U.S. NATURAL GAS OVERVIEW OF MARKETS AND USES

CENTER FOR CLIMATE AND ENERGY SOLUTIONS

Discussion Questions:

1. **Given the relative abundance of shale gas in North America, is there reason to believe that LNG imports will rise in the coming years?**
2. **Is there reason to believe that LNG exports will rise in the coming years? Why?**
3. **How would these developments impact price levels and stability? Why?**
4. **How reasonable are supply and production cost projections for the U.S. natural gas resource base?**
5. **To what extent, and in what form, do you think GHG mitigation measures will be adopted and what effects will that have on natural gas supply and end uses?**
6. **What policies—a carbon price; support for pipelines, storage, and import/export infrastructure development—would promote stable gas prices?**

HIGHLIGHTS

- Natural gas plays an important role in nearly every sector of the U.S. economy, constituting 25 percent of energy consumption (second only to oil) and roughly one fifth of electricity generation.
- Combustion of natural gas emits about half as much CO2 as coal and 30 percent less than oil, and far fewer pollutants, per unit of energy delivered.
- Advances in the efficiency and cost-effectiveness of production technologies have dramatically increased the amount of North American shale gas resources that can be economically recovered. Since 1999, U.S. proven reserves of natural gas have increased every year.
- Abundant supply, low prices, and other favorable characteristics have enabled natural gas to penetrate many markets, expanded its use, and raised its potential for reducing greenhouse gas emissions. Yet uncertainties remain about the future of prices, supply, markets, policies, and the ability to leverage natural gas to reduce U.S. emissions.

This is a joint project between the Center for Climate and Energy Solutions and the University of Texas's Energy Institute and the Energy Management and Innovation Center

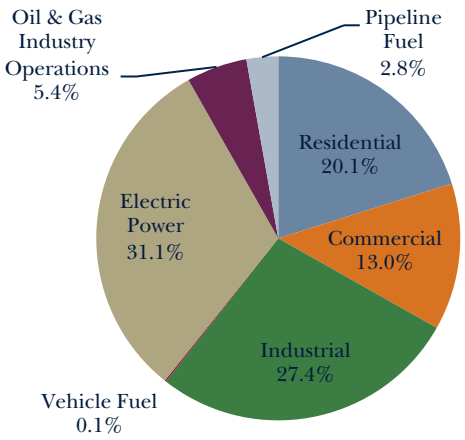
energy institute The University of Texas at Austin

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

INTRODUCTION

Natural gas is a naturally occurring fossil fuel consisting primarily of methane and small amounts of impurities such as carbon dioxide (CO_2). It may also contain heavier liquids that can be processed into valuable byproducts including propane, butane and pentane. Natural gas plays a vital role in the U.S. economy, constituting 25 percent of total U.S. energy consumption—second only to oil—and roughly one fifth of all U.S. electricity generation. Unlike other fossil fuels, natural gas plays an important role in almost every sector, in applications including generating electricity, providing heat and power to industry, buildings, homes and vehicles, and as a feedstock in the manufacture of products such as fertilizers. Natural gas is responsible for approximately 16 percent of U.S. greenhouse gas (GHG) emissions annually, most of which (90 percent) are associated with combustion, with the remainder from venting and other fugitive methane releases (8 percent) and from removing CO_2 during processing (2 percent). Combustion of natural gas produces substantially less CO_2 and far fewer pollutants per unit of energy delivered than coal and oil.[1]

FIGURE 1: U.S. Natural Gas Consumption by Sector, 2010

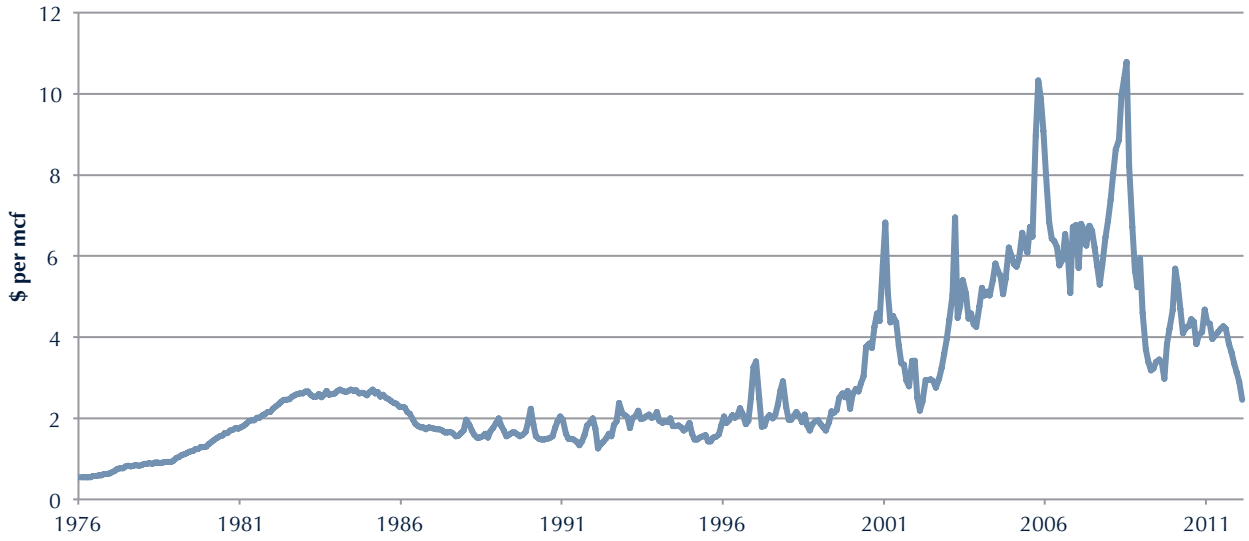


Source: U.S. Energy Information Administration, 2011[2]

Natural gas is produced from reservoirs in natural rock formations or associated with production from other hydrocarbon reservoirs such as oil fields. While this "associated" gas is an important source of domestic supply, the majority (89 percent) of U.S. gas is developed as the primary product.[3] With recent technology advances, U.S. natural gas is increasingly produced from more unconventional sources, such as coal beds, tight sandstone and shale formations that require advanced technologies for development and production and typically yield much lower recovery rates than conventional reservoirs.[4]

Despite these initial hurdles, substantial new supplies of natural gas are making their way to market in the United States, primarily due to the remarkable speed and scale of shale gas development. This increase has raised awareness of natural gas as a key component of domestic energy supply and has dramatically lowered both current prices and price expectations for the future. In recent years, the abundance of natural gas in the United States has improved its competitiveness relative to coal and oil, has expanded its use in a variety of contexts, and raised its potential for strengthening U.S. energy security and reducing GHG emissions.

FIGURE 2: U.S. Natural Gas Price History, 1976-2012



Source: Energy Information Administration, U.S. Department of Energy, 2012[5]

A HISTORY OF VOLATILITY

The erratic history of natural gas prices in the United States illustrates the difficulty of forecasting natural gas futures and the need for caution during periods of excess supply (Figure 2). Four major price spikes in the U.S. market occurred in the first decade of this century alone. By 2001, several years of declining productive capacity and increasing demand resulted in a sharp price spike. Demand eased thereafter largely due to an economic downturn, but relatively tight supplies produced a gradual return to higher prices in the first half of the decade. Prices spiked again sharply in 2005 in the wake of hurricanes Rita and Katrina, which temporarily curtailed supplies from the Gulf of Mexico. Prices remained high relative to historic norms, peaking along with other energy commodities in 2008. Since then, prices have fallen dramatically due to the economic recession and the rapid growth of shale and other unconventional gas resources. In December 2011, prices were down 70 percent from record-high prices just three years before, to $3.14 per thousand cubic feet (mcf) from $10.79/mcf.[6]

U.S. natural gas markets have only been truly open and competitive for about 20 years, when U.S. gas markets were deregulated in the early 1990s. Over that time, price fluctuations have been pronounced, ranging from less than $2/mcf to more than $10/mcf. Periods of high market prices result from changes in regulation, weather disruptions, and broader trends in the economy and energy markets—but also from perceptions of abundance or scarcity. A number of supply-side factors can also affect prices, including production and storage levels.

Looking forward, the average wellhead price[7] is expected to remain below $5/mcf through 2023 and rise to $6.52/mcf in 2035 as production gradually shifts to resources that are less productive and more expensive.[8] Due to the weak U.S. economic recovery and abundance of unconventional gas resources, prices are not expected to reach pre-recession levels until after 2035. But uncertainty remains about future price stability, which can discourage long-term investment for both natural gas producers and large consumers.

GAME CHANGING TECHNOLOGY

The higher natural gas prices of the preceding decade triggered renewed interest in developing unconventional gas resources. Advances in the efficiency and cost-effectiveness of horizontal drilling, new mapping tools, and hydraulic fracturing technologies—enabled by

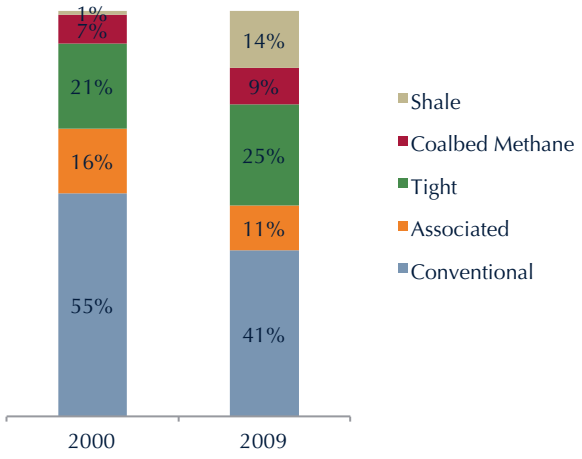
investments in R&D and demonstration from the Department of Energy and national labs—have dramatically increased the amount of North American shale gas resources that can be economically recovered. Since 1999, U.S. proven reserves[9] of natural gas have increased every year, driven mostly by shale gas advancements. In 2003, the National Petroleum Council estimated U.S. recoverable shale gas resources at 35 trillion cubic feet (tcf).[10] Today, the EIA puts that estimate closer to 482 tcf out of an average remaining U.S. resource base of approximately 2,543 tcf.[11] MIT's mean projection estimates recoverable shale gas resources at 650 tcf out of a resource base of 2,100 tcf.[12] These estimates represent nearly 100 years of domestic demand at current consumption levels.

Even as supply estimates have increased, the cost of producing shale gas has declined as more wells are drilled and new techniques are tested. In one estimate, approximately 400 tcf of U.S. shale gas can be economically produced at or below $6 per million British thermal unit (MMBtu) (in 2007 dollars).[13] In another estimate, almost 1,500 tcf can be produced at prices below $8/MMBtu and 500 tcf at $4/MMBtu.[14] By comparison, annual U.S. consumption of natural gas currently totals approximately 22 tcf.

These developments are fundamentally altering the profile of U.S. natural gas production (Figure 3). Since 2009 the United States has been the world's leading producer of natural gas, with production growing by more than 7 percent in 2011—the largest year-over-year volumetric increase in the history of U.S. production.[15] In the decade 2000-2010, U.S. shale gas production increased 14-fold and now comprises approximately 22 percent of total U.S. production.[16] From 2007 to 2008 alone, U.S. shale gas production increased by 71 percent.[17] Remarkably, 80 percent of that expansion has been driven by one resource, the Barnett shale in Texas.[18] Shale gas production is expected to grow further by almost fourfold from 2009 to 2035, and is forecast to make up 47 percent of total U.S. production.[19]

These dramatic changes are reflected in unexpectedly low and less volatile market prices (Figure 2, above), which are also due in part to the economic recession. Yet uncertainties remain which may impact future development and production. Very low prices may result in producers shutting in wells, particularly if the amount of natural gas liquids produced along with the gas is not sufficient to enhance the breakeven economics.[20] The extent to which current assessments accurately capture the economically recoverable resource base, the cost of producing and delivering shale gas, and the availability of pipeline and processing infrastructure have also been difficult to predict.

FIGURE 3: Type of Gross Gas Production in United States, 2000 and 2009



Source: MIT, 2011[21] Note: CBM is coalbed methane.

POLICY IN PLAY FOR SHALE GAS

Oil and gas industry operations, including the injection of hydraulic fracturing fluids, are exempt from regulation under the federal Safe Drinking Water Act. But in view of the speed and scale of shale gas development, U.S. regulators are taking steps to ensure that adequate environmental protections exist for air emissions, land use, and water impacts. At the federal level, the U.S. Environmental Protection Agency (EPA) is conducting a comprehensive review of hydraulic fracturing, and legislation promoting improved transparency and management practices—the Fracturing Responsibility and Awareness of Chemicals (FRAC) Act—was introduced in the 2009-2010 Congress. Draft rules from the EPA to regulate air emissions from oil and gas operations (expected to be released April 17) may also address gas leakages from conventional oil and gas wells,

unconventional shale wells, storage tanks and compressor stations. The U.S. Department of Energy's Secretary of Energy Advisory Board (SEAB) developed several specific recommendations for reducing the environmental impact and improving the safety of shale gas production, to be implemented by the DOE, EPA, and the U.S. Department of the Interior (DOI). The DOI is likely to propose creating new rules for natural gas drilling on federal lands, and the EPA has undertaken a study of the relationship between hydraulic fracturing and drinking water.

Several states—such as Arkansas, California, Colorado, Louisiana, Maryland, New York, Pennsylvania, Texas, and Wyoming—have taken action or are considering action to regulate hydraulic fracturing, to require public disclosure of the chemicals used in hydraulic fracturing operations, or to temporarily suspend shale gas development activities while they explore the issue further. The outcome of these activities may mean reduced environmental impacts and improved safety, but also a heavier regulatory burden for producers.

USE AND EMISSIONS

Among fossil fuels, natural gas has the lowest carbon intensity, generally requires limited processing for end use, and burns efficiently with fewer air pollutants (particulates, nitrogen oxides, sulfur dioxide, lead and mercury). These favorable characteristics have enabled natural gas to penetrate many markets. No one sector dominates natural gas consumption—the electric power, industrial, residential, and commercial sectors are all significant end users. In the residential and commercial building sectors, natural gas provides more than three-quarters of primary energy, largely due its efficiency and convenience for such uses as space and hot water heating. The abundance of U.S. natural gas supply has also raised interest in its expanded use in electric power and even in the transportation sector, either directly as a fuel or indirectly as power generation for electric vehicles. This diversity of uses has created real or perceived competition among sectors and customer segments for access to natural gas supplies.

The combustion of natural gas not only emits CO_2, but methane—which is emitted through venting and fugitive releases during processing, transmission or storage—is itself a potent GHG that is 23 times more powerful than CO_2 in terms of its heat-trapping ability. In light of the abundance of natural gas and its strategic importance to the U.S. fuel mix, several studies are seeking to generate a comprehensive "lifecycle" assessment of the GHG emissions associated with natural gas production and use, including efforts by the U.S. Environmental Protection Agency (EPA), the Environmental Defense Fund, and Cornell University. In addition to GHG emissions, the use of hydraulic fracturing in natural gas development has important impacts for other environmental issues, including land use, groundwater contamination, and water consumption.

A FRAGMENTED MARKET

In contrast to oil, natural gas has been primarily a domestic energy resource; trade patterns tend to be more regional (particularly in the United States); and prices determined within regional markets. Resources are concentrated geographically: 70 percent of the world's gas supply is located in only three regions—Russia, the Middle East (primarily Qatar and Iran) and North America (when including unconventional resources). In the United States, natural gas is produced in 32 states and the Gulf of Mexico, with ten areas accounting for nearly 90 percent of production: Arkansas, Colorado, Gulf of Mexico, Louisiana, New Mexico, Oklahoma, Pennsylvania, Texas, Utah and Wyoming. Moreover, due to its low density, natural gas is difficult both to store and to transport by vehicle unless compressed or liquefied. Thus, pipelines connect well sites to end consumers, sometimes served by local distribution companies in between. While much of the global gas supply can be developed economically with relatively low prices at the wellhead or the point of export,[22] in contrast to oil, high transportation costs—either via long-distance pipeline or via tankers as liquefied natural gas (LNG)—are a significant barrier to establishing a global gas market.

In 2010 natural gas constituted 29 percent of U.S. energy production and almost 90 percent was consumed domestically.[23] (By contrast, 49 percent of U.S. oil consumption was produced domestically in 2010.) In 2010 net imports, delivered via pipeline and liquefied natural gas (LNG) import facilities, constituted only 10.8 percent of total U.S. natural gas consumption (3.7 tcf), the lowest proportion since 1993.[24] Of this amount, about 88 percent came from Canada.[25] Net imports of natural

gas have decreased 31 percent since 2007, with U.S. production growing significantly faster than U.S. demand. These trends and greater confidence in U.S. domestic gas supply suggest that prices between crude oil and gas will continue to diverge, establishing a new relationship that may fundamentally change the way energy sources are used in the United States.

AN INTEGRATED GLOBAL MARKET?

While most of the world's gas supply is transported regionally via pipeline, global gas trade has accelerated with the growing use of liquefied natural gas (LNG). Natural gas, once liquefied,[26] can be transported by tanker and regasified for use in other markets. Between 2005 and 2010, the LNG market grew by more than 50 percent[27] and LNG now accounts for 30.5 percent of global gas trade.[28] Global gas liquefaction capacity increased by almost 40 percent over just the past two years, and is expected to increase by an additional one-third over the next five years.[29] With surplus domestic supply and substantially higher prices in other regional markets, several U.S. companies have applied to relevant agencies[30] for export authority and have indicated plans to install liquefaction facilities.

Prospects for U.S. LNG exports depend significantly on the cost-competitiveness of U.S. liquefaction projects relative to those at other locations. Over much of the last decade, lower supply expectations and higher, volatile prices prompted new investments in U.S. natural gas import and storage infrastructure. Since 2000, North America's LNG import capacity has expanded from approximately 2.3 billion cubic feet (Bcf)/day to 22.7 Bcf/day, around 35 percent of the United States' average daily requirement. Yet as of 2009, U.S. consumption of imported LNG was 1.2 Bcf/day, leaving most of this capacity unused.[31] The ability to make use of and repurpose existing U.S. import infrastructure—pipelines, processing plants, storage and loading facilities—would help reduce total costs relative to "greenfield," or new, LNG facilities.

Looking forward, global LNG trade is expected to increase. The U.S. Energy Information Administration (EIA) projects that world liquefaction capacity will more than double from 8 tcf in 2008 to 19 tcf in 2035.[32] Most of the projected increase comes from the Middle East and Australia, where a number of new liquefaction projects are expected to be operational within the next decade. Several LNG export projects have been proposed for western Canada and for the United States to convert underutilized LNG import facilities to liquefaction and export facilities. EIA projects the United States will become a net exporter of LNG in 2016, a net pipeline exporter in 2025, and an overall net exporter of natural gas in 2021. This outlook reflects increased use of LNG in markets abroad, strong domestic natural gas production, and relatively low U.S. natural gas prices.[33] An MIT study presents another possible scenario, in which a more liquid international gas market could drive the cost of U.S. gas in 2020 above that of international markets, which in turn could lead to the U.S. importing 50 percent of its gas by 2050.[34] Yet while increased LNG trade has started to connect international markets, these markets remain largely distinct with respect to supply, contract structures, market regulation, and prices.

Over the long term, greater international market liquidity could have several effects on the U.S. natural gas market and prices. Under low (i.e., less than 5 percent) export levels, relatively low domestic prices for natural gas would lead to expanded U.S. gas use. But more substantial export levels could drive up U.S. natural gas prices by diverting domestic surplus to the other areas of the world, where prices can be 3 to 4 times higher. Large gas-dependent industrial users, especially if they compete with producers from countries with access to low-cost natural gas, would likely be particularly hard hit by price run ups in the U.S. market. If a global market leads to significant price volatility, as has been the case with the oil market, it could discourage investment in new gas-based infrastructure or cause disruption in gas-reliant industries.

ENDNOTES

1 Union of Concerned Scientists, "Clean Energy," last revised August 2010. Available at http://www.ucsusa.org/clean_energy/technology_and_impacts/energy_technologies/how-natural-gas-works.html

2 U.S. Department of Energy, Energy Information Administration, "Natural Gas Annual 2010," Table 1. Available at http://www.eia.gov/naturalgas/annual/pdf/table_001.pdf

3 Massachusetts Institute of Technology Energy Initiative, "The Future of Natural Gas: An Interdisciplinary MIT Study," June 2011, page 17. Available at http://web.mit.edu/mitei/research/studies/natural-gas-2011.shtml

4 Unconventional resource accumulations tend to be distributed over a larger area than conventional resources, require greater pressure for extraction (have "low permeability"), and usually require advanced technologies and techniques such as horizontal wells or artificial stimulation in order to be economically productive.

5 Nominal dollars. Wellhead prices through 1994. Henry Hub prices from 1995-2010. U.S. Department of Energy, Energy Information Administration, "Natural Gas Prices," at http://www.eia.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm.

6 U.S. Department of Energy, Energy Information Administration, "Natural Gas Prices," at http://www.eia.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm

7 Natural gas prices are generally quoted at the wellhead or where delivered into a pipeline or other sales point.

8 U.S. Department of Energy, Energy Information Administration, "Annual Energy Outlook 2012: Early Release Overview," January 23, 2012, Report Number DOE/EIA-0383ER(2012), page 5. Available at http://www.eia.gov/forecasts/aeo/er/pdf/0383er(2012).pdf

9 In economic terms, the supply of natural gas is often referred to as reserves and is classified with two primary categories, proven and unproven. Proven reserves are those that are economically recoverable from known resources using currently available technology. Unproven reserves are those considered not economically or technically recoverable or somehow not producible for regulatory reasons.

10 National Petroleum Council, "Balancing Natural Gas Policy–Fueling the Demands of a Growing Economy," National Petroleum Council, September 2003.

11 U.S. Department of Energy, Energy Information Administration, "Annual Energy Outlook 2012: Early Release Overview," January 23, 2012, Report Number DOE/EIA-0383ER(2012), page 9. Note that EIA's estimated technically recoverable resource (TRR) of U.S. shale gas was reduced from 827 tcf in 2010 to 482 tcf in 2011. The decline mostly reflects changes in the assessment for the Marcellus shale, from 410 tcf to 141 tcf, based on better data provided from the rapid growth in drilling in the Marcellus over the past two years.

12 Massachusetts Institute of Technology Energy Initiative, "The Future of Natural Gas: An Interdisciplinary MIT Study," June 2011.

13 Ibid. (page 7).

14 ICF International, "2010 Natural Gas Market Review," prepared for the Ontario Energy Board, August 2010, p. 50. Available at http://www.ontarioenergyboard.ca/OEB/_Documents/EB-2010-0199/ICF_Market_Report_20100820.pdf.

15 The White House, "The Blueprint for a Secure Energy Future: Progress Report," March 2012, page 2. Available at http://www.whitehouse.gov/sites/default/files/email-files/the_blueprint_for_a_secure_energy_future_oneyear_progress_report.pdf

16 U.S. Department of Energy, Energy Information Administration, "Annual Energy Outlook 2011: Reference Case," Presentation Spring 2011. Available at http://www.eia.gov/forecasts/aeo/press.upform.updata.pptx

17 C2ES, "Fact Sheet: Natural Gas," available at http://www.c2es.org/technology/factsheet/natural-gas#7 using U.S. Energy Information Administration data.

18 Massachusetts Institute of Technology Energy Initiative, "The Future of Natural Gas: An Interdisciplinary MIT Study," June 2011. In addition to the Barnett, since 2005 producers have begun intensively developing plays in the Woodford, north of the Barnett in Texas and Oklahoma; the Fayetteville in Arkansas; and the Haynesville in Louisiana/East Texas. During this time development also began in the Marcellus Shale of the eastern United States.

19 U.S. Department of Energy, Energy Information Administration, "Annual Energy Outlook 2011," April 26, 2011, Report Number DOE/EIA-0383(2011), p. 2. Available at http://www.eia.gov/forecasts/aeo/pdf/0383%282011%29.pdf

20 Natural gas and natural gas liquids (NGLs) are a principal feedstock in the chemicals industry and a growing source of hydrogen production for petroleum refining. NGL products can add value for gas producers, especially important in a low price environment. The liquid content of a gas—the "condensate ratio"—is expressed as barrels of liquid per million cubic feet of gas (bbls/MMcf). In a typical Marcellus well, assuming a liquids price of $80/bbl, for a condensate ratio in excess of approximately 50 bbls/MMcf, the liquid production alone can provide an adequate return on the investment, even if the gas were to realize no market value. MIT Energy Initiative, "The Future of Natural Gas: An Interdisciplinary MIT Study," June 2011, page 33.

21 Massachusetts Institute of Technology Energy Initiative, "The Future of Natural Gas: An Interdisciplinary MIT Study," June 2011.

22 A set of global supply curves describing the gas resources that can be developed economically at given prices is provided in MIT Energy Initiative, "The Future of Natural Gas: An Interdisciplinary MIT Study," June 2011, page 25.

23 U.S. Department of Energy, Energy Information Administration, "Annual Energy Review 2010," Report Number: DOE/EIA-0384(2010), October 2011, pages 7, 134 and 193. Available at http://www.eia.gov/totalenergy/data/annual/pdf/aer.pdf

24 U.S. Department of Energy, Energy Information Administration, "Natural Gas Year-in-Review: Imports and Exports," December 9, 2011. Available at http://www.eia.gov/naturalgas/review/imports_exports.cfm

25 U.S. Department of Energy, Energy Information Administration, "U.S. Natural Gas Imports by Country," http://www.eia.gov/dnav/ng/ng_move_impc_s1_a.htm

26 The liquefaction process for natural gas involves removal of certain components, such as dust, acid gases, helium, water, and heavy hydrocarbons. The natural gas is then condensed into a liquid by cooling it to approximately -162°C (-260 °F). The energy density of LNG is 60 percent that of diesel fuel.

27 International Gas Union, "World LNG Report," 2010, page 5. Available at http://www.igu.org/igu-publications-2010/IGU%20World%20LNG%20Report%202010.pdf

28 BP, "Statistical Review of World Energy," June 8, 2011, page 4. Available at http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/reports_and_publications/statistical_energy_review_2011/STAGING/local_assets/pdf/statistical_review_of_world_energy_full_report_2011.pdf

29 International Energy Agency, "Q&A on Global Liquefied Natural Gas Markets," September 6, 2011. Available at http://www.iea.org/index_info.asp?ID=2067

30 Each terminal needs permits from the U.S. Environmental Protection Agency, the U.S. Federal Energy Regulatory Commission, and export authorization from the U.S. Department of Energy. Houston-based Cheniere Energy Inc. won approval to be the first company to export natural gas from the lower 48 states. See Saqib Rahim, "Cheniere Walks Financial Tightrope as It Banks on LNG Export Boom," *Energywire*, March 27, 2012. Available at http://eenews.net/public/energywire/2012/03/27/1

31 Massachusetts Institute of Technology Energy Initiative, "The Future of Natural Gas: An Interdisciplinary MIT

Study," June 2011, pages 5 and 143.

32 U.S. Department of Energy, Energy Information Administration, "International Energy Outlook 2011," Report Number: DOE/EIA-0484(2011), September 2011. Available at http://www.eia.gov/forecasts/ieo/pdf/0484%282011%29.pdf.

33 U.S. Department of Energy, Energy Information Administration, "Annual Energy Outlook 2012: Early Release Overview," page 2.

34 Massachusetts Institute of Technology Energy Initiative, "The Future of Natural Gas: An Interdisciplinary MIT Study," June 2011, page 65.