Is Natural Gas Really the Next Big Thing?

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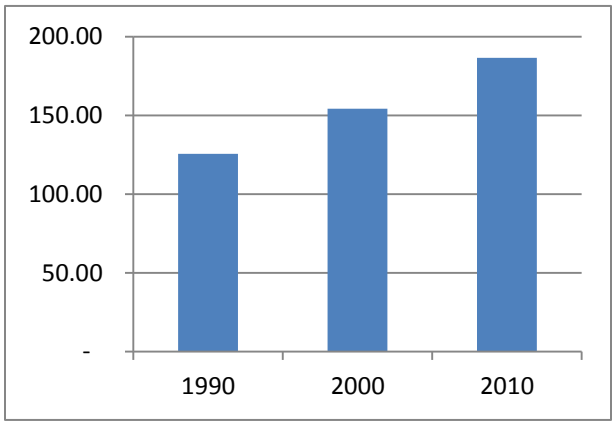
A white paper by the Washington Clean Technology Alliance natural gas and changes in energy supplies.

Is natural gas the *new* next big thing? It is being called a revolution in energy and a game-changer. Pulitzer Prize winning energy researcher Dr. Daniel Yergin claims that "By the beginning of this decade, the rapidity and sheer scale of the shale breakthrough—and its effects on markets—qualified it as the most significant innovation in energy so far since the start of the twenty-first century."[1] The President has proclaimed that the United States is "the Saudi Arabia of natural gas."[2] It is "the energy equivalent of the Berlin Wall coming down," says Robin West, Chairman and CEO of PFC Energy.[3]

Worldwide Natural Gas[4]
Proved Reserves (Trillion Cubic Meters)



[1] Daniel Yergin, The Quest: Energy, Security, and the Remaking of the Modern World (New York: The Penguin Press, 2011) p. 330.
[2] Joe Schoenmann, "Obama: We are the Saudi Arabia of Natural Gas", Las Vega Sun, January 26, 2012.
[3] John Ydstie, "Is U.S. Energy Independence Finally Within Reach? National Public Radio, March 7, 2012.
[4] BP Statistical Review of World Energy, June 2011, p. 20.

They may be right. Over the course of the next several years, we are likely to witness dramatic evolution in energy sources. It will not be overnight, but it is likely that there will be steady movement away from coal and petroleum and toward natural gas.

Natural Gas Supplies are Up Dramatically

The statistics are intriguing. From 1990 to 2010, global proved reserves of natural gas have increased by 49%. From 2000 to 2010, they increased by 21%.[5] The International Energy Agency (IEA) has estimated global gas resources at 32,000 trillion cubic feet, the energy equivalent of about 6 trillion barrels of oil.[6] This, according to Manhattan Institute Senior Fellow Robert Bryce, "is more than double the estimate for global gas resources that the (IEA) put forward in 2008."[7] The top twenty countries with the largest natural gas reserves (as of January 1, 2011) were: Russia, Iran, Qatar, Saudi Arabia, United States, Turkmenistan, United Arab Emirates, Nigeria, Venezuela, and Algeria. Significant natural gas fields may further develop in Poland, France, Turkey, South Africa, Morocco, Chile, Mexico, Libya, Argentina, Brazil, Australia, China, and Canada. Other regions may yield additional new discoveries. In Mexico, for example, as of yet, there has been little exploration.[8]

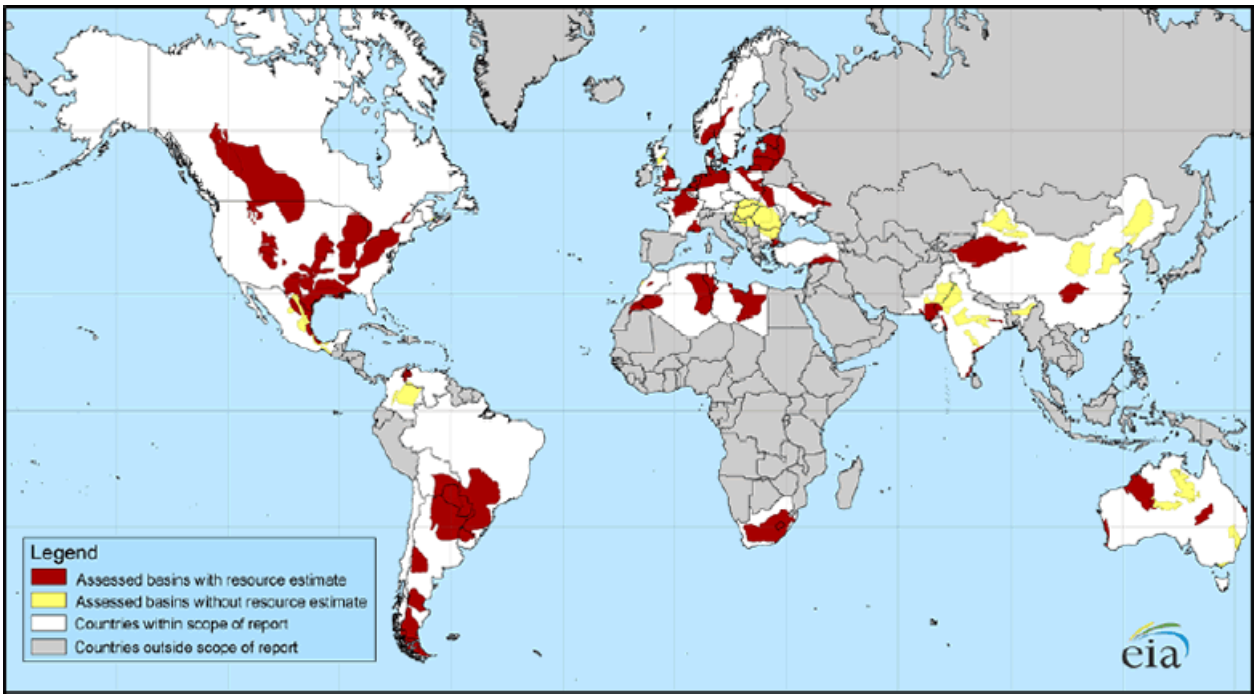
[5] Proved reserves are defined as the amount of known energy sources that are recoverable at economically viable costs.
[6] Resources may not be economically recoverable.
[7] Robert Bryce, Ten Reasons Why Natural Gas Will Fuel the Future (Center for Energy Policy and the Environment, Manhattan Institute for Policy Research: April 2010) pp. 1-2.
[8] John Deutch, "The Good News about Gas: The Natural Gas Revolution and Its Consequences," Foreign Affairs, Vol. 90 No. 1 (January/February 2011): 85.

Natural Gas Production[9]

Rank	Country/Region	Annual natural gas production (m^3)	Date
—	*World*	3,127,000,000,000	2008 est.
1	Russia	612,100,000,000	2010 est.
2	United States	611,100,000,000	2010 est.
—	European Union	182,300,000,000	2010 est.
3	Canada	152,300,000,000	2010 est.
4	Iran	138,500,000,000	2010 est.
5	India	120,000,000,000	2011
6	Qatar	116,700,000,000	2010 est.
7	Norway	106,300,000,000	2010 est.
8	China	94,410,000,000	2010 est.
9	Netherlands	85,170,000,000	2010 est.
10	Algeria	85,140,000,000	2010 est.
11	Saudi Arabia	83,940,000,000	2010 est.
12	Indonesia	82,800,000,000	2010 est.
13	Egypt	62,690,000,000	2009 est.
14	Uzbekistan	61,410,000,000	2009 est.
15	Mexico	59,070,000,000	2010 est.
16	Malaysia	58,600,000,000	2009 est.
17	United Kingdom	56,300,000,000	2010 est.
18	United Arab Emirates	48,840,000,000	2009 est.
19	Australia	45,110,000,000	2010 est.
20	Trinidad and Tobago	42,380,000,000	2010 est.

[9] U.S. Central Intelligence Agency, The World Factbook (March 2012)
https://www.cia.gov/library/publications/the-world-factbook/rankorder/2180rank.html

World Shale Gas Resources[10]



In the US, significant reserves are being found in New York, Pennsylvania, Texas, Montana, and North Dakota. "Domestic gas resources should easily last many decades," says Bryce.[11] Some believe the supply could be sufficient, at current rates of consumption, for "100 years or more."[12] In fact, in a marked change from forecasts of just a few years ago, most analysts believe that North America will be a net exporter of natural gas into the foreseeable future. Fortune says, "

> This shale boom has turned assumptions about the future of the U.S. and global energy picture upside down. Less than a decade ago the consensus was that America was beginning to run out of economically recoverable natural gas and that the country would need to import vast quantities of it from overseas. Now we're awash in natural gas."[13]

[10] U.S. Energy Information Administration, World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States (Washington, DC: April 2011).
[11] Op. Cit., Bryce, p. 1.
[12] Brian O'Keefe, "Exxon's Big Bet on Shale Gas," Fortune (April 30, 2012): 79.
[13] Ibid., p. 77.

Howard Gruenspecht, Acting Administrator of the EIA, says that it is likely the United States will become a net exporter of natural gas early in the next decade.[14] [15]

The market is reacting: Houston-based Cheniere Energy Partners is investing $6 billion for the first new plant capable of exporting natural gas by ship to be built in the U.S. since 1969. The Federal Energy Regulatory Commission is expected to approve the construction and operating permit as early as the first part of 2012.[16]

…So Prices are Dropping

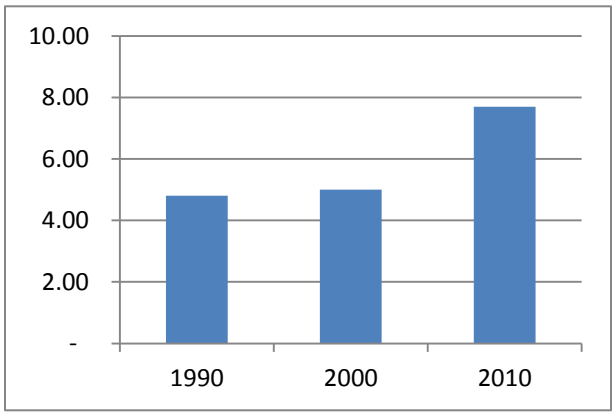
This dramatic increase in natural gas supply has put great pressure on prices. In early 2011, John Deutch of MIT noted that "In the United States today, oil is three times as costly as natural gas for a given amount for energy ($12 per million BTUs compared to $4 per million BTUs), and that is almost double the ratio that has prevailed over the past twenty years."[17]

In early 2012, the U.S. Energy Information Agency predicted that "with increased production, average annual wellhead prices for natural gas (will) remain below $5 per

[14] Howard Gruenspecht, Statement before U.S. Senate Committee on Energy and Natural Resources, 31 January 2012.
[15] In early 2012, technically recoverable resource (TRR) estimates of Marcellus shale substantially decreased from 410 trillion cubic feet (TCF) to 141 TCF. This resulted in a reduction in total U.S. TRR reserves to 482 TCF from an earlier estimate of 827 TCF. Total production, however, was forecast to increase seven percent more than in the earlier estimate. U.S. Energy Information Agency, Annual Energy Outlook 2012 Early Release Overview (23 January 2012).
[16] Rich Miller, Asjylyn Loder, and Jim Polson (Bloomberg News), "U.S. Closing in on Energy Independence," The Seattle Times, 8 February 2012, p. A3.
[17] Op. Cit., Deutch, p. 89.

thousand cubic feet (2010 dollars) through 2023.[18] Over the past decade, the price of gas has averaged $5.78 per million BTUs.[19]

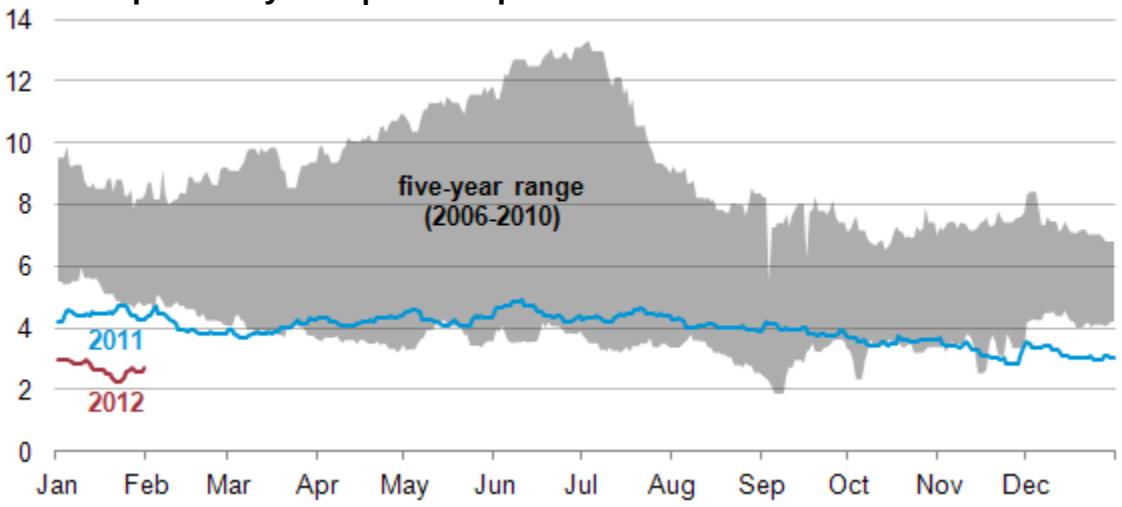
US Natural Gas[20]
Proved Reserves (Trillion Cubic Meters)



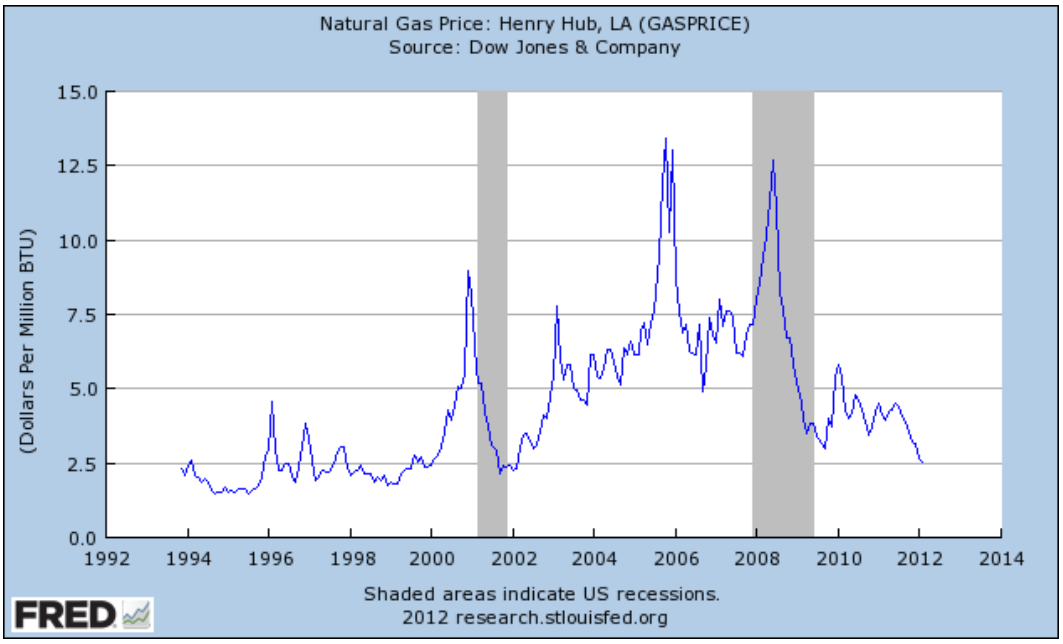
In fact, on January 20, 2012, the spot price for natural gas had decreased to $2.37,[21] an eighty percent reduction since 2008.[22] As Yergin puts it, "The potential here is enormous."[23]

[18] U.S. Energy Information Agency, Annual Energy Outlook 2012 Early Release Overview (23 January 2012).
[19] Op.Cit., O'Keefe, p. 80.
[20] Op. Cit., BP Statistical Review, p. 20.
[21] Robert Bryce, "How Fracking Lies Triumphed," New York Daily News (22 January 2012).
[22] Op. Cit., Miller, p. A3.
[23] Op. Cit., Yergin, p. 330.

Natural Gas Prices
Spot Henry Hub | Dollars per Million British Thermal Units[24]



Historic Natural Gas Prices[25]



[24] U.S. Energy Information Agency, "Natural gas spot prices near 10-year lows amid warm weather and robust supplies," Today in Energy (1 February 2012) http://www.eia.gov/todayinenergy/detail.cfm?id=4810.
[25] Federal Reserve Bank of St. Louis, Economic Research, "Natural Gas Price: Henry Hub, LA (GASPRICE)," http://research.stlouisfed.org/fred2/series/GASPRICE, 2012.

What is Natural Gas?

Natural gas is a fossil fuel in gaseous form. It is not renewable, but relative to other fossil fuels, natural gas is cleaner and can be more efficient. It has lower carbon intensity, emitting less CO_2 per unit of energy generated than other fossil fuels. It is, however, more difficult to store and transport. When it is delivered to markets via pipeline, a large fraction of the end user cost is in its delivery. Because of this, natural gas markets have traditionally been regional. Newer technologies, such as Liquefied Natural Gas (LNG) are now stimulating global trade.[26]

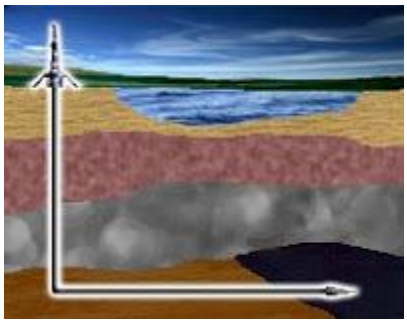
LNG removes dust, acid gases, helium, water, and heavy hydrocarbons from natural gas to compress it into a liquid that is 1/600 of the volume. It is used primarily as a means of transporting natural gas. Compressed Natural Gas (CNG) is one percent of the original volume and can be used in traditional gas internal combustion engines that have been converted.

Technical Innovations

Much of the increase in natural gas supply is due to two innovations in shale gas recovery: Horizontal drilling and hydraulic fracturing (or fracking). These technological developments have allowed drillers to economically harvest gas that was much more difficult and expensive to obtain in the past. The cost to produce shale gas today ranges from $2 to $3 per thousand cubic feet of gas—less than half of the cost of new conventional gas wells in North America.[27]

[26] Op. Cit., MIT, p. 3
[27] Op. Cit., Deutch, p. 84.

While these are not new technologies, they have become vastly more cost effective and much more utilized in the past decade.



Horizontal drilling achieved commercial viability during the late 1980s. Its successful employment, particularly in the Bakken Shale of North Dakota and the Austin Chalk of Texas, encouraged testing of it in many domestic geographic regions and geologic situations. Horizontal drilling is the process of drilling a well that begins vertically or on a slant which then angles to a target location.[28]

Hydraulic fracturing (or fracking) is a technique that was first used at the end of the 1940s. It injects large amounts of water, under high pressure, combined with chemicals and sand, into the shale formation. The quantity, characteristics, and toxicity of the chemicals are disputed. This fragments underground rock, creating pathways for otherwise trapped natural gas (and oil) to find a route and flow through to the well.[29]

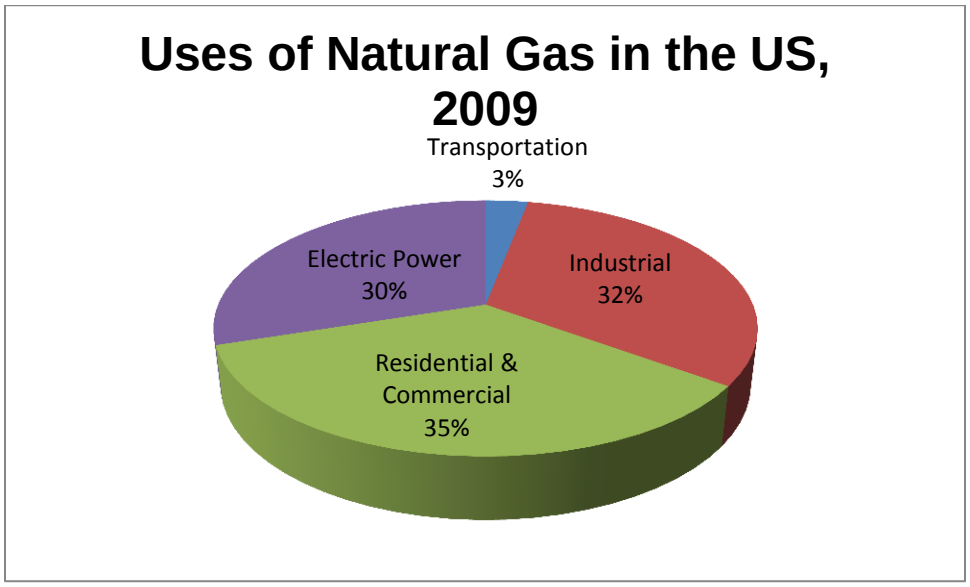
Changes are on the Way…

Natural gas already plays an important role in all sectors of the economy except transportation. It is already used widely to generate electricity and to heat water and spaces in industrial, commercial, and residential settings.[30] Lower costs, along with

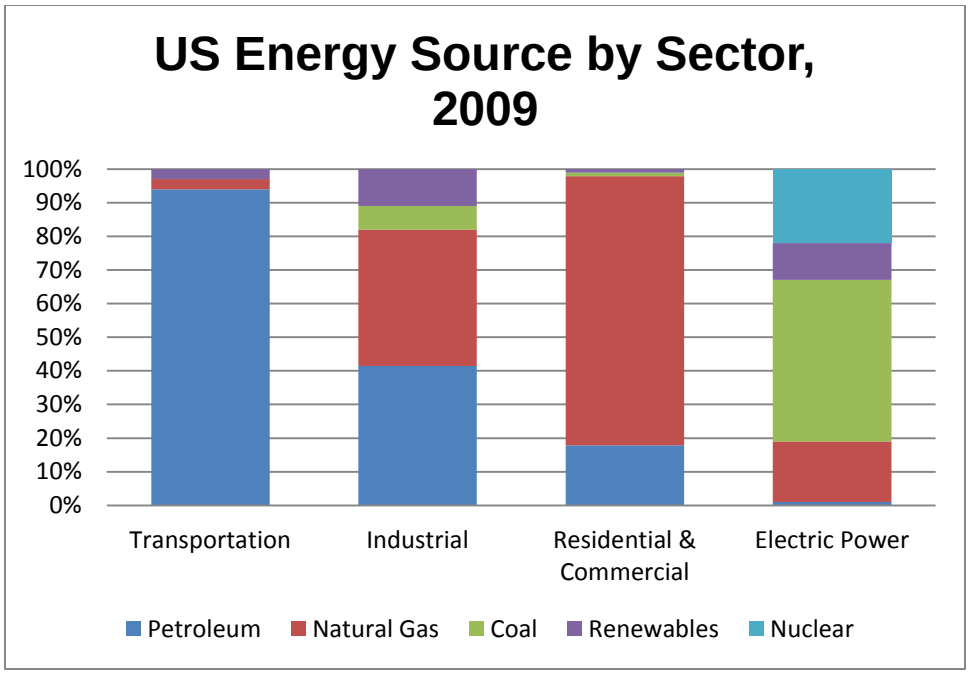
[28] U.S. Energy Information Administration, Drilling Sideways -- A Review of Horizontal Well Technology and Its Domestic Application (April 1993) p. vii.
[29] Op. Cit., Yergin, p. 327.
[30] Massachusetts Institute of Technology Energy Initiative, The Future of Natural Gas: An Interdisciplinary MIT Study (2011), p. 1.

infrastructure development, can be expected to increase the utilization of natural gas in transportation.

Natural gas has been growing in importance as a source of energy over the course of the last several decades. In 1965, natural gas accounted for 15.6% of global energy consumption (23 trillion cubic feet). Today, natural gas accounts for 24% (104 Tcf) of global energy.[31]



[31] Op. Cit., MIT, p. 4.



Source: U.S. E.I.A., Annual Energy Outlook, 2009 cited in M.I.T. Study, p. 4.

It is likely, during the next decade, that natural gas use will expand considerably in the electrical power generating sector displacing coal and may begin to displace oil in the transportation and chemical sectors.[32] Where the total cost of energy is perceived to be cheaper over the life of an investment, natural gas should be expected to be a compelling option for investors.

> *The role of natural gas in the world is likely to continue to expand under almost all circumstances*, as a result of its availability, its utility, and its comparatively low cost. (Italics in original)[33]

Daniel Yergin, in a Fortune interview, concurs.

> I believe natural gas in the years ahead is going to be the default fuel for new electrical generation. Power demand is going to go up 15% to 20% in the U.S. over this decade because of the increasing electrification of our society—everything from iPads to electric

[32] Op. Cit., Deutch, p. 82
[33] Op. Cit., MIT, p. 2.

Nissan Leafs. Utilities will need a predictable source of fuel in volume to meet that demand, and natural gas best fits that description.[34]

Potential Benefits and Concerns

The advent of this new source of energy presents several potential benefits and concerns. Fortune says that "…drilling activity has raced ahead of regulatory and public understanding. Fracking has become a dirty word to many…"[35] Predictably, advocates concerned about energy, business, economics, and the environment have strong—and often conflicting opinions—about these developments.

Air Pollution and Greenhouse Gases. For most applications, greater utilization of natural gas is expected to be beneficial to the environment. While natural gas is certainly not environmentally benign, its utilization—particularly as a replacement for oil and coal—has compelling environmental advantages. Natural gas produces no solid waste.[36] Compared to coal generated electricity, natural gas reduces nitrogen oxide emissions by 80%.[37] Natural gas emits about 29% less carbon than oil and 453% less than coal. As a transport fuel, natural gas emits about 20-30% less lifecycle carbon than oil.[38] In electricity generation, compared to coal, natural gas reduces emissions of sulfur dioxide by 100 percent.[39] Coal plants today generate more than 40% of our electricity.[40]

[34] Daniel Yergin, interview, "Will Gas Crowd Out Wind and Solar," Fortune (30 April 2012), p. 96.
[35] Op.Cit., O'Keefe, p. 79.
[36] Op. Cit., Bryce, Ten, p. 7.
[37] Ibid., p. 8.
[38] Amory B. Lovins and Rocky Mountain Institute, Reinventing Fire: Bold Business Solutions for the New Energy Era (White River Junction, Vermont: Chelsea Green Publishing Company, 2011) p. 233.
[39] Op. Cit., Bryce, Ten, p. 8.
[40] Op. Cit., Yergin, interview, p. 95.

Amory Lovins and the Rocky Mountain Institute note in Reinventing Fire that natural gas is "generally more benign than oil or coal."[41] The MIT study, The Future of Natural Gas, concluded that "substitution through increased utilization of existing combined cycle natural gas power plants provides a relative low-cost, short-term opportunity to reduce U.S. power sector CO_2 emissions by up to 20%, while also reducing emissions of criteria pollutants and mercury."[42]

Some authors are concerned that natural gas will not have sufficient impact on reducing greenhouse gases and reducing global warming. Nathan Myrhvold and Ken Caldeira note that "energy system transitions are intrinsically slow." The long lifetime of residual CO_2 results in lags before the impact of a transition on greenhouse gases can take hold. "This," they state, "underscores the urgency in developing realistic plans for the rapid deployment of the lowest-GHG-emission electricity generation technologies. Technologies that offer only modest reductions in emissions, such as natural gas and carbon capture storage, cannot yield substantial temperature reductions this century."[43]

Drilling Concerns. Natural gas recovery has been widely criticized for the impact that drilling has on the environment. These concerns fall into three basic categories: Polluted waste water, the potential for earthquakes, and the risk of contaminating drinking water. Sorting through the biases of writers on this topic is difficult. Not everything is known about these and they are certainly worthy of continued scientific monitoring and research. More regulation and industry oversight may be necessary.

[41] Op. Cit., Lovins, p. 233.
[42] Op. Cit., Massachusetts Institute of Technology Energy Initiative, p. xi.
[43] Nathan P. Myhrvold and Ken Caldeira, "Greenhouse Gases, Climate Change, and the Transition from Coal to Low-Carbon Electricity," Environmental Research Letters 7 (2012), p. 7.

But, to date, these concerns are hardly the cause of "devastation"[44] that is implied by some.

- *Polluted wastewater*. According to Daniel Yergin, "the biggest issue has become not what goes down, but what comes back—the water that flows back to the surface."[45] The fracking process generates large amounts of dirty water. Water is forced underground, along with sand and chemicals, to free natural gas for extraction. This is a significant concern and waste waters need to be handled properly, managed, and disposed of safely. "Some operators have conspicuously misbehaved and some regulators have fallen short," says the Rocky Mountain Institute's Amory Lovins, "making fracking controversial even in normally drilling-friendly places like Texas and western Colorado."[46] A reliable, responsible system of industry practices, enforced by regulation, is a reasonable and achievable goal.

- *Earthquakes*. The Washington Post editorial board asked, "Does Fracking for Natural Gas Cause Earthquakes?" Their conclusion was "yes," but these tiny earthquakes are "unfelt, but detectable directly above." Earthquake concerns are raised both from the fracking process and from disposal of waste waters pumped underground. The Washington Post writers suggest that "more study and probably more regulation will be needed" as more experience accumulates. But they note, "Of the 144,000 storage wells of this type in America, only a tiny fraction (of these wells) have been linked to earthquakes." They cite Arthur

[44]Roberta Brandes Gratz, "The Fracking Truth: Natural Gas Devastates Communities," Crosscut (2 February 2012).
[45] Op. Cit., Yergin, pp. 330-1.
[46] Op. Cit., Lovins, p. 233.

McGarr of the U.S. Geological Survey who suggests seismic monitoring at well sites and storing waste water away from population centers as reasonable precautions.

- *Contaminated drinking water aquifers*. Critics warn that fracking is contaminating drinking water aquifers. Methane has been found in water wells in gas producing regions, but, according to Yergin, there is no agreement on how this can happen. He notes that this could occur for several reasons such as improperly sealed wells or naturally occurring shallow layers of methane. The industry argues that fracking occurs a mile or more below drinking water aquifers and is separated from them by thick layers of impermeable rock. Further, there are more than a million wells where fracking has been employed in the United States dating back six decades.[47]

Continued scientific research efforts are important to determine whether this is a valid concern. Among the important research efforts is a federal E.P.A. study examining the relationship between fracking and drinking water.

> The scope of the proposed research includes study of the full life cycle of fracking water, from its acquisition to the mixing of the chemical to the fracturing and post-fracturing stages, including management of flowback and produce water and the ultimate treatment and/or disposal of the water recovered. …Initial research results are expected by the end of 2012, and a final report is expected in 2014.[48]

Most authorities conclude that increased natural gas extractions including fracking for shale involves manageable risks. Most also note the need for continued vigilance and research. They warn that the industry needs to create its own standards for safe and

[47] Op. Cit., Yergin, p. 330-1.
[48] Op. Cit., International Energy Outlook 2011, p. 53.

responsible practices.[49] In some cases, particularly in dealing with waste water, additional monitoring and regulation may be prudent. To date, these technologies are well established, have been used for decades, and the safety concerns have been minimal.[50] As a 178-page MIT study (also cited by Amory Lovins and the Rocky Mountain Institute) notes:

> The environmental impacts of shale development are challenging but manageable. Research and regulation, both state and Federal, are needed to minimize the environmental consequences.[51]

Energy Security. The United States continues to rely on imported oil for much of its petroleum utilization. In 2010, 49% of the oil used by the U.S. was imported.

Nearly half of those imports now come from the Western Hemisphere. The Persian Gulf states account for eighteen percent of crude oil and petroleum products. Canada (25%) and Saudi Arabia (12%) are our largest suppliers.

U.S. dependence on imported oil has dramatically declined since peaking in 2005. This is due to a number of factors including the economy, improvements in efficiency, and changes in consumer behavior. Competing energy sources (domestic biofuels, natural gas, and domestic production of oil) also have reduced the demand for imports.[52]

It is likely that increased utilization of natural gas, along with other factors, will reduce our dependence on imported oil from unfriendly sources. While this is a positive development, "this market penetration will not be so large that the security concerns of

[49] Op. Cit., Deutch, p. 86.
[50] Bryce, "How."
[51] Massachusetts Institute of Technology Energy Initiative, p. xi.
[52] U.S. Energy Information Administration. Energy in Brief (24 June 2011).

the United States and other oil importers about dependence on foreign oil will disappear."[53] Still, "the past image of the United States as helplessly dependent on imported oil and gas from politically unstable and unfriendly regions of the world no longer holds," (says) former Central Intelligence Agency Director John Deutch.[54]

Impact on the Economy. There can be little doubt that a significant reduction in the export of U.S. dollars to foreign nations to pay for energy imports will be a very positive development. It is likely to reduce the nation's trade deficit and enhance the value of the dollar. It is likely that new jobs and investments will develop in the creation of enhanced energy infrastructure to support growing utilization of natural gas.

Alternative Energy. Energy systems that are more expensive than natural gas are likely to become more difficult to develop and maintain. In some cases, such as coal and petroleum, this will be a welcomed change. In other cases, this change poses difficulties. The Seattle Times notes:

> The drop in natural-gas prices is also making the use of alternative energy sources such as solar, wind, and nuclear power less attractive, threatening to link the United States's future even more to hydrocarbons to run the world's largest economy.[55]

Juliet Eilperin, Washington Post national environmental reporter, wrote recently in a story entitled "Why the Clean Tech Boom Went Bust,"

> Perhaps the biggest force working against not just Solyndra but clean energy in general is this: Because natural gas has gotten so cheap, there is no longer a financial incentive to go with renewables.[56]

[53] Op. Cit., Deutch, p. 93.
[54] Op. Cit., Miller, p. A3.
[55] Op. Cit., Miller, p. A3.
[56] Eilperin, Juliet. "Why the Clean Tech Boom Went Bust." Wired, 20 January 2012.

Investors can be expected to make decisions on energy investments that are driven by maximizing their potential for returns and keep costs as low as possible.

> "Wind, on its own without incentives, is far from economic unless gas is north of $6.50," according to Morningstar utility analyst Travis Miller. Indeed, NextEra Energy has dropped plans for wind projects in the U.S. next year.[57]

And even though the costs of solar power have dropped, both coal and natural gas are currently cheaper.[58]

Impact on the Northwest

Washington State produces no natural gas. Yet business opportunities and jobs are growing for the suppliers of technology, products, and services to natural gas extraction companies.

- WaterTectonics is an Everett-based company that specializes in water cleaning systems including electrocoagulation treatment, chemical treatment, and automated pH adjustment. The company has seen significant growth in the treatment of flowback and produced water in natural gas extraction.
- World CNG specializes in the aftermarket conversion of light- and medium-duty passenger and cargo vehicles to use compressed natural gas instead of conventional gasoline or diesel.
- HotStart creates engine heating devices in markets including oil and gas. Much of the company's growth has been in delivering large pipeline pump engine heating solutions that significantly reduce wear and tear.

Conclusions

[57] Ibid.
[58] Op. Cit., Yergin, interview, p. 95.

Is natural gas the next big thing? There are few certainties in long-range economic forecasting, but it looks big. The U.S. Energy Information Agency, in its International Energy Outlook 2011 predicted that natural gas would be, "the world's fastest-growing fossil fuel."[59]

Overall, this is an enormously positive development. We can expect:

- Benefits for the environment as the economy transitions to a cleaner source of energy.
- Less global uncertainty as U.S. dependence on foreign sources of energy diminishes.
- U.S. economic benefits as we transfer less wealth to foreign energy producers.

As noted, there are legitimate concerns:

- Public health concerns to date have not been compelling enough to warrant severe changes in regulatory oversight. Objective research about drinking water, earthquake, and waste water risks from the natural gas development should be a high priority. Industry should realize the importance of public confidence and lead these research efforts. Natural gas developers should adopt prudent, conservative, industry-wide practices to ensure that risks are minimal. Regulators should be diligent in encouraging independent research and speedy, responsible reactions to new knowledge including oversight and monitoring.

[59] Op. Cit., International Energy Outlook 2011, p. 43.

- The impact of the development of natural gas on renewables is troubling. The potential for solar, wind, biofuels, and other forms of clean, renewable energy to have a significant and positive impact on our nation is high. But it is an economic reality that these forms of energy must compete and win in the marketplace.

The American people have long supported research. In the early 1990s, a federal commitment was made to enhance medical research by doubling the budget of the National Institutes of Health. This was an effort supported by Presidents and Congresses led by both parties. Today, the NIH budget is over $30 billion.

In contrast, the Department of Energy's Office of Science budget is less than $5 billion. Given the importance of this field, funding for basic research in energy should be significantly expanded.

> The U.S. government is "crazy" when it comes to funding for energy research and development, according to high-tech titan Bill Gates. "It's crazy how little we are funding this energy stuff," Gates today told an audience at a U.S. Department of Energy (DOE) conference near Washington, D.C. "Funding for energy [research] in the U.S. is underfunded by a factor of two."[60]

Ultimately, government funding policy is likely to have the most significant, positive, and long-term impact by funding the basic research that will supply the discoveries that lead to energy breakthroughs.

If natural gas can provide a bridge to this cleaner, more efficient energy future, it will indeed be a boon to the world.

[60] David Malakoff, "Bill Gates on Insanity and Energy R&D," Science Insider, http://news.sciencemag.org/scienceinsider/2012/02/bill-gates-on-insanity-and-energy.html, 28 February 2012.

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