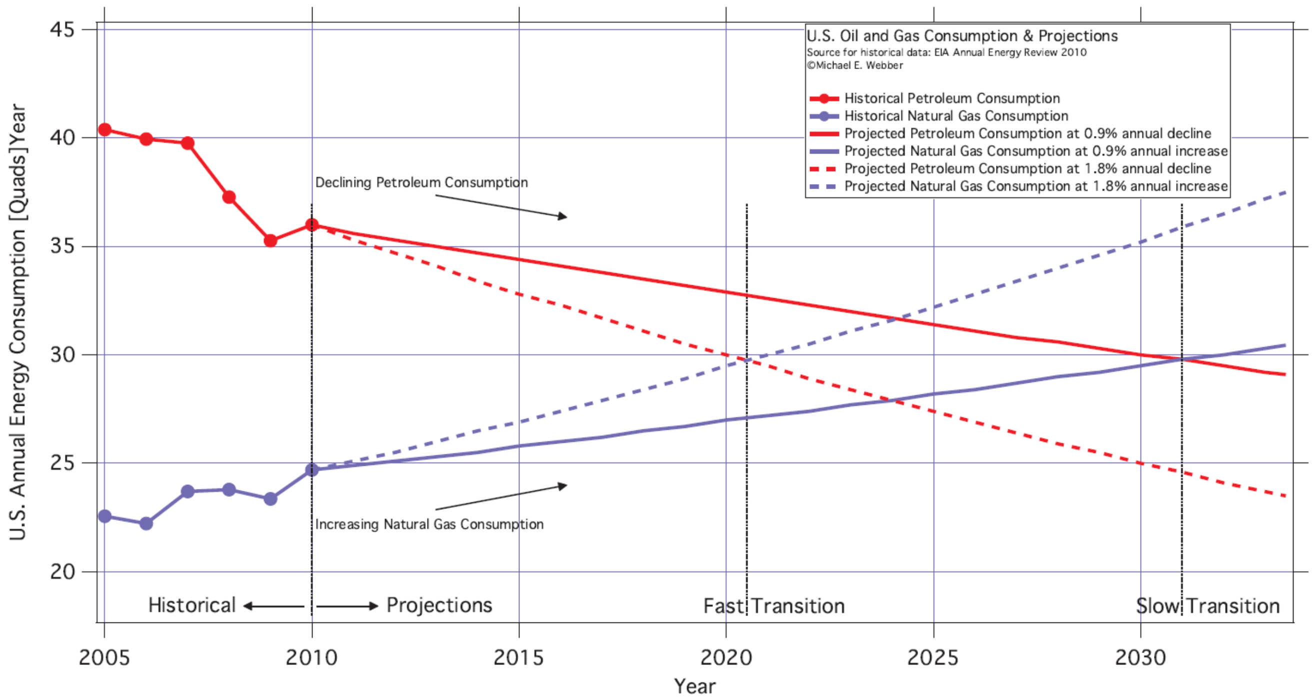
THERE ARE SIX PRICE DICHOTOMIES WITH NATURAL GAS

In light of the looming transition to natural gas as the dominant fuel in the U.S., it is worth contemplating the complicated pricing relationship that natural gas in the U.S. has with other fuels, market factors, and regions. It turns out that there are several relevant price dichotomies to keep in mind:

1. Natural Gas vs. Petroleum Prices,
2. U.S. vs. Global Prices,
3. Prices for Abundant Supply vs. Prices for Abundant Demand,
4. Low Prices for the Environment vs. High Prices for the Environment,
5. Stable vs. Volatile Prices, and
6. Long-Term vs. Near-Term Prices.

The tensions along these price axes will likely play an important role in driving the future of natural gas in the U.S. and globally.

FIGURE 3: U.S. Oil and Gas Consumption and Projections



Note: Natural gas might pass petroleum as the primary fuel source in the U.S. within one to two decades, depending on the annual rate of decreases in petroleum consumption and increases in natural gas consumption. Historical values plotted are from EIA data.

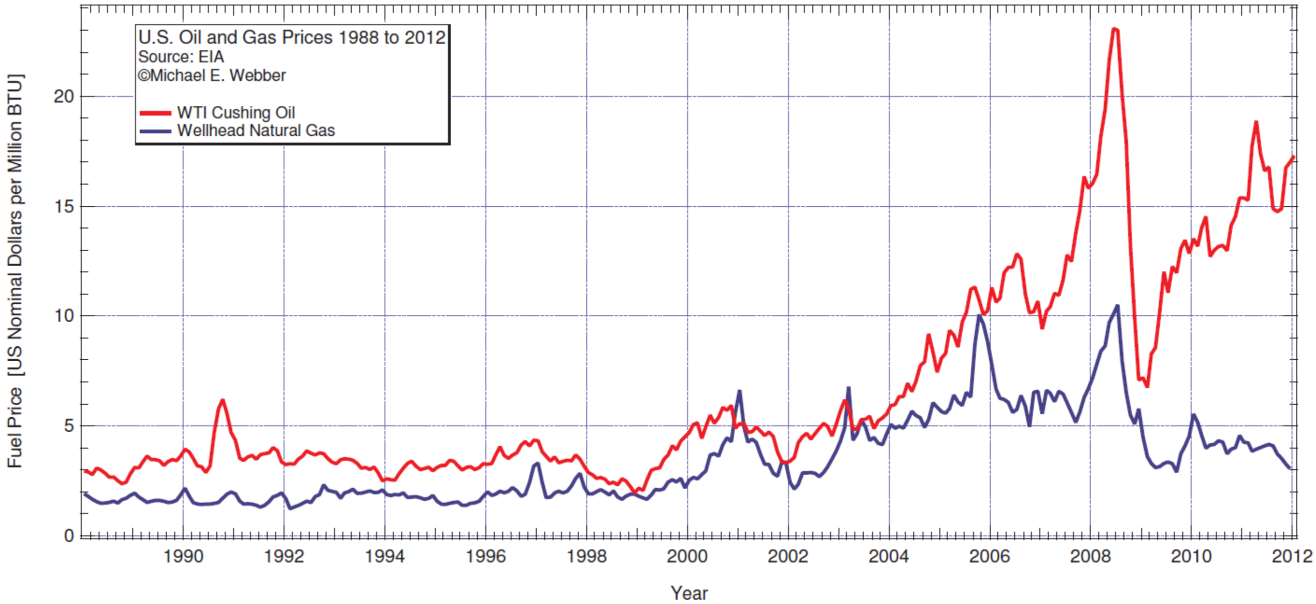
Source Energy Information Agency 2010[3]

DECOUPLING OF NATURAL GAS AND PETROLEUM PRICES

One of the most important recent trends has been the decoupling of natural gas and petroleum prices. Figure 4 shows the U.S. prices for natural gas and petroleum (wellhead, and WTI Cushing, respectively) from 1988 to 2012.[4] [5] While natural gas and petroleum prices have roughly tracked each other in the U.S. for decades, their trends started to diverge in 2009 as global oil supplies remained tight, yet shale gas production increased. This recent divergence has been particularly stark, as it's driven by the simultaneous downward swing in natural gas prices and upward swing in petroleum prices. For many years, the ratio in prices (per million BTU, or MMBTU) between petroleum and natural gas oscillated nominally in the range of 1–2, averaging 1.6 for 2000–2008. However, after the divergence began in 2009, this spread became much larger, averaging 4.2 for 2011 and, remarkably, achieving ratios greater than 9 spanning much of the first quarter of 2012 (for example, natural gas costs approximately $2/MMBTU today, whereas petroleum costs $18/MMBTU).

This spread is relatively unprecedented and, if sustained, opens up new market opportunities for gas to compete with oil through fuel-switching by end-users and the construction of large-scale fuel processing facilities. For the former, these price spreads might inspire institutions with large fleets of diesel trucks (such as municipalities, shipping companies, etc.) to consider investing in retrofitting existing trucks or ordering new trucks that operate on natural gas instead of diesel to take advantage of the savings in fuel costs. For the latter, energy companies might consider investing in multi-billion dollar gas-to-liquids (GTL) facilities to convert the relatively inexpensive gas into relatively valuable liquids.

FIGURE 4: U.S. Oil and Gas Prices 1988 to 2012



While natural gas and petroleum prices have roughly tracked each other in the U.S. for decades, their price trends started to diverge in 2009.

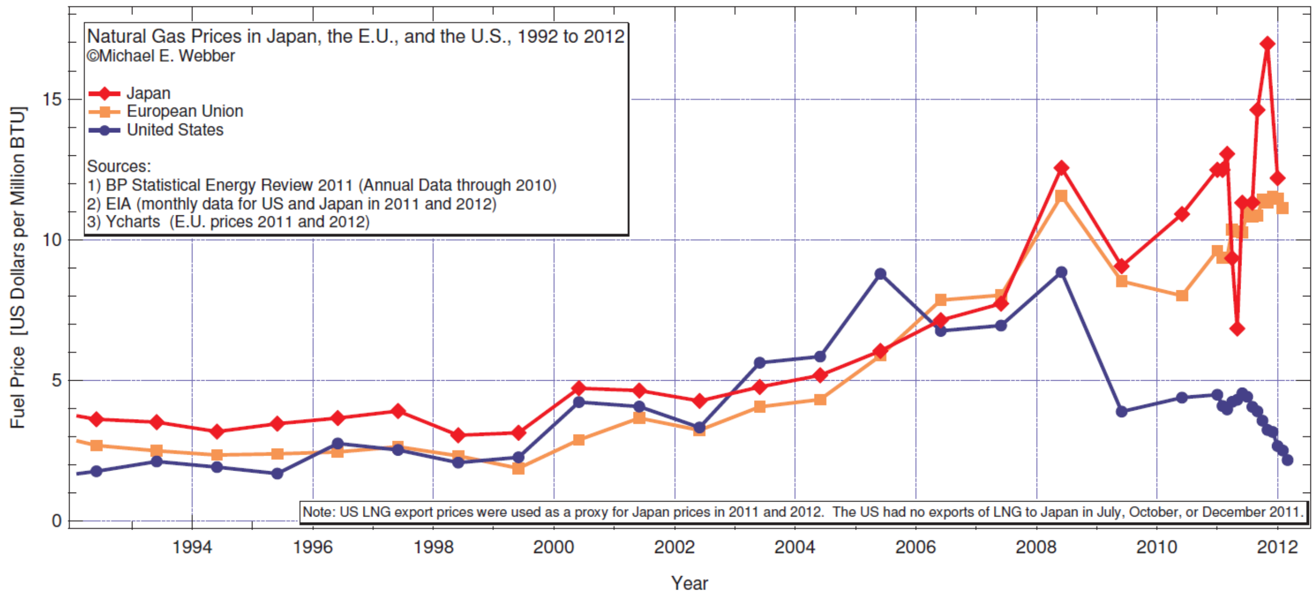
Source: EIA 2012[6 7]

DECOUPLING OF U.S. AND GLOBAL PRICES

Another important trend has been the decoupling of U.S. and global prices for natural gas. Figure 5 shows the U.S. prices for natural gas (at Henry Hub) compared with EU and Japanese prices from 1992 to 2012.[8 9 10 11] In a similar fashion as the discussion in Section 3.1, while natural gas prices in the U.S. and globally (in particular, the EU and Japan) have tracked each other for decades, their price trends started to diverge in 2009 because of the growth in domestic gas production. In fact, from 2003–2005, U.S. natural gas prices were higher than in the EU and Japan because of declining domestic production and limited capacity for importing liquefied natural gas (LNG). At that time, and for the preceding years, the U.S. prices were tightly coupled to global markets through its LNG imports setting the marginal price of gas.

Consequently, billions of dollars of investments were made to increase LNG import capacity in the U.S. That new import capacity came online concurrently with higher domestic production, in what can only be described as horribly ironic timing: because domestic production grew so quickly, those new imports were no longer necessary, and much of that importing capacity remains idle today. In fact, once production increased in 2009, the U.S. was then limited by its capacity to export LNG (which is in contrast to the situation just a few years prior, during which the U.S. was limited by its capacity to import gas), so gas prices plummeted despite growing global demand. Thus, while the U.S. was tightly coupled to global gas markets for well over a decade, it has been decoupled for the last several years. At the same time, the EU and Japan are tightly coupled to the world gas markets, (with the EU served by LNG and pipelines from the Former Soviet Union, and Japan served by LNG). How long these prices remain decoupled will depend on U.S. production of natural gas, U.S. demand for natural gas, and the time it takes for these isolated markets to connect again. In fact, LNG terminal operators are now investing billions of dollars to turn their terminals around so that they can buy cheap natural gas in the U.S. that they can sell at higher prices to the EU and Japan. Once those terminals are turned around, these geographically-divergent market prices should come back into convergence.

FIGURE 5: Natural Gas Prices in Japan, the E.U. and U.S., 1992 to 2012



So Note: While natural gas prices in the U.S. and globally (EU and Japan) have tracked each other for decades, their price trends started to diverge in 2009.

Sources: BP 2010, EIA 2012, and Ycharts 2012[12 13 14 15]

PRICES FOR ABUNDANT SUPPLY VS. PRICES FOR ABUNDANT DEMAND

Another axis to consider for natural gas prices is the tension between the price at which we have abundant supply, and the price at which we have abundant demand. These levels have changed over the years as technology improves and the prices of competing fuels have shifted, but it seems clear that there is still a difference between the prices that consumers wish to pay and producers wish to collect. In particular, above a certain price (say, somewhere in the range of $4–8/MMBTU, though there is no single threshold that everyone agrees upon), the U.S. would be awash in natural gas. Higher prices make it possible to economically produce many marginal plays, yielding dramatic increases in total production. However, at those higher prices, the demand for gas is relatively lower because cheaper alternatives (nominally coal, wind, nuclear and petroleum) might be more attractive options. At the same time, as recent history has demonstrated, below a certain price (say, somewhere in the range of $1–3/MMBTU), there is significant demand for natural gas in the power sector (as an alternative to coal) and the industrial sector (because of revitalized chemical manufacturing, which depends heavily on natural gas as a feedstock). Furthermore, if prices are expected to remain low, then demand for natural gas would increase in the residential and commercial sectors (as an alternative to electricity for water heating, for example), and in the transportation sector (to take advantage of price spreads with diesel, as noted above).

The irony here is that it's not clear that the prices at which there will be significant increases in demand will be high enough to justify the higher costs that will be necessary to induce increases in supply, and so there might be a period of choppiness in the market as the prices settle into their equilibrium. Furthermore, as global coal and oil prices increase (because of surging demand from China and other rapidly-growing economies), the thresholds for this equilibrium are likely to change. As oil prices increase, natural gas production will increase at many wells as a byproduct of liquids production, whether the gas was desired or not. Since the liquids are often used to justify the costs of a new well, the marginal cost of the associated gas production can be quite low. Thus, natural gas production might increase even without upward pressure from gas prices, which lowers the price threshold above which there will be abundant supply. At the same time, coal costs are increasing globally, which raises the threshold below which there is abundant demand. Hopefully, these moving thresholds will converge at a stable medium, though it is too early to tell. If the price settles too high, then demand might retract; if it settles too low, the production might shrink, which might trigger an oscillating pattern of price swings.

LOW PRICES FOR THE ENVIRONMENT VS. HIGH PRICES FOR THE ENVIRONMENT

Another axis of price tension for natural gas is whether high prices or low prices are better for achieving environmental goals such as reducing the energy sector's emissions and water use. In many ways, high natural gas prices have significant environmental advantages because they induce conservation and enable market penetration by relatively expensive renewables. In particular, because it is common for natural gas to be the marginal power producer in the U.S., high natural gas prices trigger high electricity prices. Those higher electricity prices make it easier for renewable energy sources such as wind and solar power to compete in the markets. Thus, high natural gas prices are useful for reducing consumption overall and for spurring growth in novel generation technologies.

However, inexpensive natural gas also has important environmental advantages by displacing coal in the power sector. Notably, by contrast with natural gas prices, which have decreased for several years in a row, prevailing coal prices have increased steadily for over a decade due to higher transportation costs (which are coupled to diesel prices that have increased over that span), depletion of mines, and increased global demand. As coal prices track higher and natural gas prices track lower, natural gas has become a more cost-effective fuel for power generation for many utility companies. Consequently, coal's share of primary energy consumption for electricity generation has dropped from 53 percent in 2003 to less than 46 percent in 2011 (with further drops in the first quarter of 2012), while the share fulfilled by natural gas grew from 14 percent to 20 percent over the same span. At the same time, there was a slight drop in overall electricity generation due to the economic recession, which means the rise of natural gas came at the expense of coal, rather than in addition to coal. Consequently, for those wishing to achieve the environmental goals of dialing back on power generation from coal, low natural gas prices have a powerful effect.

These attractive market opportunities are offset in some respects by the negative environmental impacts that are occurring from production in the Bakken and Eagle Ford shale plays in North Dakota and Texas. At those locations, significant volumes of gases are flared because the gas is too inexpensive to justify rapid construction of the pricey distribution systems that would be necessary to move the fuel to markets.[16][17] Consequently, for many operators it ends up being cheaper in many cases to flare the gas rather than to harness and distribute it.

And, thus, the full tension between the "environmental price" of gas is laid out: low prices are good because they displace coal, whereas high prices are good because they bring forward conservation and renewable alternatives. This price axis will be important to watch from a policymaker's point of view as time moves forward.

STABLE VS. VOLATILE PRICES

One of the historical criticisms of natural gas has been its relative volatility, especially as compared with coal and nuclear fuels, which are the other major primary energy sources for the power sector. This volatility is a consequence of large seasonal swings in gas consumption (for example, for space and water heating in the winter) along with the association of gas production with oil, which is also volatile. Thus, large magnitude swings in demand and supply can be occurring simultaneously, but in opposing directions. However, two forces are mitigating this volatility. Firstly, because natural gas prices are decoupling from oil prices (as discussed in Section 3.1), one layer of volatility is reduced. Many gas plays are produced independently of oil production. Consequently, there is a possibility for long-term supply contracts at fixed prices. Secondly, the increased use of natural gas consumption in the power sector, helps to mitigate some of the seasonal swings as the consumption of gas for heating in the winter might be better matched with consumption in the summer for power generation to meeting air conditioning load requirements.

Between more balanced demand throughout the year and long-term pricing, the prospects for better stability look better. At the same time, coal, which has historically enjoyed very stable prices, is starting to see higher volatility because its costs are coupled with the price of diesel for transportation. Thus, ironically, while natural gas is reducing its exposure to oil as a driver for volatility, coal is increasing its exposure.

LONG-TERM VS. NEAR-TERM PRICE

While natural gas is enjoying a period of relatively stable and low prices at the time of this writing in 2012, there are several prospects that might put upward pressure on the long-term prices. These key drivers are: 1) increasing demand, and 2) re-coupling with global markets.

As discussed above, there are several key forcing functions for higher demand. Namely, because natural gas is relatively cleaner, less carbon-intensive, and less water-intensive than coal, it might continue its trend of taking away market share from coal in the power sector to meet increasingly stringent environmental standards. While this trend is primarily driven by environmental constraints, its effect will be amplified as long as natural gas prices remain low. While fuel-switching in the power sector will likely have the biggest overall impact on new natural gas demand, the same environmental and economic drivers might also induce fuel-switching in the transportation sector (from diesel to natural gas), and residential and commercial sectors (from fuel oil to natural gas for boilers, and from electric heating to natural gas heating). If cumulative demand increases significantly from these different factors, but supply does not grow in a commensurate fashion, then prices will move upwards.

The other factor is the potential for re-coupling U.S. and global gas markets. While they are mostly empty today, many LNG import terminals are seeking to reverse their orientation, with an expectation that they will be ready for export beginning in 2014. Once they are able to export gas to EU and Japanese markets, then domestic gas producers will have additional markets for their product. If those external markets maintain their much higher prevailing prices (similar to what is illustrated in Figure 5), re-coupling will push prices upwards.

CONCLUDING COMMENTS ON PRICE DICHOTOMIES

Each of these different axes of price tensions reflects a different nuance of the complicated, global natural gas system. In particular, they exemplify the different market, technological and societal forces that will drive—and be driven by— the future of natural gas.

THE COMPLICATED RELATIONSHIP OF NATURAL GAS AND RENEWABLES

In addition to the complex pricing landscape described earlier, there is also a complicated relationship between natural gas and renewables in the power sector stemming from two aspects: 1) competition in the dispatch order between natural gas and renewables, and 2) the potential to produce renewable forms of natural gas.

For the most part, the relationship between natural gas and renewables is interpreted as competition in the power sector, by which renewables are seen as a threat to natural gas because they push natural gas-fired power plants off the bid stack. This phenomenon occurs because the power markets take bids on marginal costs, rather than all-in costs. Because the marginal cost of wind is zero, it bids zero (or negative in some cases, reflecting the effect of production tax credits for wind power). Consequently, it is a price-taker in the markets, and displaces the highest bidders, which are the price-setters. Historically, those price-setters are natural gas power plants, and so wind power displaces natural gas. Consequently the relationship between gas and wind is one of rivalry. Natural gas interests audibly complain about this rivalry, with the criticism that policy supports for wind give it an unfair advantage in this competition. Renewable energy supporters counter that gas interests are not required to pay for their pollution (which is a form of indirect subsidy) and have enjoyed government largesse in one form or another for many decades.

Despite the perception that wind and natural gas are vicious competitors in a zero-sum game where the success of one must come at the demise of the other, the relationship is actually more nuanced. In fact, wind and gas benefit from each other because they both mitigate each other's worst problems. For wind, intermittency is a problem, and for natural gas, price volatility is a problem. It turns out that the ability for natural gas power plants to serve as rapid response firming power is an effective hedge against wind's intermittency. And, it turns out the fixed fuel price (at zero) of wind farms is an effective edge against natural price volatility. Thus, they are complementary partners in the power markets.

Furthermore, many people seeking a long-term sustainable energy option will often reject natural gas automatically because it is widely considered a fossil fuel that has a finite resource base. While most reserves of natural gas were formed many millions of years ago (and thus comprise a finite fossil resource), it is important to note that there are also renewable forms of natural gas, known as biogas or biomethane. This form of gas is mostly methane with a balance of CO_2, and is created from the anaerobic decomposition of organic matter. While renewable natural gas is a small fraction of the overall gas supply, it is not negligible. For example, landfill gas is already an important contributor to local fuel supplies at the local scale. And, recent studies have noted that the total potential supply available from wastewater treatment plants and anaerobic digestion of livestock waste is over 1 quadrillion BTU annually in the United States.[18] [19]

CONCLUSIONS

Overall, it is clear that natural gas has an important opportunity to take market share from other primary fuels. In particular, it could displace coal in the power sector, petroleum in the transportation sector, and fuel oil in the commercial and residential sectors. With sustained growth in demand for natural gas, coupled with decreases in demand for coal and petroleum because of environmental and security concerns, natural gas could overtake petroleum to be the most widely used fuel in the United States within one to two decades. Along the path towards that transition, natural gas will experience a variety of price tensions that are manifestations of the different market, technological and societal forces that will drive—and be driven by— the future of natural gas. These tensions are exacerbated by the complicated relationship between natural gas and renewables. How and whether we sort out these tensions and relationships will affect the fate of natural gas and are worthy of further scrutiny.

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