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Natural Gas Reconsidered

BY ROGER COOPER

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During the past few years, the United States has received an unexpected energy windfall: put simply, we have a lot more natural gas than we previously thought.[1] This realization is altering America's energy future in a fundamental way. For many years, the conventional wisdom was that natural gas would play an important role as a bridge fuel but then fade away as the U.S. and the world turned to renewable sources of energy later in the 21st century.

Recent discoveries of enormous gas reserves in the United States offer a very different vision for the future of natural gas. Expanding domestic production will resolve the primary issue that is presently keeping natural gas from becoming the dominant energy resource in the U.S.: the inadequacy of supplies to guarantee long-term availability at reasonable and predictable prices.[2] Yet a recent report by the MIT Energy Initiative estimates that U.S. reservoirs may contain enough natural gas to meet demand for 90 to 100 years at current consumption levels with much less price volatility.[3]

New technology enabling the extraction of natural gas from shale has been called the most significant energy innovation this century; this discovery has spurred the expansion of U.S. natural gas production.[4] Technology developed primarily in the United States has made the dramatic expansion of U.S. natural gas resources possible. Further technical improvements may enable an even larger expansion of our natural gas resources. ExxonMobil, a company nearly synonymous with oil, now predicts that natural gas will be the fastest growing major fuel source worldwide through 2030.[5] Clearly, something very significant has happened in the world of energy.

A CONTINENTAL RESOURCE

Like coal, natural gas is a domestic and a North American resource. The United States recently became the largest producer of natural gas in the world.[6] According to some estimates, the U.S. natural gas resource base has almost tripled in a few short years.[7] Of the nearly 23 trillion cubic feet of natural gas consumed in the U.S. in 2009, just over 16 percent was imported and all but two

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FIGURE 1: LOWER 48 STATES SHALE PLAYS

Source: U.S. Energy Information Administration

percent of these imports were from Canada. The non-Canadian imports were in the form of liquefied natural gas (LNG), and over half of U.S. LNG imports came from Trinidad and Tobago.

Moreover, the U.S. natural gas resource base is likely to grow larger as new technologies are developed. This vast resource is not limited to a small geographical area. Thirty-two states are currently producing natural gas. While Texas, Wyoming, Oklahoma, Louisiana, Colorado, and New Mexico have historically been the dominant natural gas producers, the development of shale gas resources will likely lead to dramatic increases in natural gas production in Eastern and Midwestern states.

Each shale basin has a different composition that necessitates specialized production techniques. As more knowledge is gained and exploration technologies are advanced, it is likely that we will be able to increase estimated natural gas production from shale basins.

Areas containing gas-rich shale are called plays; the shale gas play attracting the most attention today is the Marcellus Shale. The Marcellus Shale is enormous and underlies portions of New York, Pennsylvania, Ohio, Maryland, Virginia, and West Virginia. The shale that holds the gas is up to 900 feet thick; most gas production takes place about a mile underground. In 2002, the U.S. Geological Survey estimated that the Marcellus Shale held about 1.9 trillion cubic feet (Tcf) of natural gas.[8] Today that estimate is seen to be quite an understatement. Two geologists provided a 2008 estimate that the Marcellus Shale could hold as

much as 500 Tcf, with perhaps 50 Tcf recoverable using today's technology.[9] The Marcellus Shale is important not only because of its enormous size, but also because it offers an immense energy resource on the doorstep of the large energy markets of the east coast.

Deep beneath the Marcellus Shale lies an even larger layer of shale known as the Utica Shale. Initial exploration and mapping of the Utica Shale is at its earliest stage and, because of the Utica Shale's greater depth, it is likely to be explored after the Marcellus Shale. It is unknown whether it will rival or exceed the productive possibilities of the Marcellus Shale.

In addition to the Marcellus and Utica Shales, there are vast shale resources throughout the United States. Some, like the Barnett Shale near Fort Worth, Texas, and the Haynesville Shale in Louisiana, have been in production for the last few years. Others remain largely untapped with their potential unknown. One map of U.S. shale plays shows 29 named shale plays in 20 states. Some of these shale plays, such as the Bakken Shale (Williston Basin) in North Dakota, hold large quantities of both oil and natural gas. While it will be many years before the full extent of U.S. gas shale resources is known, our experience to date indicates that we have tended to significantly underestimate the size of this energy resource.

Natural gas from shale is still considered an "unconventional" resource. An even less conventional energy source might be found in clathrate gas hydrates, solid formations of natural gas trapped in crystallized ice found hundreds of feet beneath seabeds and Arctic tundra. Significant clusters of methane hydrates have been found off the coast of Alaska and in the Gulf of Mexico, as shown in the map above.[10] Methane hydrate is similar to ice in appearance but will burn if put to flame since the melting of the ice releases methane. Gas hydrates are estimated to contain at least twice as much carbon as all other fossil fuels combined.[11] If fully exploited, gas hydrates would have the potential to become the largest US energy resource. The eventual development of gas hydrate resources may offer the U.S. an unfathomable supply of natural gas that could last many centuries.

It now appears clear that the amount of natural gas that the U.S. could produce is limited largely by our imagination and technological capacity.

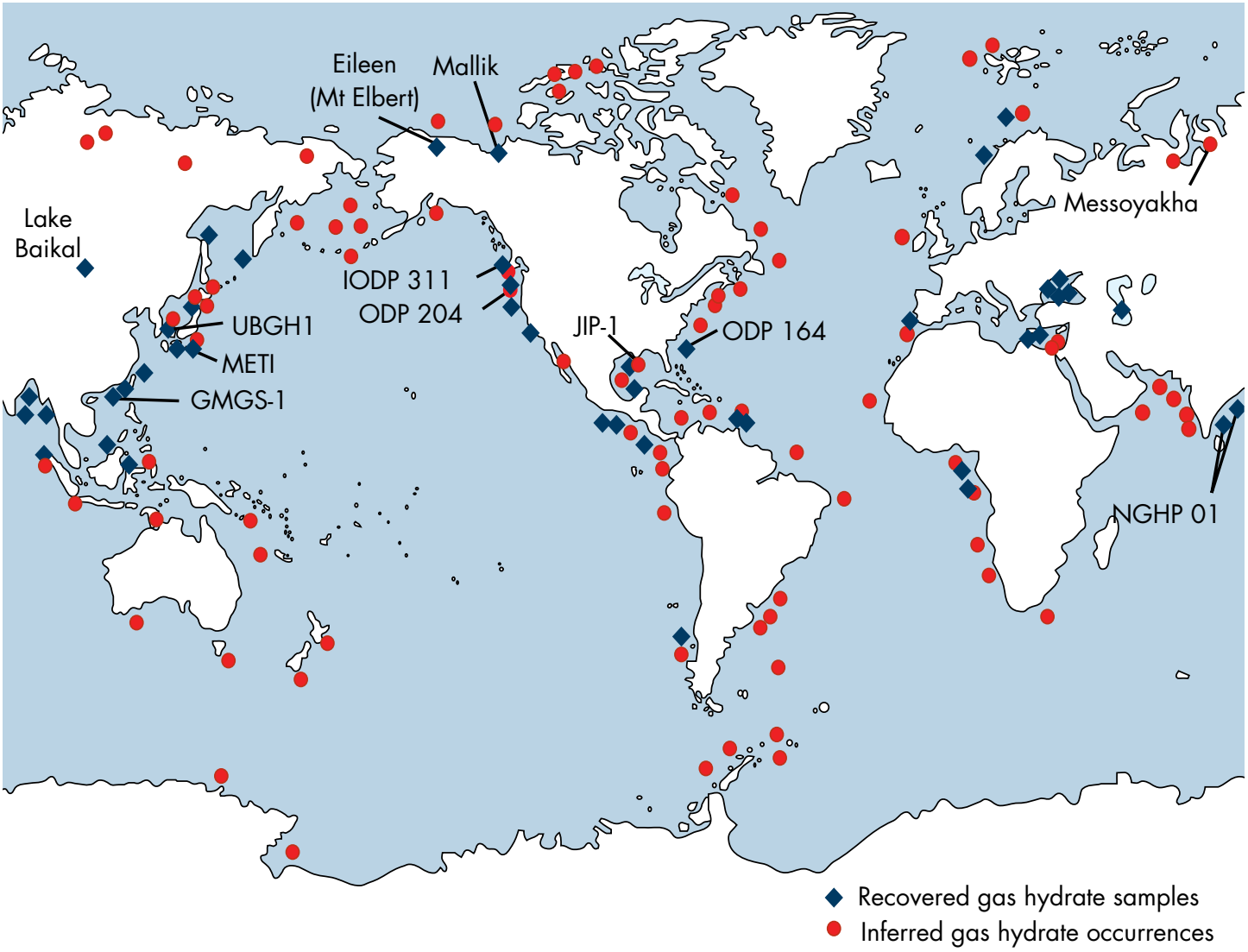
> Rather than continue to think narrowly of natural gas as a stopgap measure to hold us over while we wait for a clean energy revolution to occur, we should recognize that natural gas offers some of the most practical and meaningful improvements we can make to the ways we consume energy.

ECONOMIC IMPACT: LOWER PRICES, MORE JOBS

Because of the increase in supplies, natural gas wellhead prices have fallen more than 50 percent since 2008. The impact on consumers has been dramatic. A recent analysis shows that consumer heating bills in the northern U.S. would have been 40 to 50 percent higher in January 2011 without the increased production of shale gas.[12] This decrease in heating costs is now projected to continue into future years if natural gas production continues at current levels.

The increase in shale gas production is also leading to significant economic development in the U.S., with positive projections of future development and job growth. Today, the natural gas industry directly employs about 622,000 Americans nationwide and indirectly sustains almost 2.2 million additional jobs.[13] As the industry continues to grow, the geography of shale production is bringing badly needed employment and investment to areas that have not historically been energy producers and were hit especially hard by the recent recession.

FIGURE 2: GLOBAL GAS HYDRATE FORMATIONS



Energy Resource Potential of Methane Hydrate. National Energy Technology Laboratory, U.S. DOE at 9. http://www.netl.doe.gov/technologies/oil-gas/publications/Hydrates/2011Reports/MH_Primer2011.pdf

The most immediate economic benefits from the expansion of natural gas production are taking place in the mid-Atlantic and Great Lakes regions. Development of the Marcellus and Utica Shales in Pennsylvania, West Virginia, New York, and Ohio is already bringing new jobs to a region suffering from relatively high unemployment.[14] One recent study projected that development of the Marcellus Shale could produce anywhere from 100,000 to 280,000 new jobs in the northeast and mid-Atlantic regions and generate additional economic value of $9 to $25 billion by 2020.[15] Conversely, this study finds that continuation of New York State's moratorium on hydraulic fracturing could cost residents between $11 and $15 billion in lost economic output and between $1.4 and $2 billion in lost state tax revenues by the end of the decade.[16] Given that the Marcellus Shale has the potential to become the second-largest natural gas field in the world, it could bring about a remarkable change in the region's economics. Today, Pennsylvania relies on other states for about 75 percent of its natural

gas, but the development of the Marcellus Shale could make it a net exporter of natural gas to other states.

ADVANTAGES OF SUBSTITUTION STRATEGIES

New supply realities should prompt a reconsideration of the role natural gas can play in meeting America's future energy needs. It no longer makes sense to treat natural gas as just another dirty fossil fuel that the United States should stop burning as soon as we can find a feasible replacement. Many environmentalists and progressives have viewed gas as a transition fuel to be used until the happy day when renewable sources of energy like wind, solar, and hydroelectricity can provide enough baseload generation to power U.S. businesses and homes. That day, however, remains a very long way off.

Given that gas is abundant and cleaner than coal and oil, we should regard it instead as a permanent pillar of America's long-term energy strategy. By progressively substituting natural gas for these fuels in both the electricity and transportation sectors, we can fuel a growing economy while mitigating emissions of carbon into the earth's atmosphere.

Rather than continue to think narrowly of natural gas as a stopgap measure to hold us over while we wait for a clean energy revolution to occur, we should recognize that natural gas offers some of the most practical and meaningful improvements we can make to the ways we consume energy. Additionally, these improvements are realistic, imminently achievable in the near term, and would bring long-lasting benefits for current and future generations.

So let's look at some of the advantages of substituting more natural gas for the fuels we currently consume for transportation, electricity generation, and residential heating.

Clean Energy

When burned, natural gas is the most environmentally friendly fossil fuel, because it produces low levels of unwanted byproducts such as sulfur dioxide (SO2 that produces acid rain), particulate matter (soot), and nitrogen oxide (NOx that produces smog). Upon combustion, natural gas produces 43 percent less CO2 than coal and 28 percent less CO2 than home heating oil, two fuels that are heavily relied upon in our current energy mix.

Moving toward increased use of natural gas in electricity generation could lead to a dramatic reduction in greenhouse gas emissions today, without massive investments in new technologies or expensive and time-consuming expansions of infrastructure.[17] According to a recent MIT study, "[t]here is sufficient surplus [natural gas combined cycle electricity generating] capacity to displace roughly one-third of U.S. coal generation, reducing CO2 emissions by 20 percent and yielding a major contribution to control of criteria pollutants."[18] Using natural gas power plants that are already up and running but not being used at full capacity, U.S. greenhouse gas emissions could be reduced by about 10-20 percent almost overnight.

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Since 1970, U.S. greenhouse gas emissions have risen fairly steadily, generally paralleling the increase in U.S. energy consumption. During this same time, total greenhouse gas emissions from natural gas customers have either fallen or remained flat, despite the fact that the number of U.S. households using natural gas has increased by 70 percent.[19] The use of newer, more energy-efficient natural gas furnaces and water heaters, along with new building codes and energy efficient housing material, has caused this reduction in

per capita greenhouse gas emissions from homes using natural gas. In recent years, the amount of natural gas needed to heat a home or business has significantly decreased.[20] Simply put, natural gas – not renewable fuels – has been the U.S. leader in reducing total greenhouse gas emissions thus far, and it offers even more untapped potential for further reductions.

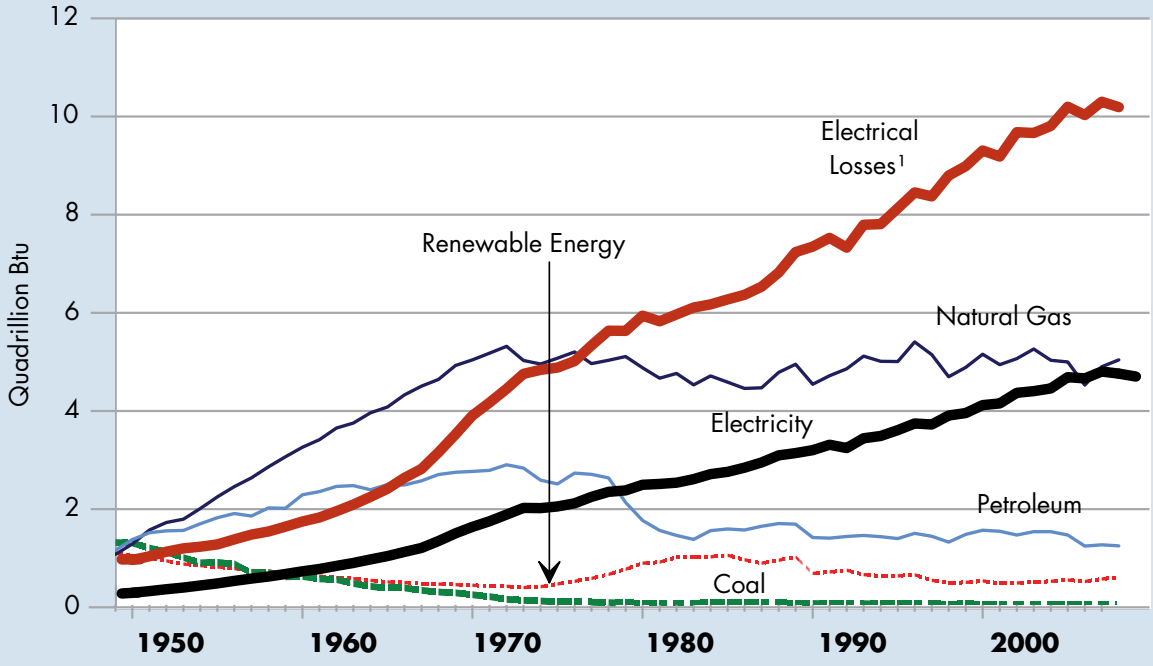
Energy Efficiency

Energy efficiency has been called the fifth fuel and is the first resource we should tap to meet rising demand. It is often seen as the low-hanging fruit that offers a bigger payout for less effort. The use of natural gas can dramatically increase energy efficiency in the U.S.

Energy efficiency can be thought of very simply – how much useful energy is produced from each unit of raw energy? In other words, how much energy is used and how much is wasted? Transforming raw primary energy (such as coal, oil, or natural gas) into useful energy (e.g., electricity) always creates energy waste. It takes energy to make useful energy. The extent of this waste is surprising: To produce useful electric energy in the United States we waste or discard, about 70 percent of the initial raw energy found in coal or most other fuel sources.[21] In fact, the amount of energy lost in generating and delivering electricity to American homes is greater than all the energy used from all sources to heat, light, and power these homes. See Figure 3, U.S. Residential Energy Consumption, below.

Unlike electricity, natural gas can be moved from its source to homes and businesses with very little energy loss. To produce useful energy from natural gas, about 10 percent of the initial raw energy is wasted during transit, rather than the

FIGURE 3. U.S. RESIDENTIAL ENERGY CONSUMPTION, 1949-2009



[1] Electrical system energy losses associated with the generation, transmission, and distribution of energy in the form of electricity.

Annual Energy Review 2009, U.S. Energy Information Administration, DOE/EIA-0384 (August 2009) Tables, Figure 2.1b, page 39
Electrical energy losses during generation, transmission, and distribution of electricity are greater than the electricity actually used by consumers. These losses have tracked the increased consumption of electricity since the 1950s.

70 percent lost during the transit and generation of electricity.[22] Obviously, natural gas cannot be substituted for all electricity use in homes and businesses. The era of gas lighting is long gone. But when it comes to heating, natural gas offers obvious energy efficiency savings over electricity. Nonetheless, natural gas is being used less and less to heat homes and businesses. After rising steadily, the share of new American homes heated with natural gas has been declining since 2003. Further, more homes are using highly inefficient electric water heaters instead of gas water heaters. U.S. energy policies inadvertently have encouraged this trend by focusing almost entirely on the efficiency of appliances and not the overall efficiency of energy systems.[23]

EFFICIENT TRANSPORT AND STORAGE

The transportation of energy from where it is found or created to where it is needed is one of the most challenging energy issues.[25] The discovery of massive natural shale gas resources near big population centers is in itself a significant energy development. New natural gas transmission lines have been sited and built as needed, and generally have not had to deal with the challenges facing large electric transmission lines. This is largely because the Federal Energy Regulatory

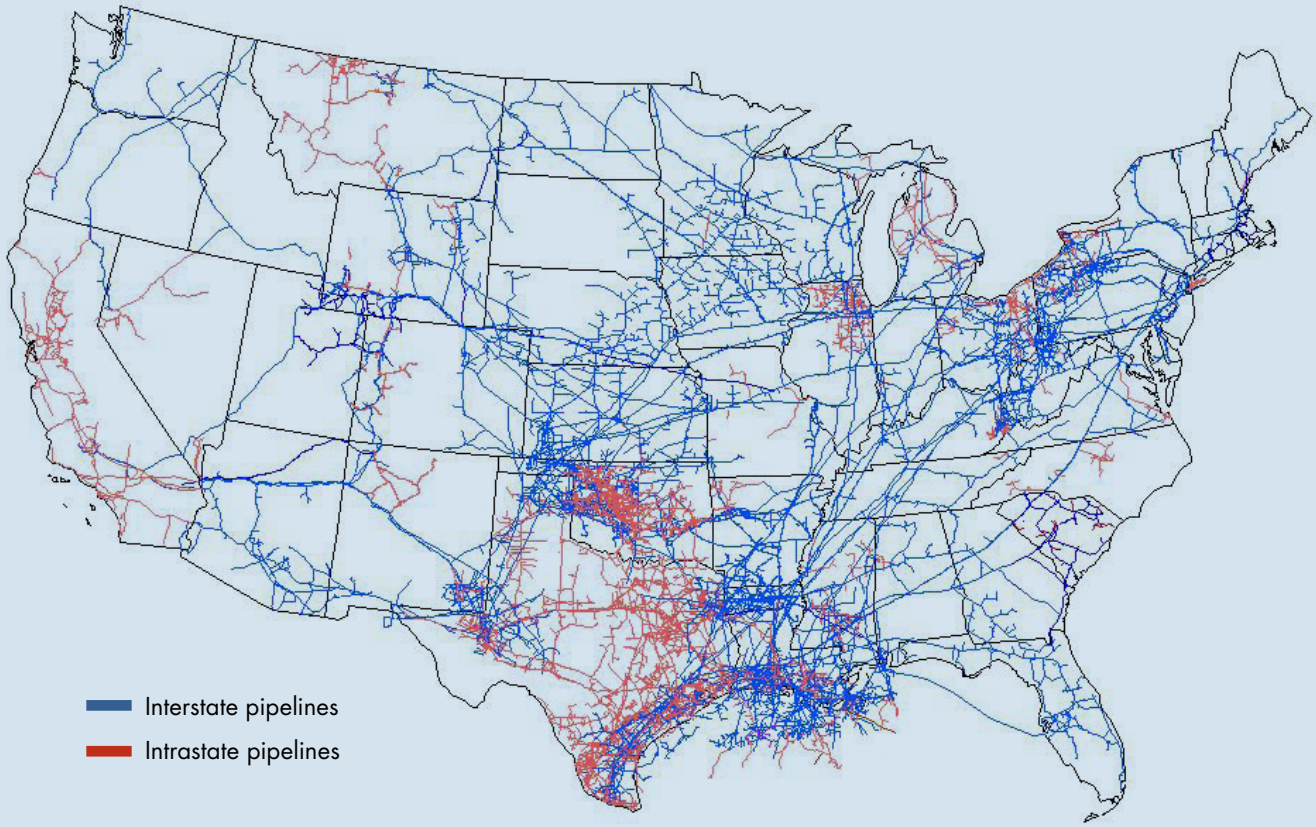
FIGURE. 4. THREE TIMES MORE ENERGY REACHES THE CUSTOMER WITH NATURAL GAS WITH FEWER GREENHOUSE GAS EMISSIONS.

	Extraction, Processing & Transportation	Conversion[1]	Distribution	Delivered to Customer	Greenhouse Gas Emissions
Electricity **32% Efficient**	100 MMBtu Energy Source	95	34	32	
CO2 equivalent[2] emissions from typical household use[3] (metric tons)	1.4	8.7	0	0	Total CO_2e **10.1**
Natural Gas **92% Efficient**	100 MMBtu Energy Source	Not Applicable	93	92	
CO2 equivalent[2] emissions from typical household use[3] (metric tons)	0.5	Not Applicable	0.1	5.8	Total CO_2e **6.4**

1 Includes all energy inputs, including renewable sources – based on actual fuel mix in 2007
2 Includes greenhouse gas impact from unburned methane
3 Energy consumed in space and water heating, clothes drying, and cooking.
NOTE: This full-fuel-cycle examines all impacts from the energy source through consumption

Source: American Gas Association, Bruce McDowell, May 2011[24]

FIGURE 5. U.S. NATURAL GAS PIPELINE



Source: U.S. Energy Information Administration

Commission has primary authority to approve the siting and construction of natural gas pipelines, while the states have primary authority to approve – or block – proposed electric transmission lines that cross state borders. In the U.S. today, there are over 305,000 miles of major natural gas transmission lines and over 2 million miles of local gas distribution lines. Additional natural gas pipelines are being approved and built to bring newly developed natural gas resources to markets.

Unlike electricity, natural gas can be stored in large quantities and brought to market fairly quickly. Natural gas is stored in three types of underground reservoirs: depleted reservoirs that originally produced natural gas or oil, aquifers, and salt dome caverns. U.S. natural gas storage capacity has been steadily increasing over the last decade and today equals almost 20 percent of annual natural gas consumption.[26]

Liquefied Natural Gas (LNG) terminals offer another way to store natural gas. LNG is natural gas that has been cooled to about minus 260 degrees Fahrenheit. At that temperature, natural gas turns into a liquid and has much higher energy density (about 610 times more energy per unit of volume than in its gaseous state). LNG is not natural gas stored under pressure; LNG storage terminals are more like giant steel-lined thermos bottles. LNG will turn back into a gas if the temperature rises. Most of the world's natural gas is produced, transported, and stored as LNG. Countries without significant natural

gas resources, like Japan and Korea, import a significant portion of their energy in the form of LNG.

In the United States, there are currently seven LNG import terminals. Before the recent development of U.S. shale gas, the conventional wisdom was that the U.S. would have to build many more LNG import terminals. While the U.S. currently has a glut of natural gas, analysts expect that the U.S. will continue to import LNG when world natural gas prices are low and store the LNG for U.S. consumption or possible re-export. Like natural gas storage fields, LNG storage capacity offers a strategic and operational supplement to existing natural gas production. Today's LNG import capacity could theoretically meet 20 percent of current market requirements.[27]

Given its ample reserves of gas, should the United States export LNG?[28] While some LNG exports may be approved, it seems unlikely that the U.S. will become a major LNG exporter anytime soon. That is because building LNG export terminals generally involves a long-term, twenty-year commitment and is hugely expensive, compared to the cost of building import terminals or LNG tankers.[29]

CHALLENGES AND REALITIES OF NATURAL GAS EXPANSION

No major energy source has been found to be perfect, and natural gas is no exception. Most of the qualms about increasing our use of natural gas surround gas production techniques and the environmental impact of drilling. A second set of concerns involves greenhouse gas emissions arising from the production, transmission, distribution, and combustion of natural gas. A third set centers on safety, and the direct health and environmental risks from transmitting, distributing, and burning natural gas.

Supply-Chain Footprint

Most Americans wouldn't know a natural gas well if they tripped over it. It is not like the familiar drilling rig, which may be in place for a few weeks and then moved to another site, nor is it the oil pump-jack seen in the background of countless films. Instead, once the drilling is completed, a typical natural gas well looks like a few feet of pipes and some gauges sticking five to eight feet into the air and covering an area around the size of a backyard deck.[30] This set-up is called a Christmas tree.

Since natural gas is trapped under pressure in reservoirs or various types of rock formations, it will naturally flow to the surface when a well is completed. After it reaches the surface, the natural gas moves through a small gathering of pipes. Moving the gas into a pipeline system requires compression. Driven either by gas or electricity, compressors can be fairly noisy. The natural gas also generally needs to go through a processing plant to remove liquids (mostly water, sometimes sulfur and also naturally occurring propane, ethane, and similar liquids). These plants are not like oil refineries, which chemically change crude oil into products like gasoline, but are somewhat simpler facilities that separate the natural gas from excess water vapor and other liquids. A typical processing plant may serve hundreds of natural gas wells.

The Fracking Controversy

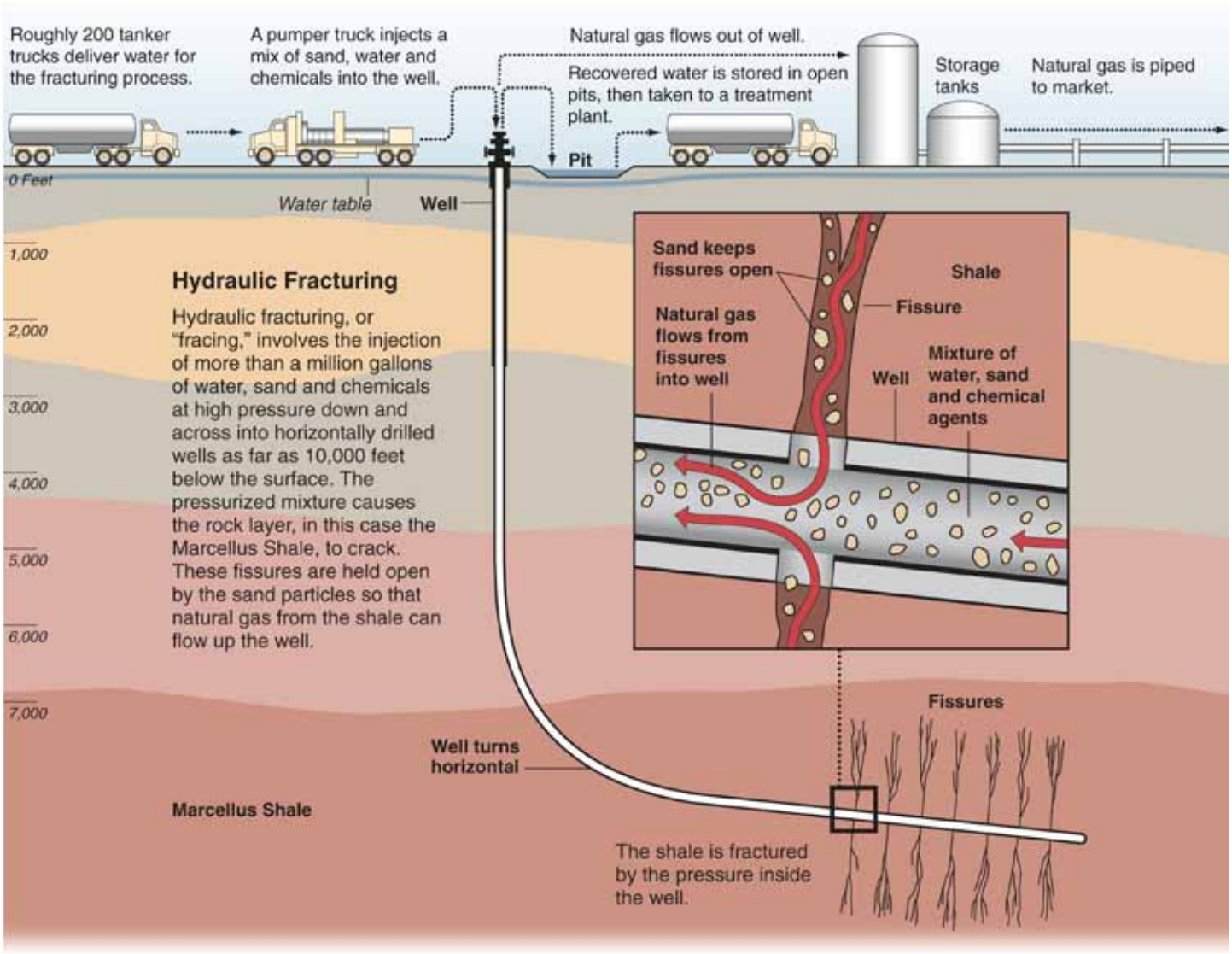
Three technological breakthroughs have made possible the huge expansion of U.S. natural gas production. The first is 3-D seismic imaging, which involves the use of sound waves to map underground formations and locate natural gas reservoirs. 3-D seismic imaging has dramatically improved the success rate for finding natural gas reservoirs. The second breakthrough is horizontal drilling, a procedure where the drill bit is turned while underground, and the drilling continues horizontally. This technique allows the drill bit to follow the seam where natural gas is found and leads to increased production with fewer drilling rigs and less disturbance to surface areas. The third breakthrough is hydraulic fracturing, or "fracking," a process designed to liberate natural gas trapped underground. During fracking, large volumes of water, sand, and chemicals are pumped down a wellbore to create fractures in the rock surrounding the pipe. These fractures create pathways for trapped natural gas to reach the pipe and travel to the surface.

Fracking has been used for over 60 years in the U.S. in over a million natural gas wells. About 90

percent of both shale and conventional natural gas wells will be "fracked" at some point in their production life. The principal ingredient of fracking fluid is water. Fracking a large horizontal shale gas well may necessitate as much as 5 million gallons of water, while a coalbed methane well may need only 50,000 to 350,000 gallons.[31] The next major ingredient is a "proppant," typically sand, which is used to keep the fissures open, allowing gas to flow to the wellbore. Water and sand make up 98 to 99 percent of what is injected into a "fracked" well, but most of the controversy concerns the use of additional chemicals. There is no single formula for fracking fluids, as their ingredients and relative mixtures are adjusted depending upon the wells being drilled and the rock formation to be fracked.

For years, manufacturers regarded the composition of their fracking fluid as proprietary and resisted public disclosure. Recently, all nine of the largest hydraulic fracturing companies agreed to supply the EPA with information on the chemical composition of their fluids.[32] The EPA will use this information as part of a two-year-long study of hydraulic fracturing, with the initial study results expected by late 2012. A 2004 EPA study

FIGURE 6. HYDRAULIC FRACTURING



Al Granberg/ProPublica, What is Hydraulic Fracturing

found hydraulic fracturing safe, saying "there was 'no unequivocal evidence' of health risks, and the fluids were neither necessarily hazardous nor able to flow far underground."[33] However, the study dealt only with the fracking of coalbed methane wells and did not consider gas shale wells, which are deeper and require considerably more fluid to fracture.

Pollution and Water Contamination

Improperly done, natural gas drilling can cause surface land pollution and well water contamination. Surface contamination can occur from spilled drilling fluids and from improper disposal of wastewater that may come up the wellbore. This wastewater may be either the water that was originally injected into the well or water that was underground and was released along with the natural gas. In one case, a well blowout in Pennsylvania sent more than 35,000 gallons of hydraulic fracturing fluid into the air.[34]

Well water contamination can result from cracks in the cement lining of the wellbore that allow natural gas to escape into an aquifer. Preparing a drilling site disturbs the landscape, and the drilling itself generates air pollution. Sometimes, new permanent roads need to be built to drilling sites, although the construction of gravel roads is more common.

As with harnessing any energy resource, there are dangers associated with extracting natural gas. Natural gas drilling is regulated in every state where it occurs and is also subject to certain federal regulations. Where government authorities have found violations, well operators have been fined and in some cases barred from further drilling.[35]

Wastewater Disposal

After a well is fracked, the wastewater must be properly treated and disposed of. In some cases, wastewater is stored in artificial ponds, where it could leach into the soil if not properly contained. In some areas of the country where the geological conditions permit, wastewater is pumped deep underground where it cannot migrate to the surface. Often wastewater is cleaned of impurities and reused. Wastewater may contain high levels of naturally occurring salt and smaller trace amounts of other natural impurities, including radium. Without doubt, government officials need to monitor processes for wastewater treatment and disposal to ensure they meet state and federal requirements.

> The combustion of natural gas produces about 30 percent fewer CO2 emissions than the combustion of oil and about 45 percent fewer emissions than the combustion of coal.

Air Pollution

Producing natural gas requires heavy industrial equipment, and during the drilling phase it is not unusual to see an increase in ozone levels as well as increased production of nitrogen oxides and volatile organic compounds. There also are some methane emissions during the production phase.[36]

Greenhouse Gas Emissions

The natural gas industry has been working with the EPA and DOE since 1993 to reduce greenhouse gas emissions, particularly methane, as part of the Natural Gas STAR program.[37] This program covers the production, transmission, and distribution of natural gas and has been successful in developing cost-effective practices for reducing methane emissions. Greenhouse gas emissions from the burning of natural gas take the form of carbon dioxide and are significant. However, the combustion of natural gas produces about 30 percent fewer CO2 emissions than the combustion of oil and about 45 percent fewer CO2 emissions than the combustion of coal.[38]

Recently, there has been some controversy regarding methane emissions from shale gas production. It is plausible that shale gas wells may produce more methane emissions than traditional

gas wells. However, these methane emissions are much smaller than the CO2 emissions produced by natural gas combustion, and they are likely to be reduced over time as control technologies for this relatively new form of production are improved. While total methane emissions have increased since 1990 along with the significant increase in gas production, they have been offset largely by reductions in methane leakage from gas processing, transportation, storage, and distribution.[39] Overall greenhouse gas emissions from natural gas production, delivery, and combustion have not increased since 1990, based on the most recent data from EPA and DOE.

Safety

Natural gas transmission and distribution via pipeline is listed as the safest form of transportation by the U.S. Department of Transportation.[40] Nonetheless, natural gas is flammable when mixed with air in the right proportion, and natural gas explosions, while rare, will almost always feature prominently in the news. The U.S. Department of Transportation and state agencies regulate natural gas transportation. Third-party contractors cause most natural gas pipeline accidents by failing to call to get natural gas lines marked before doing excavations.

CHALLENGING BUT MANAGEABLE

The recent MIT Report on the Future of Natural Gas stated; "[t]he environmental impacts of shale development are challenging but manageable."[41] New technologies, along with increased identification and use of best practices within the industry, promise to shrink the environmental footprint of shale production and even reduce production costs in some cases. Natural gas drilling and production technologies are far from static, and it is not unreasonable to assume that we will see – with a little nudging – greener natural gas production in the future.

State and federal agencies have, for the most part, taken moderate approaches thus far to regulating hydraulic fracturing and shale production, with most regulations focused on requiring greater transparency from drillers. Wyoming, Texas, Arkansas, Pennsylvania, and Michigan have adopted disclosure rules requiring companies to report the chemicals used in the fracking process. Even New York, which had implemented a de-facto ban on all fracking in the state, has announced that it plans to allow fracking on private land, which will provide access to up to 85 percent of the Marcellus Shale in the state for extraction.[42]

The natural gas industry has taken the lead on addressing concerns about fracking, in many cases going beyond the requirements of state regulations. Companies voluntarily disclose information about the chemicals used in fracking into a national online registry.[43] And the industry is increasingly promoting improved standards and best practices for safer and more effective extraction techniques.[44]

At the federal level, the U.S. Department of Energy earlier this year created a Natural Gas Subcommittee to the Secretary of Energy's Advisory Board. The Subcommittee is currently investigating fracking issues, with a focus on identifying best practices and additional steps for improving the safety and environmental performance of shale gas extraction processes.[45] The Subcommittee's report is expected in August, 2011. The Environmental Protection Agency is also conducting a scientific study of any possible environmental and health impacts of hydraulic fracturing, which it plans to complete in 2012.[46]

OPTIMAL USE OF THE SUPPLY WINDFALL

There is little doubt that Americans will expand their use of natural gas in coming years. How will we use the new supply of gas? There are four main options: to generate electricity, to expand industrial output, to fuel transportation, and to heat homes and businesses. It is tempting to say that the market should decide how best to deploy our natural gas windfall, but in practice public policy also will influence such decisions.

Substituting Gas for Coal and Nuclear Generation

There is currently more installed natural gas electricity generation capacity than coal-fired capacity in the U.S.[47] Using more of this existing gas-fired generation would lead to immediate reductions in greenhouse gas emissions, as well as SOx, NOx, and mercury emissions.[48] The

Congressional Research Service has calculated that doubling the utilization of existing natural gas-fired electric generation would displace about 19 percent of the CO2 emissions associated with coal-fired generation.[49]

In addition to using existing natural gas facilities more frequently, greenhouse gas emissions can be further reduced by building and using newer, more efficient, combined-cycle natural gas-fired electric generation units to replace existing coal or oil generation plants. These new units can be brought online more quickly at lower cost than new coal plants.

The glut of cheap natural gas, together with the failure of Congress to put a price on carbon emissions, has serious implications for the future of nuclear energy in America. The crisis at Japan's Fukushima nuclear facility complicates the matter further. Even some traditional supporters of new nuclear power plants are now favoring instead the development of natural gas combined-cycle plants.[50]

Supplementing Renewables with Natural Gas

Natural gas-fired plants will also increasingly be deployed in combination with renewable sources of energy. Natural gas can be used to provide supplemental power when renewable resources are unavailable. For example, natural gas can be used to backstop wind turbines when wind speeds are unsuitable, or to make up for shortfalls at solar power plants when bad weather reduces output. Indeed, it is generally assumed that natural gas will be the fuel that backs up intermittent wind power to ensure reliability of power supply to the grid. However, using natural gas as a standby "peaking service" will be expensive. Not only will natural gas combined-cycle turbines need to be held in reserve for periods when the wind dies down, natural gas pipeline and storage capacity will also need to be held at the ready.[51]

Manufacturing Use of Natural Gas and U.S. Jobs

If its price remains competitive with coal and cheaper than oil, manufacturers will increasingly turn to natural gas as an energy source, and also as a feedstock in the case of chemical and

fertilizer plants.[52] The use of natural gas by manufacturing facilities is driven largely by the economy and general industrial demand. However, energy costs are particularly important in the industrial sector. If the United States is able to keep U.S. natural gas prices competitive with world natural gas prices, which appears to be the case, manufacturers, particularly in the chemical and energy-intensive industries, will find it advantageous to build, operate and expand plants in the U.S. Recently a number of companies have cited lower natural gas prices, and the prospect of continued lower prices, as factors in their decisions to increase manufacturing in the U.S.[53] A March 2011 report from the American Chemistry Council found that a "hypothetical, but realistic 25 percent increase in ethane supply", which is derived from natural gas shale production, would create "17,000 new knowledge-intensive, high-paying jobs in the U.S. chemical industry" along with 395,000 additional jobs outside the chemical industry, and $4.4 billion more in federal, state, and local tax revenue.[54] Relatively low-cost energy prices helped build U.S. manufacturing in the 20th century, and the availability of large quantities of

natural gas, priced below delivered world market prices, should assist in a resurgence of U.S. manufacturing in the 21st century.

Fueling Transportation Without Oil and Gasoline

The transportation sector offers another potentially huge market for natural gas. Natural gas is cheaper than gasoline, and most cars, trucks, and buses can run on natural gas with only modest engine adjustments. However, the major obstacle facing the use of natural gas as a transportation fuel has been the dearth of natural gas refueling stations. The absence of a fueling infrastructure has hampered the development and sales of natural gas vehicles, and the lack of natural gas vehicles has hampered the development of natural gas refueling stations. This "chicken and egg" dilemma has long limited the natural gas vehicle market to applications where vehicles can be centrally fueled (urban buses, urban delivery vehicles, etc.).

> Relatively low cost energy prices helped build U.S. manufacturing in the 20th century and the availability of large quantities of natural gas, priced below deliver world market prices, should assist in a resurgence of U.S manufacturing in the 21st century.

Residential and Commercial Uses

While over half of American homes and businesses use natural gas as a fuel for heating, there remains a significant opportunity to expand the use of natural gas in both new and existing homes. The most significant expansion would occur if natural gas were used to fuel distributed power. Distributed power is electricity that is generated at, or close to, a home or business. The existing natural gas transmission and distribution network could be used to move natural gas to distributed generation units where the gas could be converted to electricity. Such a use of natural gas would significantly reduce U.S. energy waste. Distributed power comes in many forms, one exciting potential application being a low-cost, low greenhouse gas-emitting fuel cell that could be used to power individual homes and businesses or neighborhoods. Recently, one such fuel cell, the Bloom Box, has attracted significant interest,[55] although it remains somewhat more expensive than conventional energy applications.

POLICY CONSIDERATIONS

Natural gas is likely to expand its share of the U.S. energy market without any new federal or state energy policies. Current market trends are already creating powerful incentives for electricity producers and large wholesale energy consumers to use more natural gas. This is especially the case as long-term natural gas pricing has become more reliable and inexpensive than coal, nuclear, and renewable sources. In addition, there are many policy changes proposed or already underway that could stimulate the use of natural gas beyond what is predicted from current trends.

- **Greenhouse Gas Regulations.** Some policies, such as new EPA rules that put greater restrictions on emissions from old coal plants, are already being implemented and will certainly accelerate the "dash to gas" by electric generators. These regulations generated controversy as they were developed over many years, including a Supreme Court challenge that upheld the EPA's power to regulate greenhouse gasses, as well as a failed attempt by Congress to legislate an alternative regulatory approach based on a cap-and-trade model. While defenders of the energy status quo have not yet conceded the fight, it is clear that the swift and unambiguous application of new EPA rules would maximize the benefits of replacing old, dirty fossil fuel-fired generation with modern and efficient natural-gas plants. In the absence of a workable substitute from Congress, further delay and litigation would only delay the unavoidable and overdue shift to cleaner energy resources and in the process move us farther away from meeting long-term emissions goals.

- **Clean Energy Standard.** Federal and state proposals for renewable electricity standards (RES) or renewable portfolio standards (RPS) typically have increased the share of renewable electricity generation at the expense of natural gas electricity generation. However, expansion of renewable generation will likely increase the demand for natural gas as a backstop to intermittent wind and solar facilities. More recent approaches have begun to recognize the importance of natural gas to any big-picture energy strategy. President Obama's proposed "Clean Energy Standard" includes partial allowances for natural gas resources to contribute to achieving his goal of producing 80 percent of our electricity from clean energy resources by 2035.

- **Innovation Research**. Policy makers should consider stepping up efforts to pioneer the research and development of the next-generation of natural gas fuel cells. These new technologies offer enormous promise for distributed generation using existing natural gas distribution infrastructure as a realistic road to reduced greenhouse gas emissions, increased U.S. energy security, and a more robust energy network. Given the huge natural gas resources we have available and the extensive supply network that is already fully operational, it is imperative that we explore ways to convert this existing energy infrastructure to a revolutionary new use.

- **Fuel-Cycle Measurements**. Energy consumption and waste must be measured on a full fuel-cycle basis. Using all energy in the most efficient manner possible is in the long-term interest of the U.S. and is an absolute necessity to reduce the steady increase in greenhouse gas emissions worldwide. Current U.S. policies that focus only on end-use efficiency ignore the significant energy losses involved in upstream energy conversion and transmission. Those misguided measurements need to be changed to enable us to make real improvements to our entire systems of producing, delivering, and consuming energy.

- **Systems-Approach Evaluation.** All energy policies should evaluate new and existing energy resources in ways that minimize both costs and environmental impacts. This requires systematically thinking of energy choices on a full fuel-cycle basis, rather than comparing specific characteristics in a vacuum. It is essential to understand how current and future resources and infrastructure can be used as cleanly and efficiently as possible, from the first stages of research through deployment, production, transportation, distribution, storage, and consumption. When evaluated on a fuel-cycle basis, natural gas offers some of the most promising and lasting benefits on the road to a cleaner, more efficient energy future.

CONCLUSION

To observe that America has begun to capitalize on a natural gas windfall is not to hold up gas as a panacea for our nation's energy woes. There are no silver bullets in energy policy and no miracle fuels that can meet the demands of U.S. population and economic growth without impacting the environment.

It is equally true, however, that not all fuels are equal. Natural gas is relatively cheap, clean, and efficient to transport. It is abundantly available and constant rather than intermittent. If our expanding natural gas reserves can be exploited without endangering public health or doing irreversible damage to the environment, they will provide an immense boon to our economy. They can point the way toward national self-sufficiency in energy without lowering our living standards.

There is a strong correlation between high standards of living and high energy consumption per capita. To maintain our way of life – and to enable others around the world to raise their living standards – the world needs more energy. To hedge against the risks of overheating our planet, we all need to shift from high-carbon fuels to a more sustainable balance of low-carbon and carbonless fuels. U.S. natural gas can and should be a permanent part of that balance.

ENDNOTES

1. Natural gas is composed primarily of methane. Methane is a very simple hydrocarbon with just one carbon atom and four hydrogen atoms. While methane is considered a fossil fuel, it has both biological (fossil) and non-biological origins. It is common throughout our solar system and likely throughout the universe. Most if not all of the methane produced as natural gas in the U.S. is the result of microorganisms that digest organic material. While methane in natural gas is commonly associated with organic material from the age of the dinosaurs, the process of methane production continues today in swamps and landfills. Natural gas that is deliberately produced from organic material is called biogas and is a form of renewable energy.
2. Natural gas is currently second only to oil, providing 23.4% of the primary energy of the United States. Oil provides 35.3%, coal 19.7%, nuclear electric power 8.3% and renewable energy 7.7%. U.S. Energy Information Administration, *U.S. Primary Energy Flow by Source and Sector*, 2009, http://www.eia.doe.gov/emeu/aer/pecss_diagram.html.
3. The estimate of a 92-year resource base is from *The Future of Natural Gas, An Interdisciplinary MIT Study* (2011) 30 (mean remaining gas resource base equivalent to 92 times annual U.S. consumption with high case equivalent to 125 years). Web. mit.edu/mitei/research/studies/naturalgas.html In 2008 the authoritative Potential Gas Committee estimated a 90 to 91 year supply of natural gas in the United States but recently increased that estimate to over 2,170 trillion cubic feet, equivalent to over a 94 year supply at today's consumption levels. http://www.potentialgas.org/. Official and expert estimates of the U.S. natural gas resource base have always underestimated the available natural gas resources in the U.S. In 1974 Mobil Oil Corporation estimated that U.S. had enough natural gas to last 22 years.
4. Daniel Yergin, Opening Address, World Energy Conference, Montreal, September 13, 2010. Yergin is the Pulitzer Prize winning author of *The Prize* and is Chairman of IHS CERA.
5. ExxonMobil Corporation, 2010 *The Outlook for Energy: A View to 2030*, 2010, http://www.exxonmobil.com/corporate/files/news_pub_eo_2010.pdf.
6. See U.S. Energy Information Administration, Report on Russia at 6 (Nov. 2010) http://www.eia.doe.gov/countries/cab.cfm?fips=RS. Russia is now the second largest natural gas producer in the world. The countries with the largest proven natural gas reserves are (in trillion cubic feet): Russia (1,680), Iran (1,046), Qatar (899), Turkmenistan (265), Saudi Arabia (263), and the United States (245). These numbers, however, do not reflect the U.S. potential gas resource from unconventional sources such as shale gas. While the U.S. has *proven natural gas reserves* of 245 Tcf (just over a 10 year supply), the *natural gas resource base* is about ten times larger.
7. The 90 to 100 year U.S. *natural gas resource* base is best thought of as an estimate of how much natural gas there is in the U.S. that could be recovered economically using today's technologies. There are huge quantities of natural gas in the U.S. that are not included in the resource base because they cannot be recovered economically with today's technologies. Only a few years ago, most natural gas trapped in shale formations was not included in the U.S. resource base because it was not considered economically recoverable with existing technologies.
8. U.S. Geological Survey, Assessment of Undiscovered Oil and Gas Resources of the Appalachian Basin Province, 2002, http://pubs.usgs.gov/fs/fs-009-03/FS-009-03-508.pdf.
9. *Marcellus Shale – Appalachian Basin Natural Gas Play*, Geology.com, http://geology.com/articles/marcellus-shale.shtml
10. William Dillon, U.S. Geological Survey, Gas (Methane) *Hydrates – A New Frontier*, 1992, http://marine.usgs.gov/fact-sheets/gas-hydrates/title.html.
11. Dillon, Gas (Methane) *Hydrates*.
12. American Gas Association, *The Positive Natural Gas Supply Situation Benefits Consumers – A Look at January*, 2011, Energy Analysis, March 8, 2011, http://www.aga.org/Kc/analyses-and-statistics/studies/demand/Documents/1103EA02.pdf.
13. America's Natural Gas Alliance, *U.S. Benefits*. http://www.anga.us/learn-the-facts/economy/us-benefits.
14. The Utica shale is a separate shale formation that lies beneath the Marcellus shale and underlies portions of Kentucky, Maryland, New York, Ohio, Pennsylvania, Tennessee, West Virginia, Virginia, Lake Ontario, Lake Erie, and Ontario. It could prove to be another very large source of natural gas but probably would be developed after the Marcellus shale because of its greater depth.
15. Timothy J. Considine, *The Economic Impacts of the Marcellus Shale: Implications for New York, Pennsylvania, and West Virginia*, Natural Resource Economics, Inc., July 14, 2010, http://www.scribd.com/doc/34656839/The-Economic-Impacts-of-the-Marcellus-Shale-Implications-for-New-York-Pennsylvania-West-Virginia. The study models three scenarios, with a low development scenario that assumes continuation of the de facto New York moratorium on horizontal drilling and a high development scenario with substantially increased drilling similar to the levels seen in the Barnett shale in Texas.
16. Considine, *Economic Impacts of the Marcellus Shale*, iv and 28-30.

17. *The Future of Natural Gas: An Interdisciplinary MIT Study*, (2011) 53-64.. The study proposes that substantial reductions in greenhouse gas emissions can be achieved by switching from coal to natural gas using already existing natural gas combined cycle electricity generation units.
18. *The Future of Natural Gas*, 86.
19. American Gas Association, *Natural Utilities and their Customers: Efficient Naturally*, http://www.aga.org/our-issues/energyefficiency/Pages/NaturalGasUtilitiesandTheirCustomers.aspx.
20. American Gas Association, *Energy Efficiency and Natural Gas Utilities*, American Gas Association, 2011. http://www.aga.org/Newsroom/factsheets/Documents/Energy%20Effiency%20%20Utilities%20(JAN%202011).pdf
21. American Gas Association, *Energy Efficiency and Natural Gas Utilities*.
22. American Gas Association, *Energy Efficiency and Natural Gas Utilities*..
23. Energy efficiency programs typically measure the efficiency of end use appliances but not the efficiency of energy systems. The Energy Policy and Conservation Act of 1975 gives DOE authority to measure appliance efficiency and set minimum appliance efficiency standards but does not consider the overall efficiency of energy systems.
24. The conversion of primary energy sources into electricity includes all energy inputs, including renewable sources, based on the U.S. actual fuel mix in 2007. The CO2 numbers are the commonly used CO2 equivalent measurements in metric tons and therefore include the greenhouse gas impact from unburned methane. The CO2 equivalent emissions for typical household use are for energy consumed in space and water heating, clothes drying, and cooking. American Gas Association, *A Comparison of Energy Use, Operating Costs, and Carbon Dioxide Emissions of Home Appliances*, Energy Analysis, October 20, 2009.
25. A major challenge facing wind energy is building transmission lines from large-scale wind sources in flat prairies or along the shallow Atlantic shelf to east coast population centers.
26. The U.S. has about 8.7 trillion cubic feet (Tcf) of storage capacity but about half of that capacity is considered base gas that provides the pressure to make the storage field operate. Working storage capacity – the amount that can be withdrawn or re-injected each year – is about 4.3 Tcf. See *Peak Underground Working Natural Gas Storage Capacity*, U.S. Energy Information Administration (Sept. 3, 2010).http://www.eia.gov/pub/oil_gas/natural_gas/feature_articles/2010/ngpeakstorage/ng_peak.html
27. *Report of Bipartisan Policy Center's Task Force on Ensuring Stable Natural Gas Markets*, March 2011, 42.
28. There is one small U.S. LNG export terminal in Kenai, Alaska that has been operating since 1969.
29. One estimate of the cost of a new U.S. LNG export terminal is around three billion dollars.
30. A typical natural gas well occupies a much smaller footprint than the number of windmills needed to produce a similar amount of energy would.
31. U.S. Environmental Protection Agency, *Hydraulic Fracturing Research Study*, EPA/600/F-10/002, June 2010, http://www.epa.gov/safewater/uic/pdfs/hfresearchstudyfs.pdf. A typical golf course uses slightly more than 5 million gallons in a month while a coal power plant uses about this much water in 12 hours of operation.
32. U.S. Environmental Protection Agency, *Draft Hydraulic Fracturing Study Plan*, 2011, http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/index.cfm. Many states are also requiring natural gas producers to file or post the chemicals that are contained in their fracking fluids.
33. U.S. Environmental Protection Agency, *Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs*, June 2004.
34. Anya Litvak, "Marcellus Shale well blowout prompts second DEP suspension," Pittsburgh Business Times, June 9, 2010.
35. State of Colorado Oil and Gas Conservation Commission, Department of Natural Resources, Correction of Errors in the Gasland Portrayal of the Colorado Incidents, http://cogcc.state.co.us/library/GASLAND%20DOC.pdf. Natural gas may be found in well water due to natural causes. In some areas of the country it is common to find natural gas seeping into well water from shallow natural gas deposits. The State of Colorado's Oil and Gas Conservation Commission investigated three cases where natural gas was found in well water and featured in the film *Gasland*. In two cases the Commission found that the natural gas in the water was not the result of oil and gas development and that the gas was biogenic gas that came out of coal beds. In one case the water well penetrated at least four different coal beds and gas from these coal beds contaminated the well water. In the third case the well water was contaminated by natural gas caused by Encana's failure to properly cement a natural gas well.
36. Matthew Harrison et al., *Methane Emissions from the Natural Gas Industry*, U.S. Environmental Protection Agency, 1996.

37. U.S. Environmental Protection Agency, *Natural Gas STAR Program: Basic Information*. http://www.epa.gov/gasstar/basic-information/index.html#overview1. Since 1993, the EPA STAR participating companies have eliminated more than 904 billion cubic feet (Bcf) of methane emissions through the implementation of approximately 150 cost-effective technologies and practices.

38. See, e.g., *Natural Gas and the Environment,* NaturalGas.org, http://www.naturalgas.org/environment/naturalgas.asp#greenhouse, Emissions of Greenhouse Gases in the U.S., U.S. Energy Information Administration (March 31, 2011) http://www.eia.doe.gov/environment/emissions/ghg_report/ghg_overview.cfm.

39. American Gas Association, *Reducing Greenhouse Gas Emissions with Natural Gas – Have the Benefits Lessened?* April 29, 2011. See also Gregory C. Staple and Joel N. Swisher, The Climate Impact Of Natural Gas and Coal-Fired Electricity: A Review of Fuel Chain Emissions Based on Updated EPA National Inventory Data, American Clean Skies Foundation, April 19, 2011, http://www.cleanskies.org/ghgemissions/report/staple_swisher.pdf

40. U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, *Transport Fatalities by Mode*, January 2011, http://www.bts.gov/publications/national_transportation_statistics/html/table_02_01.html. The DOT tracks the safety of various forms of transportation in terms of annual fatalities and natural gas transportation is almost always the safest (in 2003 there were 42,884 highway fatalities, 703 recreational boating fatalities and 12 gas pipeline fatalities).

41. *The Future of Natural Gas: An Interdisciplinary MIT Study* (2011) 7 http://web.mit.edu/mitei/research/studies/natural-gas-2011.shtml

42. New York State Department of Environmental Conservation, *New Recommendations Issued in Hydraulic Fracturing Review*, issued June 30, 2001 (http://www.dec.ny.gov/press/75403.html).

43. FracFocus, the hydraulic fracturing chemical registry website, is a joint project of the Groundwater Protection Council and the Interstate Oil and Gas Commission (http://fracfocus.org/). The American Gas Association released a Position Statement on Responsible Natural Gas Resource Development, which states in part that natural gas producers must be committed to operational standards that ensure safe, environmentally sound, responsible, economically sensible and sustainable development of natural gas resources in the United States. http://www.aga.org/our-issues/responsible-natural-gas-resource-development/Documents/responsible-natural-gas-resource-development.pdf

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45. U.S. Department of Energy, "Secretary Chu Tasks Environmental, Industry and State Leaders to Recommend Best Practices for Safe, Responsible Development of America's Onshore Natural Gas Resources," May 5, 2011 (http://www.energy.gov/news/10309.htm).

46. EPA's Draft Hydraulic Fracturing Study Plan, along with status updates, is available on the EPA website (http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/index.cfm).

47. Gregory C. Staple and Christopher K. Carr, Growing the Market for Clean Power: The EPA's New Power Plant Regulations and What They Mean for Utilities and Public Health, American Clean Skies Foundation, December 16, 2010, http://www.cleanskies.org/pdf/12-20AG_MEF.pdf.

48. Stan Mark Kaplan, *Displacing Coal with Generation from Existing Natural Gas-Fired Power Plants*, Congressional Research Service, January 19, 2010, 4, http://assets.opencrs.com/rpts/R41027_20100119.pdf. Natural gas generation made up 39% of total U.S. generation capacity while coal made up 31% of capacity.

49. Kaplan, *Displacing Coal*, 9.

50. John Rowe, the CEO of Exelon, the largest nuclear power plant operator in the U.S. recently said Congress should do nothing on energy policy because of the windfall of abundant natural gas. Rowe went on to say that "Neither new nuclear, coal with carbon capture and sequestration, wind nor solar are economic." He also said "if new plants need to be built, new natural gas combined cycle plants cost less than half of a new coal plant and only a sixth of the cost of a new nuclear plant." See John Rowe, *Energy Policy: Above All, Do No Harm, Remarks before the American Enterprise Institute*, Washington, DC, March 8, 2011, http://www.exeloncorp.com/assets/newsroom/speeches/docs/spch_Rowe_AEI2011.pdf.

51. ICF International, *Firming Renewable Electric Power Generators: Opportunities and Challenges for Natural Gas Pipelines*, The INGAA Foundation, Inc, March 16, 2011, 2, http://www.ingaa.org/cms/31/7306/9622.aspx. A forecasted increase in wind power generation of 88 gigawatts in the next 15 years would probably require about 33 gigawatts of natural gas generating capacity as back-up

52. While coal prices have increased and natural gas prices have declined recently, coal is expected to remain somewhat cheaper than natural gas. Oil is more expensive than natural gas and will likely remain so.

53. Nucor recently announced ground breaking for a $750 million direct reduced iron making facility in St. James Parish, Louisiana, which uses a technology to convert natural gas and iron ore pellets to high quality direct reduced iron used by Nucor's steel mills. If later phases of the project move forward it could lead to more than 1,000 quality jobs. http://www.nucor.com/investor/news/releases/?rid=1536511

54. *Shale Gas and New Petrochemicals Investment: Benefits for the Economy, Jobs and US Manufacturing*, American Chemistry Council (March 2011) 1 http://www.americanchemistry.com/ACC-Shale-Report

55. K.R. Sidhar, interview by Lesley Stahl, "The Bloom Box: An Energy Breakthrough," 60 Minutes, CBS, February 18, 2010, http://www.cbsnews.com/stories/2010/02/18/60minutes/main6221135.shtml

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