

# TEN REASONS WHY NATURAL GAS WILL FUEL THE FUTURE

Robert Bryce  
*Senior Fellow*  
*Manhattan Institute for Policy Research*





In a relatively short period of time—less than five years—technological breakthroughs have unlocked massive quantities of natural gas in shale deposits that were previously thought to be unprofitable. The International Energy Agency's latest estimate of global natural gas resources is more than double the estimate it put forward in 2008. And much of that gas is in the United States.

For decades, drillers were unable to extract profitable quantities of natural gas from low-permeability shale, coal beds, and tight sands deposits. In recent years, however, drillers have perfected two techniques that have long histories in the oil and gas industry: horizontal drilling and hydraulic fracturing. The combination of these techniques ushered in what is known as the “shale gas revolution.” The results of that revolution are only now coming into focus.

This paper provides ten reasons why natural gas continues to gain market share and why it will be a key fuel of the future.

1. Natural gas saves consumers money.
2. If it's not going to be nuclear, it's got to be gas.
3. Natural gas is abundant and the globalization of the gas market is accelerating.
4. Unconventional gas is driving unconventional oil production
5. Unconventional oil production is stimulating the U.S. petrochemical sector and global oil production.
6. The United States's huge gas production capability, and its vast gas infrastructure, make it uniquely well positioned to take advantage of the shift to natural gas.
7. Increasing regulatory pressure on the coal sector is leading electricity generators to switch to natural gas.
8. Low-cost natural gas means lower-cost electricity.
9. Two key trends—decarbonization and urbanization—favor increased use of natural gas.
10. Global electricity demand is growing rapidly.

## ABOUT THE AUTHOR

---

**ROBERT BRYCE** is a senior fellow at the Manhattan Institute's Center for Energy Policy and the Environment. He has been writing about energy for two decades, and his articles have appeared in numerous publications ranging from *The Wall Street Journal* to *The Nation* and the *Atlantic Monthly* to the *Washington Post*. Bryce's first book, *Pipe Dreams: Greed, Ego, and the Death of Enron*, was named one of the best nonfiction books of 2002 by Publishers Weekly. In 2008, he published *Gusher of Lies: The Dangerous Delusions of "Energy Independence"*. A review of *Gusher of Lies* in the *New York Times* called Bryce "something of a visionary and perhaps even a revolutionary." His fourth book, *Power Hungry: The Myths of "Green" Energy and the Real Fuels of the Future*, was published in April 2010 by PublicAffairs. The *Wall Street Journal* called *Power Hungry* "precisely the kind of journalism we need to hold truth to power." The *Washington Times* said Bryce's "magnificently unfashionable, superlatively researched new book dares to fly in the face of all current conventional wisdom and cant." Bryce appears regularly on major media including CNN, FOX News, PBS, NPR, and the BBC. He received his B.F.A. from the University of Texas at Austin in 1986.

# CONTENTS

---

- 1 Introduction
- 2 Natural gas saves consumers money.
- 2 If it's not going to be nuclear, it's got to be gas.
- 3 Natural gas is abundant and the globalization of the gas market is accelerating.
- 5 Unconventional gas is driving unconventional oil production.
- 5 Unconventional oil production is stimulating the U.S. petrochemical sector and global oil production.
- 6 The United States's huge gas production capability, and its vast gas infrastructure, make it uniquely well positioned to take advantage of the shift to natural gas.
- 7 Increasing regulatory pressure on the coal sector is leading electricity generators to switch to natural gas.
- 8 Low-cost natural gas means lower-cost electricity.
- 8 Two key trends—decarbonization and urbanization—favor increased use of natural gas.
- 10 Global electricity demand is growing rapidly.
- 11 Endnotes



# TEN REASONS WHY NATURAL GAS WILL FUEL THE FUTURE

Robert Bryce

## INTRODUCTION

In less than five years, the natural gas business has gone from shortage to surfeit. Technological breakthroughs have unlocked massive quantities of natural gas from shale deposits that were previously thought to be uneconomic. The result: the United States no longer needs to import huge quantities of natural gas. Domestic gas resources should easily last many decades.

Relatively inexpensive, abundant supplies of natural gas will affect everything from electricity generation to petrochemical production. And while the effects of what is now known as the shale gas revolution will be felt most quickly in the United States, the technologies behind that revolution are going global. In late January 2011, ONGC, the Indian energy company, announced that it was producing gas from a shale gas well in West Bengal. The well is the first productive shale gas well located outside of the United States or Canada.<sup>1</sup> Other shale deposits, located in Poland, France, Australia, and China, could also yield vast quantities of oil and gas.

The impact of the shale gas revolution can be seen in a report put out in January 2011 by the International Energy Agency (IEA), which estimated global gas resources at 32,000 trillion cubic feet (Tcf), the energy equivalent of about 6 trillion barrels of oil.<sup>2</sup> The IEA's latest

estimate is more than double the estimate for global gas resources that it put forward in 2008.<sup>3</sup>

A significant portion of that gas is in the United States. In June 2009, the Potential Gas Committee, a U.S. nonprofit organization, put domestic gas resources at 2,074 Tcf—the highest resource evaluation in the committee’s forty-four-year history.<sup>4</sup> That quantity of gas is the energy equivalent of more than 350 billion barrels of oil, or about three times as much as the proved oil reserves of Iraq.<sup>5</sup>

The dramatic jump in the estimates of gas resources is due to increased production of “unconventional” gas, a term given to gas produced from geologic formations with low permeability. Shale deposits, coal beds, and tight sands, all have low permeability.<sup>6</sup> For decades, drillers were unable to extract profitable quantities of natural gas from those low-permeability deposits. But in recent years, drillers have perfected two techniques that have long histories in the oil and gas industry: horizontal drilling and hydraulic fracturing. The combination of these techniques is unlocking vast quantities of hydrocarbons.

This paper provides ten reasons why natural gas continues to gain market share and why it will be a key fuel of the future.

## I. NATURAL GAS SAVES CONSUMERS MONEY.

Between 2005 and 2008, U.S. natural gas prices averaged about \$7 per million British thermal unit (Btu).<sup>7</sup> But thanks to surging production, natural gas prices in 2010 had fallen to an average of about \$4.25 per million Btu.<sup>8</sup> That price reduction of about \$3 per million Btu is now saving U.S. consumers about \$65 billion per year or about \$180 million per day<sup>9</sup>, savings which are particularly important in an economy characterized by high rates of unemployment, stagnant wages, and rising prices for commodities such as corn, oil, coffee, sugar, and copper.<sup>10</sup>

Consumers are saving money because U.S. drillers are producing record amounts of natural gas. In 2010,

U.S. natural gas production was 21.5 Tcf, only a bit shy of the production record (21.73 Tcf) set in 1973.<sup>11</sup> And the nation is using more natural gas than ever. In 2010, consumption hit a record 24.1 Tcf, an increase of nearly 6 percent over 2009 levels.<sup>12</sup>

Even better news may be ahead. Analysts are expecting a sustained period of robust gas production and relatively low prices. There are many reasons for this expectation, but chief among them is this: domestic gas producers are, in many cases, compelled to continue drilling even though the return on their investments may be minimal. Why? Many U.S. energy companies have leased properties with contracts that require them to drill within a certain time frame. If they do not drill, they could lose the money invested in the lease. Furthermore, as gas producers gain experience drilling in unconventional formations, they are getting better at reducing costs and increasing production. Those improvements are reducing the breakeven costs for drillers, which in turn is fostering yet more drilling. Finally, an increasing number of energy companies are drilling for oil and natural gas liquids (NGLs) such as ethane, butane, and propane, as the prices for those commodities make them more attractive than natural gas. But as they are extracting increasing quantities of those liquids, they are also extracting significant quantities of natural gas.

All of these factors are helping increase natural gas supplies in the United States. Increased supply helps keep the price of natural gas relatively low. If \$4 natural gas prevails for the next several years, U.S. consumers will continue reaping the benefits.

## 2. IF IT'S NOT GOING TO BE NUCLEAR, IT'S GOT TO BE GAS.

In response to the accidents at the Fukushima reactors in Japan, electricity generators around the world have announced plans to slow, or even halt, the development of new reactor projects. And environmental groups have seized on the problems in Japan to promote their anti-nuclear agenda. For instance, on March 26, 2011, some 200,000 protesters



took to the streets in Berlin and other German cities to urge that country's leaders to abandon nuclear energy altogether.<sup>13</sup>

But if nuclear energy is taken off the table, then natural gas is the only non-coal energy source that can provide dispatchable electricity generation in the volumes needed and at affordable prices. Concerns about global carbon dioxide emissions provide yet another argument for natural gas, which produces about half as much carbon dioxide during combustion as coal. Furthermore, unlike coal, natural gas produces almost no air pollutants and no solid waste.

Although some environmental groups and a few politicians are using the Fukushima mess to push for increased use of renewables, wind energy and solar energy simply cannot provide the vast quantities of electricity that the world demands at prices consumers can afford. And even if they could overcome the daunting challenges of cost and scale, wind and solar energy remain by nature intermittent and highly variable. That intermittency and variability can only be overcome by deployment of widespread, ultra-cheap energy storage—which does not exist—or through continuous backup from natural gas-fired generation.

Indeed, if the developed world continues to pursue low-carbon energy policies, and if nuclear power is not an option, then these rich nations must be willing to accept significant increases in carbon dioxide emissions. The Breakthrough Institute recently estimated that if Germany phases out its fleet of reactors, that country's carbon dioxide emissions will increase by four percent.<sup>14</sup> If the United States were to get rid of its fleet of 104 reactors, carbon dioxide emissions would likely rise by about five percent.<sup>15</sup>

When it comes to producing large quantities of electricity while reducing air pollution, solid waste production, and carbon dioxide emissions, nuclear energy has no rival. But if policymakers are squeamish about promoting nuclear energy, then natural gas is the next best option.

### 3. NATURAL GAS IS ABUNDANT AND THE GLOBALIZATION OF THE GAS MARKET IS ACCELERATING.

In June 2005, Lee Raymond, who was then CEO of ExxonMobil, stated the accepted wisdom when he declared that “gas production has peaked in North America.”<sup>16</sup> That month, U.S. gas production totaled 1.53 Tcf. In June 2010, exactly five years after Raymond made his declaration, U.S. gas production hit 1.75 Tcf, an increase of 14 percent over the level achieved in June 2005.<sup>17</sup>

Surging gas production in the United States is being matched by increased natural gas availability around the world. Indeed global markets are now awash in gas. And last November, the IEA's chief economist, Fatih Birol, said that the world is oversupplied with gas and that “the gas glut will be with us ten more years.”<sup>18</sup>

This surfeit of gas stems from soaring production of unconventional gas as well as huge increases in natural gas liquefaction capacity in countries such as Qatar, Russia, and Nigeria. Although the United States—and the rest of the world—is producing and using more natural gas than ever, gas resources continue to grow apace. It is one of the great paradoxes of the global gas business: the more gas the world uses, the more gas it finds. In 1970, about ten countries were producing more than 1 billion cubic feet of gas per day.<sup>19</sup> By 2009, forty-one countries were producing at least 1 billion cubic feet of gas per day.<sup>20</sup>

As stated above, the IEA has estimated global gas resources at some 32,000 Tcf. If all of it can be exploited (a highly unlikely scenario) then the world has enough natural gas to last for nearly three centuries at current levels of demand.<sup>21</sup>

To be clear, resources are not reserves. In oilfield parlance, a “resource” is something that probably exists. “Reserves” applies to in-the-ground hydrocarbons that have been surveyed by drilling and other agreed-upon techniques. In 2010, the BP Statistical Review of World Energy, a common energy reference, estimated proved global gas reserves at about 6,600 Tcf, or

about one-fifth of the IEA's 2011 estimate of global gas resources.<sup>22</sup> BP puts proved U.S. gas reserves at about 238 Tcf, or about one-tenth of the Potential Gas Committee's estimate of U.S. gas resources.<sup>23</sup>

While the resources-versus-reserves caveat applies, the enormous gas estimates being put forward are adding momentum to the rapidly globalizing gas marketplace. The combination of new unconventional gas, continuing maturation of the global liquefied natural gas (LNG) sector, and a string of major conventional gas discoveries in several countries around the world, has dramatically increased the availability of natural gas. This increased availability will likely translate into low prices for the next few years.

The surge in unconventional gas from shale deposits is a recent development in an industry that has been growing rapidly for decades. Between 1973 and 2008, worldwide consumption of natural gas jumped by 156 percent—faster than growth in the use of any other primary energy source with the exception of nuclear.<sup>24</sup> Demand for gas is accelerating because consumers want fuels that emit less carbon dioxide and fewer air pollutants.

Furthermore, unconventional gas represents only part of the global gas picture. There has also been a string of recent conventional gas discoveries around the world. In 2008, Petrobras, the Brazilian national energy company, announced a major conventional gas discovery called Jupiter in an offshore area located due east of the massive Tupi oil field. The gas reservoir is comparable in geographic size to the oil reservoir at Tupi, implying that the total gas resources at Jupiter could be enormous.<sup>25</sup>

In January 2009, Israel announced a massive offshore conventional gas find at the Tamar-1 drilling site, located ninety kilometers west of Haifa in 5,500 feet of water.<sup>26</sup> The discovery, by Houston-based Noble Energy, instantly made Israel a major player in the Mediterranean gas business. In July 2009, Noble declared that the volume of conventional gas in the field was about 6.3 Tcf. By itself, the Tamar gas find could be enough to supply Israel's needs for two decades.<sup>27</sup> In late 2010, Noble announced yet more positive drilling results,

saying that another offshore field known as Leviathan, likely contains at least 16 Tcf of conventional gas.<sup>28</sup> The Israelis plan to use that gas to replace most, if not all, of their coal-fired power plants.

Major offshore conventional gas deposits sit just a few miles south of Tamar. A decade ago, Britain's BG Group, along with construction giant CCC, drilled two successful offshore wells, Gaza Marine-1 and Gaza Marine-2. The two wells sit atop a field that contains an estimated 1.4 Tcf of conventional gas. That is likely enough fuel to supply all of Gaza's natural gas requirements—for electricity generation and other uses—for years to come. And it's close to a major population center. The two wells sit just 30 kilometers west of Gaza City. But development of the Gaza gas field continues to be blocked by the Israeli government.<sup>29</sup>

In October 2009, Chevron announced a major conventional gas discovery offshore Western Australia. Although the company did not provide estimates of the size of the find in the Greater Gorgon region, it said that the Achilles-1 well had hit a gas pay zone (the geologic segment containing hydrocarbons) that was 375 feet thick.<sup>30</sup> The new discovery will add yet more reserves to Gorgon, one of the world's biggest and most expensive gas projects. About \$37 billion is being invested in gas liquefaction facilities aimed at turning the 40 Tcf of gas at Gorgon into marketable commodities. The first LNG from the project will likely begin shipping in 2014 or 2015.<sup>31</sup>

In February 2011, Houston-based Anadarko Petroleum announced another major conventional natural gas discovery off the coast of Mozambique. The latest wildcat well encountered more than 110 net feet of natural gas pay zone.<sup>32</sup> The company has estimated that the offshore Mozambique gas potential at more than 4 Tcf.<sup>33</sup>

Discoveries of conventional gas deposits will continue feeding the growing global market for LNG. In 2008, global gas liquefaction capacity was 280 billion cubic meters. By 2013, total capacity is expected to grow by nearly 50 percent to some 410 billion cubic meters.<sup>34</sup> In 2009 alone, four major LNG liquefaction projects—Sakhalin II, Yemen LNG, Tangguh, and Qatar Mega Trains—came online.<sup>35</sup>

The globalization of the LNG market is occurring at the very same time that the domestic need for LNG imports has largely disappeared. The sudden flood of unconventional gas has made the United States largely self sufficient in natural gas. That point was made succinctly by Ian Cronshaw of the IEA in October 2009 when he said, "The United States is now a virtual liquefied natural gas exporter because all the LNG that was supposed to be going there is now going somewhere else."<sup>36</sup>

A number of companies are considering projects that could, at least in theory, lead to the export of liquefied natural gas from the United States.<sup>37</sup> A Canadian LNG-export plan appears to be moving forward as well. The company proposing the idea, Calgary-based Kitimat LNG, recently let an engineering and design contract for a gas liquefaction facility in British Columbia, and the company claims to have several potential buyers in Asia for its production.<sup>38</sup>

#### 4. UNCONVENTIONAL GAS IS DRIVING UNCONVENTIONAL OIL PRODUCTION.

The revolution in unconventional gas has fostered breakthroughs in unconventional oil. By using horizontal drilling and hydraulic fracturing on low-permeability formations, drillers are now unlocking huge quantities of liquid hydrocarbons. Those breakthroughs are reshaping the U.S. oil business, a sector that has been on a long, steady decline since production peaked in the early 1970s. In 2010, U.S. crude oil production was 5.5 million barrels per day, the highest level since 2003.<sup>39</sup> And some analysts are now predicting that domestic oil production could increase by as much as 1 million barrels per day over the next five years.<sup>40</sup>

The importance of unconventional oil can be seen by looking at the Bakken Shale, a giant formation which underlies parts of Canada, Montana, and North Dakota. In July 2010, oil production in North Dakota averaged some 303,000 barrels per day, more than triple the amount produced in July 2005.<sup>41</sup> North Dakota now ranks fourth among U.S. states in oil production, ahead of more familiar oil producing locales like Wyoming, New Mexico, Oklahoma, and Louisiana.<sup>42</sup> And North

Dakota regulators are predicting that production in the state could hit 700,000 barrels per day by 2018.<sup>43</sup> Furthermore, some industry officials are now saying that the Bakken alone may hold as much as 24 billion barrels of recoverable oil.<sup>44</sup>

Other shale deposits are also yielding sizable quantities of oil. The Eagle Ford Shale in Texas, after being tapped by drillers using horizontal drilling and hydraulic fracturing, is yielding wells that can produce more than 1,000 barrels of oil per day.<sup>45</sup>

One of the hottest oil plays in the United States is located in the Permian Basin. Various known as the Wolfcamp, or Wolfberry play, the shale formation sits near the middle of a region that has likely seen more drilling over the past fifty years than any other place in the United States.<sup>46</sup> And just as in other shale plays, drillers in the Wolfcamp are using hydraulic fracturing with great success. In October 2010, Texas oil production averaged 1.2 million barrels per day, that's the highest level of production in the Lone Star State since February 2000.<sup>47</sup>

The increasing push for unconventional oil is having a knock-on effect on natural gas production. As more companies are drilling for oil in low-permeability reservoirs, they are also producing significant quantities of natural gas. The economic returns from oil-focused drilling depend largely on the value of the liquids extracted, not the gas. For some operators, therefore, the gas that comes up alongside the liquids is, from an economic perspective, essentially free. The likely result of this increased push for unconventional oil production is that domestic production of natural gas will continue rising in the years ahead, resulting in downward pressure on prices.

#### 5. UNCONVENTIONAL OIL PRODUCTION IS STIMULATING THE U.S. PETROCHEMICAL SECTOR AND GLOBAL OIL PRODUCTION.

In September 2010, U.S. production of NGLs hit a record 2 million barrels per day.<sup>48</sup> That surging production of ethane and other NGLs has spurred several petrochemical companies to announced major

expansion plans. CP Chem and Eastman Chemical have both announced plans to restart production at dormant plants. And in December 2010, Dow Chemical said it was going to upgrade its capacity to crack ethane (high-temperature cracking is one of the first steps in the petrochemical production process) in the United States by up to 30 percent over the next three years.<sup>49</sup> Indeed, for the first time in decades, petrochemical producers and refiners are saying that the United States has a competitive advantage over the rest of the world due to the abundance of low-cost feedstock and relatively cheap natural gas.

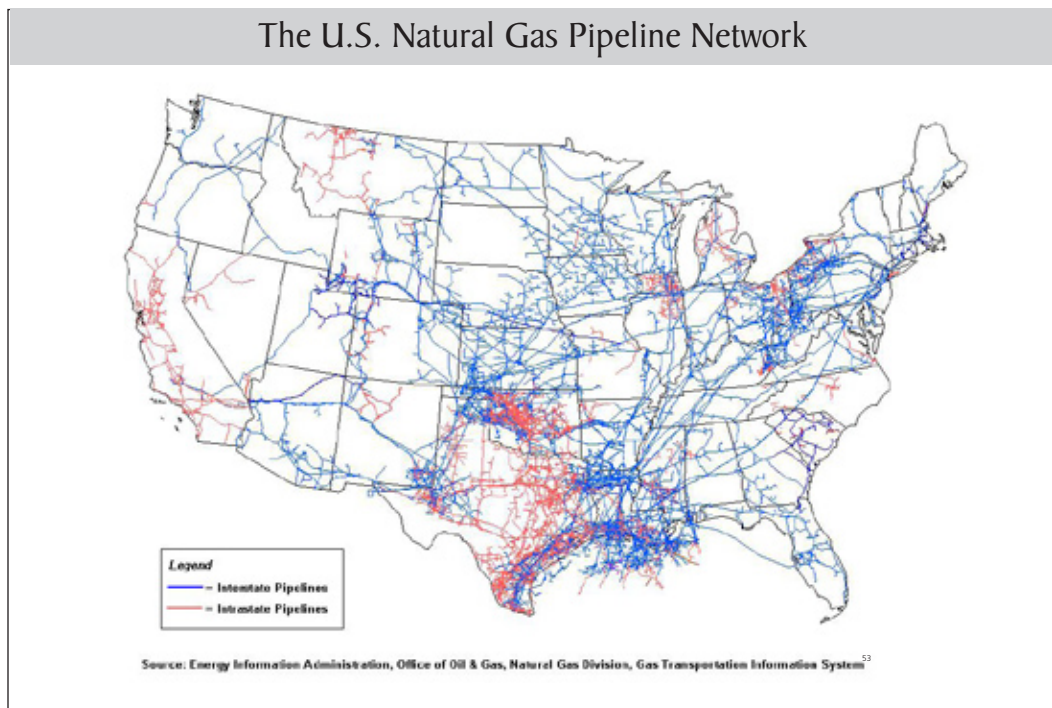
The potential turnaround in the petrochemical and refining sector provides some much-needed good news for the U.S. manufacturing sector, which has been steadily losing jobs for many years.

Finally, just as unconventional gas is going global in places like Europe and India, so, too, is unconventional oil. In February, Continental Resources, an Oklahoma-based company, announced that it is hoping to begin drilling in the Paris basin in France. The company says it believes there are “significant recoverable oil reserves” in the shale formations near the French capital.<sup>50</sup> Other companies, includ-

ing Colorado-based Century Exploration Resources, are also looking hard at the shale oil potential in France. As the technologies needed to develop shale oil spread, the pursuit of shale oil will accelerate around the world.

## 6. THE UNITED STATES'S HUGE GAS PRODUCTION CAPABILITY, AND ITS VAST GAS INFRASTRUCTURE, MAKE IT UNIQUELY WELL POSITIONED TO TAKE ADVANTAGE OF THE SHIFT TO NATURAL GAS.

The United States is both the world's biggest producer and consumer of natural gas. With some 2.2 million miles of gas pipelines, it has the world's most extensive gas distribution network.<sup>51</sup> In addition, the United States has more natural gas storage capacity than any other country; its 4 trillion cubic feet of natural gas storage capacity is ten times the capacity of France and nearly six times that of Germany.<sup>52</sup> Gas storage provides a vital buffer against transportation and supply interruptions. Furthermore, the United States is home to the biggest, most transparent, and most liquid gas trading market.



The United States's robust natural gas system can be leveraged to increase the use of natural gas for electricity generation but it also provides opportunities to increase use of the fuel for transportation. Currently, the volume of natural gas used for transportation is miniscule when compared to that used for electricity generation. For instance, in 2009, the amount of natural gas consumed by the transportation market averaged just 87 million cubic feet per day.<sup>54</sup> That's nearly insignificant in a market that burns about 62 billion cubic feet per day.

Put another way, in 2009, the electricity generation sector consumed over 200 times more natural gas than did the transportation sector. Nevertheless, use of natural gas in transportation is increasing. Between 1999 and 2009, domestic consumption of natural gas in the transportation sector nearly tripled.<sup>55</sup> That growth will likely continue over the coming decades, particularly if natural gas prices stay relatively low and crude oil prices rise. But even if the use of natural gas-fueled vehicles continues to grow, the amount of gas used for transportation will remain a small fraction of the volumes used for power generation. (However, that could change relatively quickly if an inventor can develop a cheap, scalable process that can convert natural gas into quality liquid fuel.)

Finally, the vast U.S. natural gas distribution system could become the backbone for a system of home- or neighborhood-based fuel cells. Those fuel cells could produce pollution-free electricity while dramatically strengthening the resilience of the nation's electricity grid.

## 7. INCREASING REGULATORY PRESSURE ON THE COAL SECTOR IS LEADING ELECTRICITY GENERATORS TO SWITCH TO NATURAL GAS.

Owners of coal-fired power plants are facing a myriad of regulatory challenges including increasingly stringent standards on air quality, restrictions on heavy metals emissions, and possible new rules on the management of coal ash. Add in the possibility of taxes or caps on carbon dioxide emissions, and coal's disadvantages become even more apparent.

Coal's share of the power market has been flat since the mid-1990s. In fact, between 1997 and 2009, the amount of electricity generated by coal actually declined slightly, falling from 1,845 billion kilowatt hours to 1,764 billion kilowatt hours.<sup>56</sup> During that same time period, nearly all the growth in U.S. electricity generation came from natural gas. In November 2010, analysts at Deutsche Bank estimated that 60 gigawatts of older, inefficient, coal-fired generation capacity will be retired by 2020 and another 92 gigawatts will be retired by 2030.<sup>57</sup> And most of that 152 gigawatts of capacity will be replaced by natural gas-fired units. Deutsche Bank estimates that coal's share of U.S. electricity generation will fall from nearly 50 percent today to about 22 percent by 2030.<sup>58</sup>

Coal-fired generators must contend with increasing restrictions on pollutants and heavy metals. In 2005, the EPA issued the Clean Air Interstate Rule, which aims to cut releases of sulfur dioxide and nitrogen oxide by as much as 70 percent by 2015.<sup>59</sup> In addition, the agency has issued the Clean Air Mercury Rule, which aims to cut the releases of mercury from coal-fired power plants.<sup>60</sup>

Emissions of mercury and other heavy metals are particularly problematic for coal-fired power plants. Coal-fired power plants are the largest emitters of mercury in the United States, releasing some 96,000 pounds of mercury into the air each year.<sup>61</sup> In addition to mercury, U.S. coal plants release significant amounts of lead, chromium, and arsenic. Cutting the emissions of these toxins will cost the U.S. owners of coal-fired power plants many billions of dollars. And rather than install all the equipment needed to cut those emissions, many companies will instead switch to natural gas.

Natural gas produces no solid waste, an attribute that has become increasingly important since the failure of a coal-ash holding pond operated by the Tennessee Valley Authority in late 2008. The spill flooded some 300 acres with coal ash contaminated with a variety of heavy metals including arsenic, lead, barium, chromium, and manganese.<sup>62</sup> That accident has led the EPA to consider rules that could classify coal ash as a hazardous waste under the Resource Conservation

and Recovery Act. Even if the agency takes a less-aggressive approach, and only requires generators to change the management of their coal ash, the per-plant cost of that change could approach \$30 million.<sup>63</sup>

## 8. LOW-COST NATURAL GAS MEANS LOWER-COST ELECTRICITY.

There are many reasons why natural gas will retain a cost advantage over other forms of electricity generation. Perhaps the most important: in some areas of the United States, natural gas is now cheaper than coal. The cost advantage with regard to fuel makes gas even more attractive when you consider other key factors. Among those factors: gas-fired power plants have shorter lead times than other forms of conventional generation. A gas-fired plant can be built in about two years. A comparable coal plant could take twice as long. In the wake of Fukushima, the permitting process for a new nuclear plant in the United States is likely to become extremely lengthy.

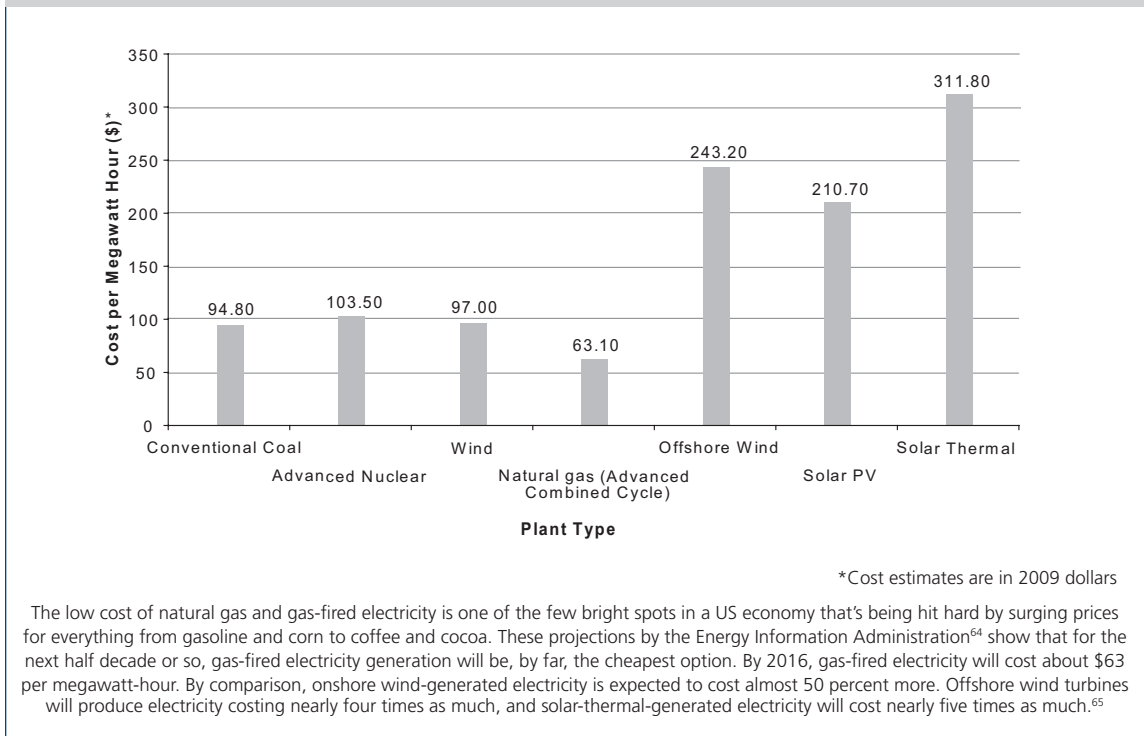
Finally, when compared to coal-fired electricity generation, natural gas dramatically cuts emissions of the two most problematic air pollutants—sulfur dioxide and nitrogen oxide—by 100 percent, and 80 percent, respectively.<sup>66</sup>

## 9. TWO KEY TRENDS—DECARBONIZATION AND URBANIZATION—FAVOR INCREASED USE OF NATURAL GAS.

Decarbonization is a trend that was first identified by a group of scientists that included Nebosa Nakicenovic, Arnulf Grübler, Jesse Ausubel, and Cesare Marchetti.<sup>67</sup> They found that over the past two centuries, consumers in nearly every country around the world wanted the cleanest, densest forms of energy and power that they could find.

The decarbonization trend can be understood by looking at the ratio of carbon to hydrogen atoms in the most common fuels. From pre-history through the

Levelized Cost of New Electricity Generation Capacity Entering Service in 2016



early 1800s, wood was the world's most common fuel. Wood has a carbon-to-hydrogen ratio (C:H) of about 10:1. That is, it contains about 10 carbon atoms for every hydrogen atom. But wood lost its dominance to coal, which has far higher energy density, and a C:H ratio of about 2:1. Coal lost out to oil, which has an even higher energy density as well as being easier to handle. In addition, oil has a C:H ratio of about 1:2. Now we are seeing the rise of natural gas, which, as its chemical symbol (CH<sub>4</sub>) suggests, has a C:H ratio of 1:4, or one carbon atom for every four hydrogens. In 2005, Italian physicist Cesare Marchetti wrote about the decarbonization trend and declared that for the

next five decades natural gas "is to be the dominant primary energy."<sup>68</sup>

Policymakers have decided that decarbonization should be a top global priority. In late 2008, Nobuo Tanaka, the executive director of the IEA, declared that, "Preventing irreversible damage to the global climate ultimately requires a major decarbonization of world energy sources."<sup>69</sup> Of course, not all countries are decarbonizing at the same rate. And some countries, including China and India, are increasing, rather than decreasing, their consumption of coal. But the long-term decarbonization of the global economy is

### The Unconventional Becomes Conventional: A Short Primer on Oil and Gas Terminology

Among the many misperceptions about the oil and gas industry is the belief that hydrocarbons exist underground in giant underground pools. The reality is that subsurface oil and gas is trapped in the pores and cracks of reservoir rocks. For decades, drillers have relied almost exclusively on hydrocarbon-bearing formations, like sandstone, that are highly porous and highly permeable. That means that those conventional formations have pores that can hold hydrocarbons as well as interconnections and fissures through which petroleum and natural gas can move rather freely. And when that reservoir rock is tapped by a well, the hydrocarbons trapped in the rock can then flow into the well bore and from there, to the surface.

Shale and other unconventional or "tight" geologic formations, have very low permeability. Thus, while those formations may contain huge quantities of oil and gas, those substances cannot travel through the rock or into the well bore.

Permeability is measured in darcies, a unit named for the French scientist, Henry Darcy. A conventional offshore well in the Gulf of Mexico may have a permeability of 1,000 millidarcies, while drillers in the Barnett Shale may be measuring the permeability of their source rock in nanodarcies, or billionths of a darcy. Put another way, a conventional well may have permeability that is 100,000,000 times greater than the permeability of an unconventional well drilled into shale or another tight formation. Overcoming this low permeability requires drillers to use techniques such as horizontal drilling, which exposes more of the well bore to the reservoir, and hydraulic fracturing, which cracks the rock and creates passages through which the hydrocarbons can flow.

So what makes a well conventional or unconventional? Alas, there is not a widely accepted definition as to what qualifies a source as unconventional. Broadly speaking, "unconventional" oil and gas refers to hydrocarbons that are being produced from a low-permeability reservoir. Historically, that has included reservoirs with permeabilities of 0.1 millidarcy.<sup>76</sup> But with permeabilities in some of today's most prolific oil and gas plays being measured in nanodarcies, the line between conventional and unconventional has blurred.

Whatever the definition, the key takeaway is this: unconventional natural gas and unconventional oil are changing the global energy picture for the better. Those sources are making hydrocarbons more readily available, at lower cost. And that's good for consumers.

continuing, and given concerns about climate change, that trend is likely to accelerate as countries around the world build more nuclear reactors and increase their consumption of natural gas.

The second key trend, urbanization, has been the focus of a spate of recent books. Edward Glaeser, a senior fellow at the Manhattan Institute, has a clever line in his new book, *Triumph of the City*. Taking a gentle poke at *New York Times* columnist Thomas Friedman, Glaeser declares that “the world isn’t flat; it’s paved.”<sup>70</sup> Glaeser says that cities “have been the engines of innovation since Plato and Socrates bickered in an Athenian marketplace,” and that “urban density provides the clearest path from poverty to prosperity.”<sup>71</sup>

Stewart Brand, the California-based entrepreneur and environmentalist, is also a big fan of cities, calling them, “the greenest things that humans do.”<sup>72</sup> In his 2009 book, *Whole Earth Discipline*, Brand writes that “Every week there are 1.3 million new people in cities. That’s 70 million a year, decade after decade. It is the largest movement of people in history.”<sup>73</sup> As millions more move into cities, they are living in much closer proximity. That proximity, by necessity, requires the use of easily transported, clean-burning fuels. That largely disqualifies bulky fuels such as wood and coal.

And it favors fuels like natural gas and NGLs such as propane and butane. The urbanization trend is directly linked to another trend: electrification.

## 10. GLOBAL ELECTRICITY DEMAND IS GROWING RAPIDLY.

The essentiality of electricity to modernity is incontrovertible. As tens of millions of people move from the countryside into cities, they want what nearly all urban dwellers take for granted: cheap, abundant, reliable electricity. And the trend toward electrification shows no sign of slowing.

Over the past two decades, electricity use has grown faster than any other type of fuel consumption. Between 1990 and 2007, electricity use increased by about 68 percent, that’s nearly three times as fast as the growth in oil consumption over that period.<sup>74</sup> And demand for electricity will continue to grow. In late 2010, the IEA projected that global electricity demand will soar by some 80 percent by 2035.<sup>75</sup> The vast majority of that electricity will have to be produced from hydrocarbons. And the hydrocarbon of choice will be natural gas.



## ENDNOTES

---

1. LNG World News, "India: ONGC Finds Shale Gas Near Durgapur," February 4, 2011, <http://www.lngworldnews.com/india-ongc-finds-shale-gas-near-durgapur/>
2. Roger Harrabin, "IEA doubles global gas reserves estimates," BBC, January 20, 2011, <http://www.bbc.co.uk/news/business-12245633>. Note that in this story, the IEA official puts global gas resources at 920 trillion cubic meters. To convert cubic meters to cubic feet, multiply by 35.3.
3. Robert Bryce, "The New Natural Gas Paradigm: 30,000 Trillion cubic feet (and counting)", *Energy Tribune*, November 13, 2009, <http://www.energytribune.com/articles.cfm?aid=2592>
4. Potential Gas Committee, "Potential Gas Committee Reports Unprecedented Increase In Magnitude Of US Natural Gas Resource Base," June 18, 2009. Available: <http://www.mines.edu/Potential-Gas-Committee-reports-unprecedented-increase-in-magnitude-of-US-natural-gas-resource-base>
5. BP Statistical Review of World Energy 2009.
6. Permeability is often measured in millidarcies, which is 1/1000th of a darcy, a unit named for the French scientist Henry Darcy. The darcy has become a standard unit of measure in hydrology, petroleum engineering, and other realms where scientists need to measure fluid flows through various media. A darcy is defined thusly: "A porous medium has a permeability of 1 darcy when differential pressure of 1 atmosphere across a sample 1 centimeter long and 1 square centimeter in cross section will force a liquid of 1 centipoise of viscosity through the sample at the rate of 1 cubic centimeter per second."  
A conventional oilfield in the Gulf of Mexico may have a permeability of 1,000 millidarcies. A shale bed like the Barnett may measure 0.0001 millidarcy. As Houston energy analysts Jeff Hayden and Dave Pursell put it in a 2005 report on the Barnett Shale, the flow capacity of a typical reservoir in the Gulf of Mexico may be "ten million times higher than an organic shale." But even that number may be off by an order of magnitude. According to some drillers, the permeabilities in the Barnett Shale are measured in nanodarcies, or billionths (1/1,000,000,000) of a darcy. Thus, some wells in the Barnett may have permeability of about 0.00001 millidarcy. The huge variations in permeability – differences between an offshore field and an onshore shale play might be 100,000,000-fold – means that prospectors must tailor their fracturing techniques to each region, depending on each formation's permeability. For more on this, see: Jeff Hayden and Dave Pursell "The Barnett Shale: Visitors Guide to the Hottest Gas Play in the US," Pickering Energy Partners, October 2005, 45. Available: <http://www.tudorpickering.com/pdfs/TheBarnettShaleReport.pdf>
7. EIA data, <http://www.eia.gov/dnav/ng/hist/n9190us3A.htm>
8. EIA data, <http://www.eia.gov/dnav/ng/hist/n9190us3M.htm>
9. US gas consumption is about 60 billion cubic feet per day. Multiply \$3 x 60 million x 365 days = \$65.7 billion. For gas consumption figures, see EIA data, <http://www.eia.doe.gov/steo/>
10. Keith R. McCullough, "How inflation is turning breakfast into a luxury item," *Hedgeye*, February 2, 2011, [http://finance.fortune.cnn.com/2011/02/02/how-inflation-is-turning-breakfast-into-a-luxury-item/?section=magazines\\_fortune](http://finance.fortune.cnn.com/2011/02/02/how-inflation-is-turning-breakfast-into-a-luxury-item/?section=magazines_fortune)
11. Note that this is dry gas production. Gross U.S. gas production peaked in 1971. EIA data, <http://www.eia.doe.gov/dnav/ng/hist/n9070us2A.htm>
12. EIA data, <http://www.eia.doe.gov/dnav/ng/hist/n9140us2a.htm>
13. Associated Press, "Some 200,000 in Germany protest nuclear power," March 26, 2001, [http://www.google.com/hostednews/ap/article/ALeqM5gERVTdp3OjRBov\\_5Gct4pCss1H-g?docId=1d40a09a75344ca8b823c787bf757870](http://www.google.com/hostednews/ap/article/ALeqM5gERVTdp3OjRBov_5Gct4pCss1H-g?docId=1d40a09a75344ca8b823c787bf757870)

14. Ted Nordhaus, Michael Shellenberger, and Jesse Jenkins, "Nuclear as Usual: Why Fukushima Will Change Less Than You Think," *The Atlantic*, March 23, 2011, <http://www.theatlantic.com/technology/archive/2011/03/nuclear-as-usual-why-fukushima-will-change-less-than-you-think/72913/>
15. Ibid.
16. Reuters, "Exxon says N. America gas production has peaked," June 21, 2005. Available: <http://www.reuters.com/article/Utilities/idUSN2163310420050621>
17. EIA data, <http://www.eia.gov/dnav/ng/hist/n9070us2m.htm>
18. Daniel Fineren and Muriel Boselli, "IEA sees gas glut lasting until 2020," Reuters, November 9, 2010, [http://in.reuters.com/article/idINLDE6A815R20101109?loomia\\_ow=t0:s0:a54:g12:r1:c0.605462:b39103646:z3](http://in.reuters.com/article/idINLDE6A815R20101109?loomia_ow=t0:s0:a54:g12:r1:c0.605462:b39103646:z3)
19. BP Statistical Review of World Energy 2009.
20. BP Statistical Review of World Energy 2010.
21. Global gas consumption is about 300 billion cubic feet per day, or about 110 trillion cubic feet per year. Thus,  $32,000/110 = 290$ .
22. BP Statistical Review of World Energy 2010.
23. BP Statistical Review of World Energy 2009.
24. BP Statistical Review of World Energy 2009.
25. Petrobras, "Important Discovery of Gas and Light Oil in the Pre-Salt Layer Confirmed," September 24, 2008. Available: [http://www2.petrobras.com.br/ri/spic/bco\\_arq/DescobertaJúpiter-Ing.pdf](http://www2.petrobras.com.br/ri/spic/bco_arq/DescobertaJúpiter-Ing.pdf)
26. Neal Sandler, "Israel Gas Find Tips Energy Balance," *Business Week*, January 19, 2009. Available: [http://www.businessweek.com/globalbiz/content/jan2009/gb20090119\\_996007.htm?chan=top+news\\_top+news+index++temp\\_global+business](http://www.businessweek.com/globalbiz/content/jan2009/gb20090119_996007.htm?chan=top+news_top+news+index++temp_global+business)
27. Noble Energy, "Noble Energy Announces Successful Tamar Appraisal in Israel and Increases Resource Size," July 7, 2009. Available: <http://investors.nobleenergyinc.com/releasedetail.cfm?ReleaseID=394724>
28. Calev Ben-David, "Natural gas find off Israel is huge," Bloomberg, December 29, 2010, <http://www.chron.com/disp/story.mpl/business/7358373.html>
29. Eric Silver, "Sharon Vetoes BG Group Deal to Supply Israel With Gas From Gaza," *The Independent*, August 19, 2003. See also, Robert Bryce, "Oil, Peace and Palestine: Energy Key to Holy Land's Past, Future," *World Energy Monthly Review*, July 2005.
30. Chevron, "Chevron Announces Natural Gas Find in Australia," October 18, 2009. Available: <http://www.chevron.com/news/press/release/?id=2009-10-18>
31. Bloomberg, "Exxon to Ship Gorgon LNG to PetroChina from 2014-15," August 20, 2009. Available: <http://www.bloomberg.com/apps/news?pid=newsarchive&sid=aDPdYPg0QkX0>
32. Anadarko Petroleum Corporation, "Anadarko Announces Discovery Offshore Mozambique," February 7, 2011, <http://www.anadarko.com/SiteCollectionDocuments/PDF/Media/Tubarao%20Discovery%202-7-11.pdf>

33. Anadarko presentation, "Credit Suisse 2011 Energy Summit," slide 14, <http://www.anadarko.com/SiteCollectionDocuments/PDF/Media/Tubarao%20Discovery%202-7-11.pdf>
34. International Energy Agency, "Natural Gas Market Review 2009," 99.
35. Ibid, 96.
36. Robert Campbell, "Natgas giants still reeling from US shale shock," Reuters, October 9, 2009. Available: <http://uk.reuters.com/article/idUKTRE5983V020091009>
37. Companies looking at possible LNG export include Dominion, EOG Resources, and Cheniere, see for additional info: <http://www.reuters.com/article/2011/02/01/lng-dominion-export-idUSN0122810220110201>
38. *Oil & Gas Journal*, "Kitimat LNG partners award FEED contract," March 4, 2011. For more, see Kitimat LNG. Available: <http://www.kitimatlng.com>
39. EIA data, <http://www.eia.doe.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MCRFPUS2&f=M>
40. Author interview with Porter Bennett, CEO of Bentek Energy, an energy analytics firm.
41. EIA data, <http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MCRFPND1&f=M>. For annual EIA data production information, see: <http://www.eia.doe.gov/dnav/pet/hist/LeafHandler.ashx?n=pets&mcrcpus2&f=a>
42. EIA data, available: [http://www.eia.gov/dnav/pet/pet\\_crd\\_crpdn\\_adc\\_mbbldpd\\_m.htm](http://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbldpd_m.htm), see also, [http://www.eia.gov/dnav/pet/pet\\_crd\\_crpdn\\_adc\\_mbbldpd\\_m.htm](http://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbldpd_m.htm)
43. James MacPherson, "ND Oil Patch May Double Production," AP, January 2, 2011, <http://abcnews.go.com/Business/wireStory?id=12523340>
44. *Oil & Gas Journal*, "Continental: Bakken's giant scope underappreciated," February 16, 2011. For reference, according to BP, US proved oil reserves at the end of 2009 totaled 28.4 billion barrels.
45. *Oil & Gas Journal*, "Carrizo Updates Eagle Ford, Niobrara activity," November 30, 2010, [http://www.ogj.com/index/article-display/6955607842/articles/oil-gas-journal/exploration-development-2/2010/11/carrizo-updates\\_eagle/QP129867/cmpid=EnDailyNovember302010.html](http://www.ogj.com/index/article-display/6955607842/articles/oil-gas-journal/exploration-development-2/2010/11/carrizo-updates_eagle/QP129867/cmpid=EnDailyNovember302010.html)
46. Oilshalegas.com, <http://oilshalegas.com/wolfcampshale.html>
47. EIA data, <http://www.eia.doe.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MCRFPTX2&f=M>
48. Natural gas liquids include ethane, propane, butane, octane, and other compounds.
49. Samantha Santa Maria, "Shale-driven ethane price declines unlikely: Bentek report," *Platts*, January 4, 2011, <http://www.platts.com/RSSFeedDetailedNews/RSSFeed/NaturalGas/6720997>
50. Naturalgasforeurope.com, "Continental Resources Seeks Paris Basin Permits," February 24, 2011, <http://naturalgasforeurope.com/continental-resources-seeks-paris-basin-permits.htm>
51. American Gas & Technologies Inc. data, [http://www.agtlng.com/why\\_natural\\_gas-natural\\_gas\\_distribution.aspx](http://www.agtlng.com/why_natural_gas-natural_gas_distribution.aspx)
52. Evans, D.J. & Chadwick, R.A. (eds) 2009. *Underground Gas Storage: Worldwide Experiences and Future Development in the UK*. Geological Society, London, Special Publications, 313.

53. EIA data, [http://www.eia.doe.gov/pub/oil\\_gas/natural\\_gas/analysis\\_publications/ngpipeline/ngpipelines\\_map.html](http://www.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/ngpipeline/ngpipelines_map.html)
54. EIA data, [http://www.eia.gov/dnav/ng/ng\\_cons\\_sum\\_dcu\\_nus\\_a.htm](http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm)
55. EIA data, <http://www.eia.gov/dnav/ng/hist/n3025us2a.htm>
56. EIA data, [http://www.eia.doe.gov/emeu/mer/pdf/pages/sec7\\_5.pdf](http://www.eia.doe.gov/emeu/mer/pdf/pages/sec7_5.pdf)
57. Mark Fulton and Nils Melquist, "Natural Gas and Renewables: A Secure Low Carbon Future Energy Plan for the United States, DB Climate Change Advisors, Deutsche Bank Group, November 2010, 18.
58. Ibid, 3.
59. EPA data, <http://www.epa.gov/cair/>
60. EPA data, <http://www.epa.gov/oar/mercuryrule/>
61. Jeff Goodell, *Big Coal*, 134.
62. Shaila Dewan, "At Plant in Coal Ash Spill, Toxic Deposits by the Ton," *New York Times*, December 29, 2008. Available: [http://www.nytimes.com/2008/12/30/us/30sludge.html?\\_r=1&em](http://www.nytimes.com/2008/12/30/us/30sludge.html?_r=1&em)
63. Fulton and Melquist, op cit., 44.
64. EIA data, [http://www.eia.doe.gov/oiaf/aeo/electricity\\_generation.html](http://www.eia.doe.gov/oiaf/aeo/electricity_generation.html)
65. EIA data, [http://www.eia.doe.gov/oiaf/aeo/electricity\\_generation.html](http://www.eia.doe.gov/oiaf/aeo/electricity_generation.html)
66. Mark Fulton and Nils Melquist, "Natural Gas and Renewables: A Secure Low Carbon Future Energy Plan for the United States, DB Climate Change Advisors, Deutsche Bank Group, November 2010, 50.
67. See, for example, Marchetti, "On Decarbonization: Historically and Perspectivevely," International Institute for Applied Systems Analysis, January 2005. Available: <http://www.iiasa.ac.at/Admin/PUB/Documents/IR-05-005.pdf>
68. Ibid.
69. IEA, "IEA Executive Director: The climate challenge is immense but we have the clean technology," November 25, 2008. Available: [http://www.iea.org/Textbase/press/pressdetail.asp?PRESS\\_REL\\_ID=277](http://www.iea.org/Textbase/press/pressdetail.asp?PRESS_REL_ID=277)
70. Glaeser, *Triumph of the City*, 2.
71. Ibid, 1.
72. Marketplace, "A pragmatic response to climate change," October 26, 2009,
73. Brand, *Whole Earth Discipline*, 26.
74. Bryce, *Power Hungry*, 56.
75. International Energy Agency, "World Energy Outlook 2010," 77. Note that this projection is based on what the IEA calls its "New Policies Scenario." Furthermore, the IEA expects that by 2035, oil demand will grow by 19 percent, coal by 20 percent, and natural gas by a whopping 44 percent.
76. National Petroleum Council, "Topic Paper #29, Unconventional Gas," July 18, 2007, 4, [http://www.npc.org/Study\\_Topic\\_Papers/29-TTG-Unconventional-Gas.pdf](http://www.npc.org/Study_Topic_Papers/29-TTG-Unconventional-Gas.pdf)



## FELLOWS

Robert Bryce  
Peter W. Huber  
James Manzi

The Manhattan Institute's Center for Energy Policy and the Environment advances ideas about the practical application of free-market economic principles to address today's energy issues. It challenges conventional wisdom about energy supplies, production, and consumption, and examines the intersection of energy, the environment, and economic and national security.

[www.manhattan-institute.org/cepe](http://www.manhattan-institute.org/cepe)

The Manhattan Institute is a 501(C)(3) nonprofit organization. Contributions are tax-deductible to the fullest extent of the law. EIN #13-2912529