The Future of Natural Gas

AN INTERDISCIPLINARY MIT STUDY

INTERIM REPORT

MIT Energy Initiative

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While the members of the advisory committee provided invaluable perspective and advice to the study group, individual members may have different views on one or more matters addressed in the report. They are not asked to individually or collectively endorse the report findings and recommendations.

Executive Summary

Natural gas has moved to the center of the current debate on energy, security and climate. This study examines the role of natural gas in a carbon-constrained world, with a time horizon out to mid-century.

The overarching conclusions are that:

- *Abundant global natural gas resources imply greatly expanded natural gas use, with especially large growth in electricity generation.*

- *Natural gas will assume an increasing share of the U.S. energy mix over the next several decades, with the large unconventional resource playing a key role.*

- *The share of natural gas in the energy mix is likely to be even larger in the near to intermediate term in response to CO_2 emissions constraints. In the longer term, however, very stringent emissions constraints would limit the role of all fossil fuels, including natural gas, unless capture and sequestration are competitive with other very low-carbon alternatives.*

- *The character of the global gas market could change dramatically over the time horizon of this study*.

The physical properties of natural gas, the high degree of concentration of the global resource and the history of U.S. energy policy have profoundly influenced the use of natural gas and the market structure governing its trade:

- the substantially lower carbon footprint of natural gas relative to other fossil fuels, combined with the development of North American unconventional natural gas supply and the high cost and slow pace of lower carbon alternatives, has focused attention on natural gas as a "bridge" to a low-carbon future;

- there are regionalized markets in North America, Europe and industrialized Asia, each with a different market structure; and

- "feast or famine" expectations for U.S. natural gas supply, associated with price swings and policy changes, have often led to costly investment decisions.

The confluence of these factors is central to today's energy and climate change policy debate. The primary motivation for this study is to provide integrated, technically grounded analysis that will inform this debate. The analysis must deal with multiple uncertainties that can profoundly influence the future of natural gas:

- the extent and nature of greenhouse gas mitigation (GHG) measures that will be adopted in the U.S. and abroad;
- the ultimate size and production cost of the natural gas resource base in the U.S. and in other major supplier countries;
- the technology mix, as determined by relative costs of different technologies over time and by emissions policy; and
- the evolution of international gas markets, as dictated by economics, geology and geopolitics.

This study analyzes various possibilities for the last three of these, principally by application of a well-tested global economic model, for different GHG policy scenarios.

Our audience is principally U.S. government, industry and academic leaders and decision-makers interested in the interrelated set of technical, economic, environmental and political issues that must be addressed in seeking to limit GHG emissions materially. However, the study is carried out with an international perspective.

FINDINGS

Supply

Globally, there are abundant supplies of natural gas, much of which can be developed at relatively low cost. The current mean projection of remaining recoverable resource is 16,200 Trillion cubic feet (Tcf), 150 times current annual global gas consumption, with low and high projections of 12,400 Tcf and 20,800 Tcf, respectively. Of the mean projection, approximately 9,000 Tcf could be economically developed with a gas price at or below $4/Million British thermal units (MMBtu) at the export point.

Unconventional gas, and particularly shale gas, will make an important contribution to future U.S. energy supply and carbon dioxide (CO_2) emission reduction efforts. Assessments of the recoverable volumes of shale gas in the U.S. have increased dramatically over the last five years. The current mean projection of the recoverable shale gas resource is approximately 650 Tcf, with low and high projections of 420 Tcf and 870 Tcf, respectively. Of the mean projection, approximately 400 Tcf could be economically developed with a gas price at or below $6/MMBtu at the well-head.

The environmental impacts of shale development are manageable but challenging. The largest challenges lie in the area of water management, particularly the effective disposal of fracture fluids. Concerns with this issue are particularly acute in those regions that have not previously experienced large-scale oil and gas development. It is essential that both large and small companies follow industry best practices, that water supply and disposal are coordinated on a regional basis, and that improved methods are developed for recycling of returned fracture fluids.

Policy Effects

In a carbon-constrained world, a level playing field — a CO_2 emissions price for all fuels without subsidies or other preferential policy treatment — maximizes the value to society of the large U.S. natural gas resource.

Even under the pressure of an assumed CO_2 emissions policy, total U.S. natural gas use is projected to increase in magnitude up to 2050.

Under a scenario with 50% CO_2 reductions to 2050, using an established model of the global economy and natural gas cost curves that include uncertainty, the principal effects of the associated CO_2 emissions price are to lower energy demand and displace coal with natural gas in the electricity sector. *In effect, gas-fired power sets a competitive benchmark against which other technologies must compete in a lower carbon environment.* A major uncertainty that could impact this picture in the longer term is technology development that lowers the costs of alternatives, in particular, renewables, nuclear and carbon capture and sequestration (CCS).

A more stringent CO_2 reduction of, for example, 80%, would probably require the complete de-carbonization of the power sector. This makes it imperative that the development of competing low-carbon technology continues apace, including CCS for both coal and gas. It would be a significant error of policy to crowd out the development of other, currently more costly, technologies because of the new assessment of gas supply. Conversely, it would also be a mistake to encourage, via policy and long-term subsidy, more costly technologies to crowd out natural gas in the short to medium term, as this could significantly increase the cost of CO_2 reduction.

Some U.S. regions that have not traditionally been gas producers do have significant shale gas resources and the development of these resources could change patterns of production and distribution of gas in the U.S.

To the degree that economics is allowed to determine the global gas market, trade in this fuel is set to increase over coming decades, with major implications for investment and for possible U.S. gas imports in a couple of decades and beyond.

Demand & Infrastructure

There is a degree of resilience in overall gas use in that less use in one of the three major sectors (power, heating, industry) will lead to lower gas prices and more use in another sector.

The electricity sector is the principal growth area for natural gas under CO_2 emission constraints.

The scale-up of intermittent electricity sources, wind and solar, significantly affects natural gas capacity and use in the electricity sector because of variability and uncertainty. The impacts are quite different in the short term, during which the response is through the dispatch pattern, and in the long term, during which capacity additions and retirements will be responsive to large-scale introduction of intermittent sources.

- In the short term, the principal impact of increased intermittent generation is displacement of generation with highest variable cost, which is natural gas in most U.S. markets.

- In the long term, increased intermittent generation will have two likely outcomes: more installed capacity of flexible plants, mostly natural gas, but typically with low utilization; and displacement of capacity of and production from baseload generation technologies. There will be regional variation as to how such effects are manifested.

In the U.S., there are opportunities for more efficient use of natural gas (and other fuels), and for coal to gas fuel switching for power generation. *Substitution of gas for coal could materially impact CO_2 emissions in the near term*, since the U.S. coal fleet includes a significant fraction of low-efficiency plants that are not credible candidates for carbon capture retrofit in response to carbon emissions prices, and since there is significant underutilized existing Natural Gas Combined Cycle (NGCC) capacity.

Development of the U.S. vehicular transportation market using compressed natural gas (CNG) powered vehicles offers opportunities for expansion for natural gas use and reduction of CO_2 emissions, but it is unlikely in the near term that this will develop into a major new market for gas or make a substantial impact in reducing U.S. oil dependence. However, significant penetration of the private vehicle market before mid-century emerges in our carbon-constrained scenario. Liquefied natural gas (LNG) does not currently appear to be economically attractive as a fuel for long-haul trucks because of cost and operational issues related to storage at minus 162 degrees Centigrade.

The conversion of natural gas to methanol, for which there is already large-scale industrial use and a well-established cost basis, is an option for providing a cost-competitive, room temperature liquid transportation fuel and reducing oil dependence. However, it would not materially affect carbon emissions relative to gasoline.

The expansion of shale gas development in areas that have not previously seen significant gas production will require expansion of the related pipeline, storage and processing infrastructure. Infrastructure limitations need to be taken into account in decisions to advance coal substitution with natural gas.

Markets & Geopolitics

There are three distinct regional gas markets — North America, Europe and Asia — resulting from the degree of market maturity, the sources of supply, the dependence on imports and the significant contribution of transportation to the total delivered cost.

The U.S. natural gas market functions well and, given even-handed treatment of energy sources, needs no special policy help to contribute materially to CO_2 emissions mitigation.

International natural gas markets are in the early stages of integration, with many impediments to further development. If a more integrated market evolves, with nations pursuing gas production and trade on an economic basis, there will be rising trade among the current regional markets and the U.S. could become a substantial net importer of LNG in future decades.

Greater international market liquidity would be beneficial to U.S. interests. U.S. prices for natural gas would be lower than under current regional markets, leading to more gas use in the U.S. Greater market liquidity would also contribute to security by enhancing diversity of global supply and resilience to supply disruptions for the U.S. and its allies. These factors moderate security concerns about import dependence.

As a result of the significant concentration of conventional gas resources globally, policy and geopolitics play a major role in the development of global supply and market structures. Consequently, since natural gas is likely to play a greater role around the world, natural gas issues will appear more frequently on the U.S. energy and security agenda. Some of the specific security concerns are:

- Natural gas dependence, including that of allies, could constrain U.S. foreign policy options, especially because of the unique American international security responsibilities.

- New market players could introduce impediments to the development of transparent markets.

- Competition for control of natural gas pipelines and pipeline routes is intense in key regions.

- Longer supply chains increase the vulnerability of the natural gas infrastructure.

Research, Development and Demonstration

New science and technology, particularly in the case of unconventional resources, can significantly contribute to the long-term economic competitiveness of domestic supplies of natural gas with imports, by helping to optimize resource use, to lower costs, and to reduce the environmental footprint of natural gas.

Some government and quasi-government RD&D programs have had important successes in the development of unconventional gas resources. These programs, combined with short-term production tax incentives, were important enablers of today's unconventional natural gas business.

HIGH-LEVEL RECOMMENDATIONS

1. To maximize the value to society of the substantial U.S. natural gas resource base, U.S. CO_2 reduction policy should be designed to create a "level playing field," where all energy technologies can compete against each other in an open marketplace conditioned by legislated CO_2 emissions goals. A CO_2 price for all fuels without long-term subsidies or other preferential policy treatment is the most effective way to achieve this result.

2. In the absence of such policy, interim energy policies should attempt to replicate as closely as possible the major consequences of a level-playing-field approach to carbon emissions reduction. At least for the near term, that would entail facilitating energy demand reduction and displacement of some coal generation with natural gas.

3. Notwithstanding the overall desirability of a level playing field, and in anticipation of a carbon emissions charge, support should be provided through RD&D and targeted subsidies of limited duration, for low-emission technologies that have the prospect of competing in the long run. This would include renewables, carbon capture and sequestration for both coal and gas generation, and nuclear power.

4. Coal generation displacement with NGCC generation should be pursued as a near-term option for reducing CO_2 emissions.

5. In the event of a significant penetration of intermittent renewable electricity production, policy and regulatory measures should be developed (e.g. ancillary services compensation) or adapted (e.g. capacity mechanisms) to facilitate adequate levels of investment in natural gas generation capacity.

6. Regulatory and policy barriers to the development of natural gas as a transportation fuel (both CNG and natural gas conversion to liquid fuels) should be removed, so as to allow it to compete with other technologies. This would reduce oil dependence, and CNG would reduce carbon emissions as well.

7. For reasons of both economy and global security, the U.S. should pursue policies that encourage an efficient integrated global gas market with transparency and diversity of supply, and governed by economic considerations.

8. Since natural gas issues will appear more frequently on the U.S. energy and security agenda as global demand and international trade grow, a number of domestic and foreign policy measures should be taken, including:

   - integrating energy issues fully into the conduct of U.S. foreign policy, which will require multiagency coordination with leadership from the Executive Office of the President;

   - supporting the efforts of the International Energy Agency (IEA) to place more attention on natural gas and to incorporate the large emerging markets (such as China, India and Brazil) into the IEA process as integral participants;

   - sharing know-how for the strategic expansion of unconventional resources;

   - advancing infrastructure physical- and cyber-security as the global gas delivery system becomes more extended and interconnected; and

   - promoting efficient use of natural gas domestically and encouraging subsidy reduction for domestic use in producing countries.

9. There is a legitimate public interest in ensuring the optimum, environmentally sound utilization of the unconventional gas resource. To this end:

   - Government-supported research on the fundamental challenges of unconventional gas development, particularly shale gas, should be greatly increased in scope and scale. In particular, support should be put in place for a comprehensive and integrated research program to build a system-wide understanding of all subsurface aspects of the U.S. shale resource. In addition, research should be pursued to reduce water usage in fracturing and to develop cost-effective water recycling technology.

   - The United States Geological Survey (USGS) should accelerate efforts to improve resource assessment methodology for unconventional resources.

   - A concerted coordinated effort by industry and government, both state and Federal, should be organized so as to minimize the environmental impacts of shale gas development through both research and regulation. Transparency is key, both for fracturing operations and for water management. Better communication of oil- and gas-field best practices should be facilitated. Integrated regional water usage and disposal plans and disclosure of hydraulic fracture fluid components should be required.

10. The Administration and Congress should support RD&D focused on environmentally responsible, domestic natural gas supply, through both a renewed Department of Energy (DOE) program weighted towards basic research and a synergistic "off-budget" industry-led program weighted toward technology development and demonstration and technology transfer with relatively shorter-term impact. Consideration should also be given to restoring a public-private "off-budget" RD&D program for natural gas transportation and end use.