Fueling the Future

Natural Gas &

New Technologies for a

Cleaner 21ST Century

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Foreword

The dawn of a new millennium represents a symbolic point of reference for viewing the lessons of the past and predicting the promise of the future. In 1999, Washington Policy and Analysis (WPA) began a thoughtful analysis of the United States' national energy priorities in the context of such key factors as national security, environmental quality and energy efficiency. We asked tough questions about the national energy outlook: Will the current energy mix serve our future needs? What surprises may be lurking on the horizon? What is the optimal energy mix for best serving our national interests?

For more than a decade, WPA has prepared comprehensive studies of the U.S. and global energy outlook, using a combination of energy modeling, scholarly research and market analysis. As we surveyed key trends in the U.S. energy sector, we saw the promise of new technologies and the challenge of changing market structures. In particular, the pivotal role natural gas could play in meeting our future energy and environmental priorities was abundantly clear although the path to achieving this optimal energy future was not.

We realized that without careful long-term planning and implementation of enlightened energy policies, we could end up with a dirtier, less efficient and precarious energy mix. With this in mind, WPA approached the American Gas Foundation for support in our study of the U.S. energy future. The results of our investigations were revealing and insightful. While many contemporary studies continue to hype the use of natural gas in central station electricity generation, our analysis shows that direct use of natural gas offers the prospect of a vastly more efficient economy. "Fueling the Future" represents a new vision for the fuller utilization of natural gas and ultimately for the development of a rational national energy policy for the 21st century.

This is not the first time that WPA has challenged conventional wisdom about natural gas. In 1988, WPA projected a growth in gas usage that exceeded estimates by most analysts at the time. While the 1988 study was viewed as "wildly optimistic," current data demonstrates that we actually might have understated the demand for gas. The expanding role of natural gas came from a combination of regulatory reform, more effective exploration and production techniques, and timely market penetration by efficient end-use technologies. A subsequent policy paper published in 1992 looked further ahead, stressing the need for research and development on fuel cells and other visionary technologies.

These two natural gas studies were the result of collaboration among WPA and scholars from MIT, Princeton, the University of Texas and other key institutions. The studies showed that achieving a 25 quad future was not only possible, but also highly desirable from the points of view of the national economy, the environment and national security.

This most recent study, "Fueling the Future: Natural Gas & New Technologies for a Cleaner 21st Century," differs from most gas studies in its focuses. We devote much attention to how and where gas might be used in the four major U.S. consumption sectors as well as in generating electricity for end-use. As with past studies, WPA asked distinguished experts to advise and review the project findings. These distinguished individuals include one of the nation's preeminent geologists, a former science adviser to President Clinton, a leading expert on air pollution and the organizer of the Rio summit. WPA also solicited the views and expertise of industry representatives to test the "real world" validity of our analysis.

Joining us as a co-author of this third study is Gregg D. Renkes, former staff director of the Senate Committee on Energy and Natural Resources and president of the Renkes Group, who provided critical input on legislative and regulatory policies conducive to greater direct use of natural gas.

A summary of the study results follows. A more comprehensive technical report may be obtained by contacting WPA at (202) 965-1161 or evan@wpainc.com.

We would like to thank those individuals who have advised and assisted us in this endeavor—and particularly Joseph Dukert for his keen analysis and review throughout the study.

We encourage you to thoughtfully review the results of this study and to work to ensure that appropriate state and federal policies are pursued to stimulate natural gas demand and overcome obstacles to enhanced gas use.

William F. Martin
Chairman

Scott L. Campbell
President

Washington Policy and Analysis (WPA) is an international consulting firm specializing in energy, environment, trade and technology issues. WPA's founding partners, Scott L. Campbell and William F. Martin, both served in the Reagan-Bush administration in various high-level positions. Campbell served as President Reagan's director of the Office of Policy Planning and Analysis at the Department of Energy, and on the National Petroleum Council under President Bush. Martin served as President Reagan's deputy secretary of energy and executive secretary to the National Security Council, and was executive director of the 1992 Republican Platform Committee.

The **American Gas Foundation** was incorporated in 1989 as a 501(c)(3) tax-exempt charitable foundation. It strives to educate key audiences about natural gas by providing training and educational programs and conferences, and conducting charitable and other activities.

Editorial Review Board

"Fueling the Future: Natural Gas & New Technologies for a Cleaner 21st Century" was completed with the assistance of the following experts:

ADVISORY REVIEW PANEL

Dr. William Fisher is professor of geological sciences and interim director of the Bureau of Economic Geology at the University of Texas at Austin. Fisher served as Assistant Secretary of the Interior in the mid-1970s and has been an active member of the White House Science Council, the Outer Continental Shelf Advisory Board to the Department of Interior, and the National Petroleum Council.

"Long-term trends in ever-increasing energy efficiency have put the United States at the threshold of a methane economy. With vigorous development and application of technology, the ample natural gas resource base of the nation can be converted to producible reserves at attractive costs and in volumes sufficient to meet a much enlarged demand, thus allowing us to realize the tremendous benefits of a methane economy."

Dr. John H. Gibbons is a former science adviser to President Clinton (1993 to 1998). Previously, Gibbons served as the director of the Congressional Office of Technology Assessment. Gibbons is currently the Karl T. Compton lecturer at Massachusetts Institute of Technology and senior fellow at the National Academy of Engineering.

"The ancient Jewish people told of the gift of manna that rained down from heaven to give them sustenance in the wilderness. Modern man benefits from another substance, partly cosmic in origin and partly stored up in the earth for many millennia through photosynthesis and anaerobic digestion. This modern manna is natural gas. It is of such high quality that, through using advanced technology, it can provide energy services and useful chemicals at a very high efficiency and low environmental cost."

Dr. Nancy Kete is director of the Climate, Energy and Pollution program at World Resources Institute (WRI). Previously, Kete worked as a senior policy analyst in the Office of Air and Radiation of the U.S. Environmental Protection Agency before becoming deputy director of the Office of Atmospheric Programs.

"Natural gas provides a strong front line defense against global climate change. Natural gas is a vital bridge between today's energy mix, dominated by coal-fired central power stations and gasoline-powered cars, and our energy future, where hydrogen, fuel cells and renewable energy resources will meet our energy needs. Greater use of natural gas, and better total energy efficiency can reduce greenhouse gas emissions over the next few decades and buy the time still needed for new energy technologies to mature."

Maurice Strong is chairman of the Earth Council and senior adviser to the United Nations and the World Bank. He was secretary general of the landmark 1992 UN Conference on Environment and Development in Rio de Janiero. In addition to public service, Strong has had a distinguished career in the energy sector and served as chairman of Petro-Canada and Ontario Hydro.

"This study makes a compelling and well-reasoned case for expanding the role natural gas plays in the U.S. energy economy, the means by which this can be achieved and the advantages of doing so.

"Especially noteworthy is the emphasis on 'total energy efficiency,' or TEE, as the most practical and effective means of achieving a significant (17%) increase in the natural gas component of a 'clean energy portfolio.' From my own experience at Ontario Hydro, I strongly support the case the WPA study makes for TEE and its benefits in both environmental and economic terms.

"I also applaud the emphasis the study places on the economic and security benefits of a major increase in the role of natural gas for meeting domestic energy needs."

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Executive Summary

Washington Policy and Analysis with the support of the American Gas Foundation conducted the study "Fueling the Future: Natural Gas & New Technologies for a Cleaner 21st Century" to address a paradox that has bedeviled the U.S. natural gas industry at least since the wellhead price of natural gas was deregulated in the early 1980s: How can a fuel that is domestically abundant, safe and reliable to deliver, more environmentally friendly than oil or coal, and nearly four times as efficient as electricity from the point of origin to the point of use, power only about one-fourth of the American economy? This paradox is all the more puzzling given the fact that it has been national policy, as affirmed by successive U.S. presidents going back to Ronald Reagan, to encourage the broader use of natural gas.

"Fueling the Future" both posits and proves that a national energy policy encouraging the use of natural gas has not been fully realized. It then outlines a comprehensive strategy showing how fulfilling the potential of natural gas will help the United States better meet its energy needs for the next 20 years. Specifically, it addresses the questions of how much natural gas might be used and in what applications, as well as what national benefits — environmental, economic, conservation — might result from such increased use.

In sum, "Fueling the Future" offers the nation's energy decision-makers, from the leaders on Capitol Hill and in the state capitals, to the consumers on Main Street, an alternative economic future in which an affordable, efficient and readily available energy source powers new, advanced technologies for the betterment of all.

This study projects U.S. natural gas consumption to the year 2020 under two alternate scenarios. The two scenarios contrasted in this study are referred to as "current" and "accelerated."

The current projection in "Fueling the Future" is not merely a constrained, "business-as-usual" scenario. It assumes significant increases in the efficiency of equipment that uses natural gas as well as continued technological advances in energy supply and energy use. However, it does not account for the removal of barriers or the adoption of policy measures that would stimulate gas consumption.

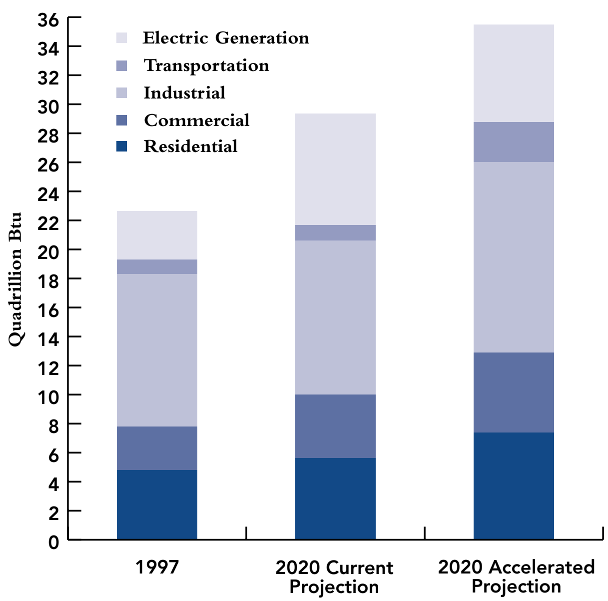
In contrast, the study's accelerated projection does assume the removal of barriers and the implementation of positive policies. Under this scenario, overall natural gas consumption is estimated to reach 35 quadrillion Btu (quads) by 2020, more than 20 percent more than the 29 quads forecast under the current projection. In 1998, 21.9 quads of natural gas were consumed in the United States.

More important than the level of overall consumption is the pattern of consumption. That is, the accelerated projection shows relatively higher levels of gas consumption in the residential, commercial, industrial and transportation sectors but somewhat less gas consumption by central-station electricity generating plants.

Key Findings

Using natural gas in place of other energy sources provides multiple national and consumer benefits. Substituting natural gas, primarily for electricity, coal and oil, helps ease a number of environmental concerns, including greenhouse gas emissions, acid rain, smog, solid waste and water pollution.

Natural Gas Consumption Forecasts



In 2020, for example, emissions of carbon dioxide, the primary "greenhouse" gas, would be reduced by an estimated 930 million tons annually if the increased use of natural gas projected in this study is achieved.

The use of natural gas also reduces the United States' dependence on imported oil. If gas use increases by the amount projected in the accelerated costs, oil imports will be reduced by an estimated 2.6 million barrels per day.

Further, due to the high efficiency of the natural gas system and natural gas appliances, energy consumption is 6 percent lower in the accelerated scenario than in the current scenario.

By implementing appropriate policies, natural gas use could be increased by 20 percent. Under the accelerated projection, natural gas consumption in 2020 is more than 35 quads a year, nearly 6 quads above the demand forecast of the current projection. Nearly half of the increase comes in the residential and commercial sectors, where more new customers are choosing natural gas and more existing customers are switching from other fuels to natural gas.

This scenario also shows continued expansion in the amount of natural gas sold for relatively new applications, such as residential gas fireplaces and commercial gas cooling systems. In addition, distributed generation in the form of reciprocating engines, microturbines and fuel cells advances, accounting for roughly 20 percent of all new electricity generating capacity.

Industrial gas demand could grow over the next 20 years by approximately 2.5 quads under the accelerated projection, continuing the robust growth of the past 10 to 15 years. Although the cogeneration market becomes fairly saturated, other forms of distributed generation are expected to prosper. Highly efficient heating, cooling and process equipment continues to evolve, enabling natural gas to remain the dominant source of energy for the nation's factories.

Natural gas-powered transit buses, trucks, vans and cars consume about 1 quad more natural gas under the accelerated projection than under the current projection. Although these vehicles account for less than 1 percent of the overall vehicular market in 2020, they can make significant contributions to air quality and operational economics, primarily in fleet applications in congested urban areas.

Although natural gas consumption used by central-station power plants to generate electricity more than doubles by 2020 under the accelerated case, it is about 1 quad less than under the current projection. Natural gas remains the dominant fuel for new generating capacity even though some new coal-based capacity is added after 2010.

More important, under the accelerated scenario, a lower amount of new generating capacity will be required than under the current projection. The accelerated scenario assumes that the lives of some existing nuclear and coal power plants will be extended and that strong growth will occur in the use of distributed generation. See page 37 for specific policy recommendations that would enable the realization of the accelerated projection.

New technologies and gas source flexibility will ensure adequate supply. The decade of the 1990s has demonstrated the vast and diverse nature of the gas resource base. Further, the resource base continues to "expand" — estimates of its size are larger today than in the early 1990s despite the fact that the nation consumed more than 150 trillion cubic feet (Tcf) of gas from the resource base during that decade. Some sources of today's gas supply, such as coalbed methane, were not even acknowledged 10 to 15 years ago. Now, coalbed methane, which was not included in most resource-base estimates before 1988, accounts for 6 percent of domestic gas production.

Tremendous technological advances in natural gas exploration and production also have occurred in the past 10 years, including three-dimensional seismology, horizontal drilling and innumerable computer-related breakthroughs. Similar advances are required, and expected to take place, over the next 20 years to enable the achievement of the projected 35-quad gas-demand level. With such advances, domestic gas production can increase from today's 19-plus quads to more than 29 quads in 2020.

Canada will contribute a slightly greater share of total supply in the future by increasing its exports to the United

States from 3 quads to roughly 5 quads a year. Abundant gas resources worldwide and in Alaska offer mid-term insurance while methane hydrates and other more exotic sources of gas provide long-term potential.

Significant but achievable gas infrastructure expansion is needed to support higher demand. The natural gas industry is very capital-intensive, and significant expansion of its production, storage, transmission and distribution systems will be needed to meet the higher demand level of the accelerated projection.

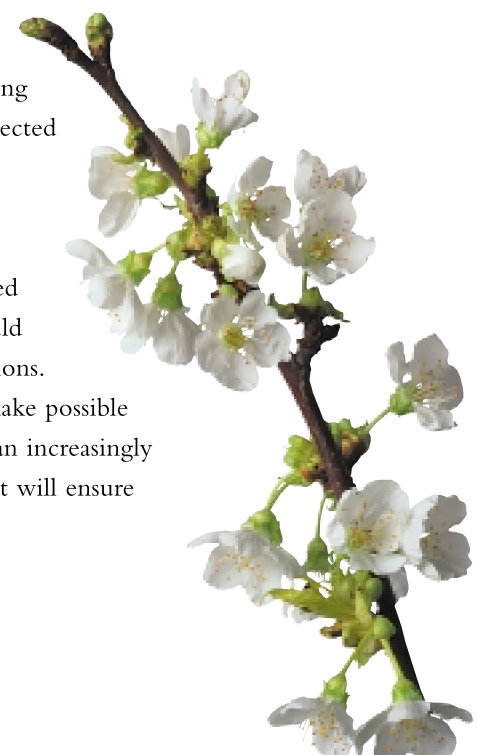
For example, the number of oil and gas wells drilled each year may have to double from today's level to about 50,000 wells. This number, however, is well below the peak levels experienced in the mid-1980s when 70,000 to 90,000 wells were drilled each year. The ramp-up for the production segment may prove to be more challenging than the expansion required of the transmission (interstate pipeline) and distribution (local utility) segments.

Gas prices will remain competitive even as demand increases. Price regulation of natural gas was eliminated about a decade ago. From 1987 to 1999, the price of gas delivered to consumers increased by only 3 percent while consumer prices overall rose by 36 percent. Thus, natural gas prices have declined significantly in "real," or inflation-adjusted, dollars during this period of deregulation.

The main factor in this price decline has been the steady downward movement in the cost of transporting and distributing natural gas through the nation's pipeline and utility systems. This downward movement is attributable to efficiency gains that have reduced the cost of the transmission and distribution component of gas service by 35 percent, in inflation-adjusted terms. The wellhead price of gas also has decreased, in real dollars, during this period, even though the movement of wellhead prices was more erratic and less pronounced than movement of the transmission and distribution component.

While the gas demand levels analyzed in this study will exert a bit more pressure on prices than the demand levels in other forecasts, the study expects only modest gas price increases over the next 20 years. Wellhead prices will remain in the mid-$2 per million Btu (MMBtu) range, and gas prices to consumers will be relatively constant, in real dollars. The expansion of the gas resource base and technological advances related to finding, producing and delivering gas are expected to continue.

The factors that led to declining, inflation-adjusted gas prices in the past should not be considered aberrations. These same factors will make possible future price stability, and an increasingly competitive energy market will ensure this stability.



Although a challenge, the higher gas consumption levels of the accelerated scenario and the resultant national benefits are achievable. The accelerated projection may be viewed as optimistic from gas production and consumption perspectives, but it is also realistic and achievable. It is based on technologies and practices that are available today or that in all likelihood will be available within the timeframe of this study.

Further, the rate of advance embodied in the accelerated projection is similar to what has been realized recently. The 1990s saw dramatic improvements in terms of energy-related equipment and services. The ability to find and produce gas, to use gas in cleaner and more efficient applications, and to provide adequate supplies of gas in an increasingly competitive market is far superior to what it was 10 or 20 years ago. The accelerated projection embodies the assumption that such progress will continue and even intensify in the years 2000 and beyond.

Specific actions must be taken to realize the potential of the accelerated projection. Although the potential national benefits of the accelerated projection are pronounced, they will not be realized unless certain key actions occur. A number of such actions that would increase gas consumption, through the removal of barriers or implementation of stimuli, are included in the appendix of this document.

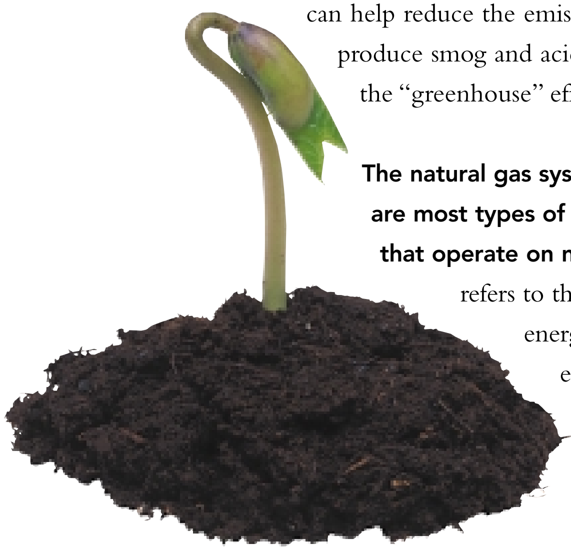
The purpose of this document is to identify measures that would increase gas consumption and the benefits to the nation that would accrue from higher usage levels. It is not meant to recommend the adoption of these or related policy measures.

Chicago's Brookfield Zoo relies on natural gas-fueled cogeneration to produce two-thirds of its electricity, ensuring the welfare of its many inhabitants.

More Than Energy: The Benefits of Natural Gas

Using natural gas in place of other fuels can help ease a number of environmental concerns — greenhouse gas emissions, acid rain, smog, solid waste and water pollution. When natural gas is burned, it produces virtually no emissions of sulfur dioxide or particulate matter and far lower levels of "greenhouse" gases and nitrogen oxides than such competing sources of energy as oil and coal. In addition, unlike the oil, coal and nuclear processes, the natural gas process produces virtually no solid waste and has much less impact on water quality.

The inherent cleanliness of natural gas when compared with those other fuels, coupled with the high efficiency of natural gas equipment, means that substituting gas for the other fuels can help reduce the emission of the air pollutants that produce smog and acid rain and that could exacerbate the "greenhouse" effect.



The natural gas system is very energy efficient as are most types of appliances and equipment that operate on natural gas. Energy efficiency refers to the energy input per unit of useful energy output. In other words, energy efficiency measures how much energy is used or lost in providing such things as hot water, steam, warm or cool air. The higher the energy efficiency, the greater the conservation of energy and the lower the environmental impacts.

When the entire cycle of producing, processing, transporting and using energy is considered, natural gas is delivered to the consumer with a "total energy efficiency" of about 90 percent, compared with about 27 percent for electricity. Moreover, gas appliances and equipment are extremely efficient as evidenced by the fact that the residential use of gas per customer is about 16 percent less today than it was in 1980.

Natural gas is the most economical energy choice. Natural gas is usually the most economical form of energy available regardless of which competing fuel it is measured against, the application involved or the geographical location of the consumer.

For instance, using the 1999 average national energy prices published by the Department of Energy, heating an average-size house in a moderate climate costs 5 percent less to heat with gas than with heating oil and 33 percent less than with an electric heat pump. Similarly, using gas to heat household water is about half as expensive as using electricity. Even with the aggressive demand levels of the accelerated projection, gas will remain price-competitive.

Natural gas is a highly reliable North American energy source. Approximately 85 percent of the natural gas consumed in the United States is produced domestically from the nation's extensive gas resource base. Nearly all of the remaining 15 percent is produced in North America, primarily in Canada. In comparison, close to 60 percent of the oil used in the United States is imported from foreign countries, some of which are politically unstable.

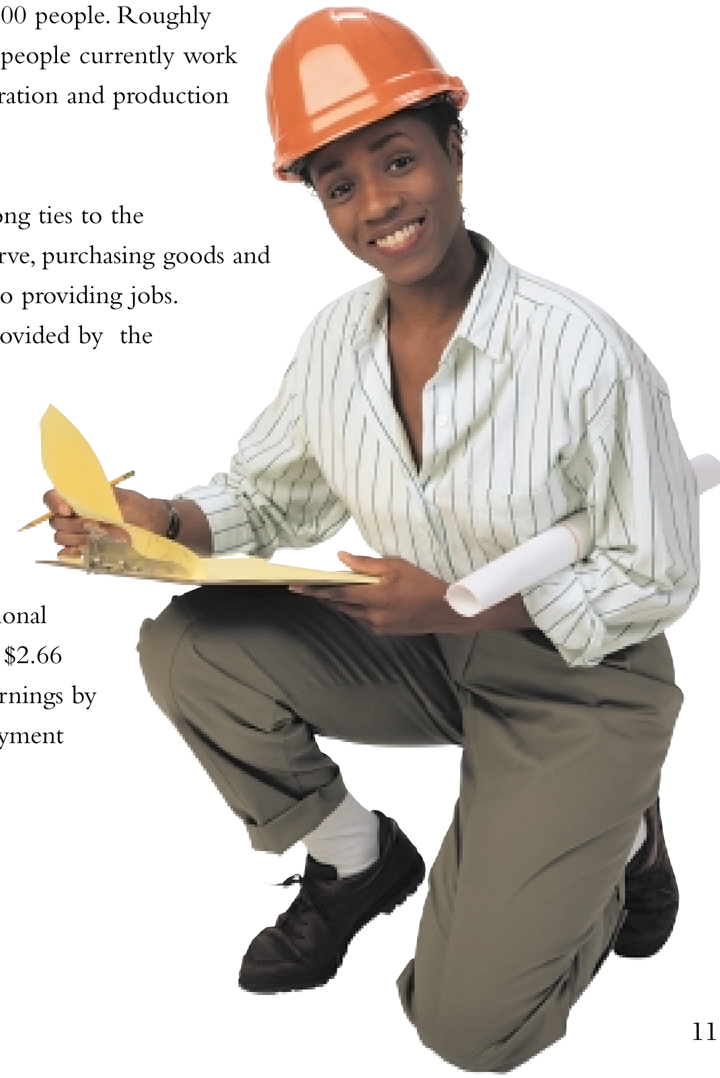
Furthermore, natural gas is a reliable source of fuel not only because most of the supply is domestic, but also because the pipeline delivery system is underground and protected from weather-related disruptions.

This reliability is one of the reasons businesses that cannot afford power disruptions find gas-fired distributed electricity generation so attractive *(see "Gas Puts Electricity on the Doorstep," page 23)*. For instance, McDonald's and other food chains are testing gas-based distributed generation because they cannot afford power outages that could destroy their food products.

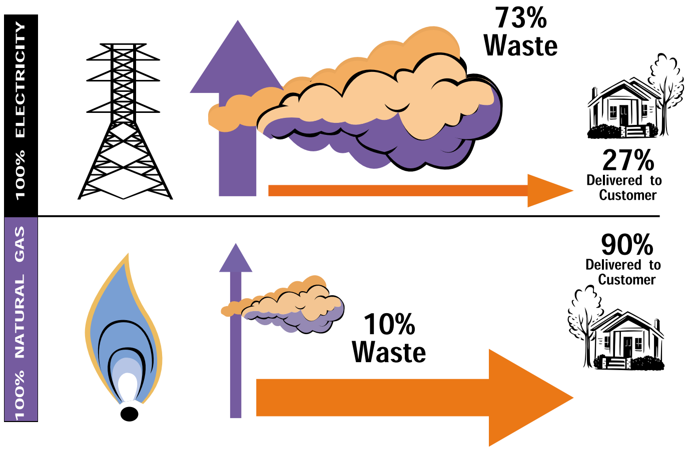
Natural gas technologies can contribute to the United States' foreign trade offerings. An expanding domestic natural gas industry offers worldwide trade opportunities. The United States leads the world in terms of its natural gas infrastructure, and U.S. companies are furnishing equipment and expertise to countries in Central America, South America, Europe and the Far East that are just beginning to develop natural gas systems. In addition, a strong global market exists for gas-related products such as high-efficiency gas turbines.

The domestic natural gas industry employs hundreds of thousands of workers and helps fuel the economy. Besides providing one of the fuels that drive economic activity, the U.S. natural gas utility industry employs about 150,000 people. Roughly the same number of people currently work for oil and gas exploration and production companies.

Gas utilities have strong ties to the communities they serve, purchasing goods and services in addition to providing jobs. According to data provided by the Department of Commerce's Bureau of Economic Analysis, every $1 million of revenue generated by gas utilities increases national economic output by $2.66 million, employee earnings by $450,000 and employment by 14 workers.



Natural Gas is Cleaner, More Efficient Than Coal-Fired Electric Power



To look solely at the efficiency of the appliance or equipment provides incomplete and misleading results when examining energy and environmental issues.

TEE: A Key to Sound Energy Decisions

The concept of energy efficiency often is applied only to the efficiency of a specific product, such as a boiler, furnace or turbine.

A truer measurement of energy efficiency takes into account all of the energy used or lost in the production, processing and delivery steps involved in supplying energy to run factories, businesses, homes and vehicles, plus the efficiency of the energy-using product itself. Measuring the efficiency of the entire energy cycle from production through actual use is called "total energy efficiency," or TEE.

The difference TEE makes can be illustrated by a household water heater. An electric water heater may be considered "90 percent energy efficient." In reality, however, only about 27 percent of the energy contained in the coal, oil, natural gas or uranium used to generate the electricity that runs the water heater actually reaches the equipment in a useful form. In other words, about 73 percent of the energy is "lost," mostly in the process of making the electricity. On the other hand, using the TEE measure, natural gas is delivered to consumers with a total energy efficiency of roughly 90 percent.

More Consumers at Home With Natural Gas

In the accelerated projection, residential gas consumption could be 30 percent higher in 2020. Residential natural gas consumption peaked in 1996 at 5.2 quads but fell to 4.5 quads in 1998 due to unusually mild weather. The accelerated scenario projects residential consumption of 7.4 quads by 2020, up 30 percent from the 5.7 quads forecast under the current projection. The accelerated projection reflects continued high penetration by gas in new homes and conversions from other fuels to gas in existing homes. Roughly 200,000 heating customers per year have converted to gas over the past decade, and there is significant conversion potential in other non-heating uses where gas market share is lower such as in cooking and clothes drying. The accelerated projection also includes growth in nontraditional gas markets, including gas cooling and distributed generation.

More than 56 million homes, or 55 percent of all U.S. households, use natural gas. Of the roughly 102 million households in the United States, more than 56 million are served with natural gas. Gas is highly valued by consumers, and, in fact, 70 percent of all single-family homes completed in the United States in 1998 heat with natural gas.

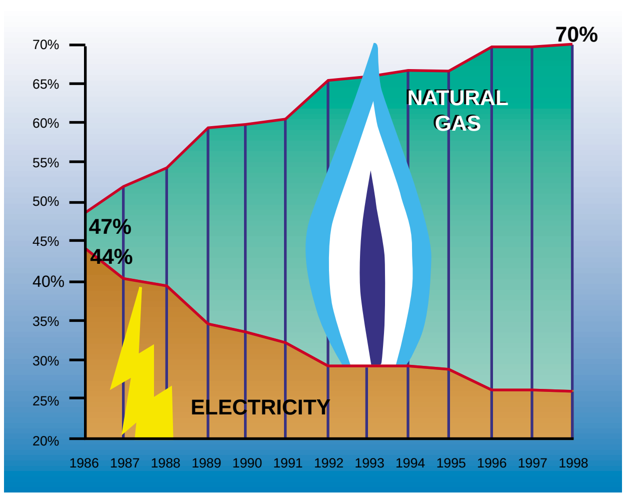
Nationwide, 52 percent of the market is served by gas, but there is significant regional variation. Gas holds 47 percent of the market in the Northeast, 38 percent in the South, 73 percent in the Midwest and 58 percent in the West.

In addition to space heating, gas is used primarily for water heating, cooking and clothes drying. Gas also is being used in a number of less traditional applications as discussed below. Consumers prefer gas because it is a high quality yet economical energy source. Gas provides warmer air for heating than heat pumps, more precise temperature control for cooking than electricity and quicker recovery time for water heating than electricity, yet it is the most economical source of residential energy, according to the Department of Energy.

Residential gas use is becoming increasingly energy efficient. Approximately 90 percent of the gas energy produced reaches the ultimate consumer in a usable form.

In addition, homes have become better insulated and more tightly designed, and gas appliances have become increasingly efficient. Thus, energy resource requirements, customer bills and environmental impacts are reduced. The average residential customer consumes 16 percent less gas today than in 1980, with 53 percent of this decline attributable to more efficient gas appliances and one-third due to better-constructed homes.

% of New U.S. Single-Family Homes Using Natural Gas



Natural gas continues to dominate the new-home heating market, warming 70 percent of the single-family homes built in 1998.

Homes using natural gas produce an estimated 60 percent less greenhouse gases than electric homes and 42 percent less than oil homes. Given the clean-burning characteristics of natural gas and the high level of total energy efficiency when compared with the major competing fuels, the potential for environmental benefits is clear. In general, natural gas burns more cleanly than oil, and it also is preferable to electricity due to the lower efficiency of the electricity system and the emissions generated at electricity power plants. As an example, compare the carbon dioxide emissions attributable to the natural gas-fueled space- and water-heating, cooking and clothes-drying appliances of a typical new 1,500-square-foot home with those of a similar-sized, new oil or electric home. Carbon dioxide is the principal greenhouse gas, and anticipated annual emissions in this example are 7,400 pounds per year from the gas home versus 13,100 pounds from the oil home and 19,700 from the electric home. (This comparison assumes that electricity is generated by today's fuel mix of coal, natural gas and oil.)

Significant opportunities exist for the conversion of existing customers to gas. Generally, the market share for gas water heaters is very close to the market share for heating on a regional basis. For example, 73 percent of the homes in the Midwest use gas for space heating, and 65 percent use gas to heat water. Similarly, 38 percent of the homes in the South have gas space heating, and 34 percent have gas water heating. However, gas ranges have a 39 percent market share in the Midwest and a 23 percent share in the South, and the respective market shares for clothes dryers drops to 32 and 9 percent, respectively, in these regions. Clearly, there is a significant opportunity to increase the number of tasks fueled by natural gas.

New residential gas uses range from fireplaces and air conditioners to microturbines and fuel cells. Residential customers are using gas in a number of new and innovative ways, and technologies currently being demonstrated could change the nature of the market.

Gas fireplaces have become a particularly strong new market due to economical operation and ease of use as well as environmental considerations. The typical gas fireplace is far cleaner than its wood counterparts, eliminating or making major reductions in a variety of pollutants, including carbon dioxide, nitrogen oxides, carbon monoxide and soot. In fact, wood fireplaces are banned or restricted in a number of areas, including Denver, Portland, Phoenix and Los Angeles due to environmental concerns. Currently, fireplaces account for 125 trillion Btu of gas demand annually. The sales of natural gas and propane fireplaces now far exceed sales of wood-burning units.

Gas air conditioners have been available for decades, but they have not fully met customer needs in terms of performance, economics and reliability. That is now changing. The residential gas absorption units now on the market use 30 percent less energy than their predecessors, are expected to last 20 years with a low level of maintenance, run quietly and produce no polluting CFCs or HCFCs. Gas air conditioning has great potential, particularly in the West and South.

This Connecticut home features 14 natural gas appliances, including a master-bath towel warmer and a patio campfire.

It can cost one-third less to heat the same house with natural gas than with an electric heat pump.

1999 Average Annual Operating Costs

GAS	
93% efficient gas furnace:	$556
78% efficient gas furnace:	$693
ELECTRIC	
Electric 8.0 HSPF heat pump:	$831
Electric resistance furnace:	$1,763

Source: U.S. Department of Energy

Fuel Cells Come Home

Gas-based distributed generation has the potential to radically alter the residential market. Rather than purchasing electricity from distant generating plants, various modes of distributed generation offer residential customers the option of using natural gas to produce electricity at their home. This can be done through very small gas turbines, or “microturbines.” It also can be done through fuel cells.

In July 1998, a single-family home in Latham, N.Y., was disconnected from its local electric utility and powered up with Plug Power’s 7 kW residential PEM fuel cell — the first house ever to do so. In August 1999, the system was converted to use the home’s incoming natural gas line as the fuel supply.

A fuel cell is a self-contained unit that converts natural gas to electricity and heat through a chemical reaction (as opposed to a combustion process). Fuel cells preclude the need to construct costly and disruptive transmission lines, and they protect consumers from power outages.

Fuel cells are energy efficient (40-60 percent), and they can reduce a number of pollutants, including carbon dioxide (by 70 percent relative to coal-based electricity) and nitrogen oxides (by 85 percent relative to the ultra-tight Los Angeles standards) — with no discharge. A limited number of residential fuel cells are in use today, including the 7 kW residential PEM fuel cell installed by Plug Power in the house pictured, with installed costs ranging from $7,000 to $10,000. Mass production could cut the cost in half within the timeframe of this study.

Commercial Markets: **Cold Comfort and Hot Opportunities**


Consumers can shop in comfort when malls use natural gas.

Commercial gas consumption could be 25 percent higher in 2020. Today, 3 quads of gas are consumed annually in the commercial sector. Under the assumptions of the accelerated projection, consumption could increase to 5.5 quads by 2020, roughly 25 percent above the current projection of 4.4 quads. The more aggressive scenario reflects continued success in space and water heating and in food-service establishments as well as significant growth in the markets for commercial cooling and various forms of distributed generation.

Natural gas accounts for more than 40 percent of commercial energy consumption. The commercial sector includes office buildings, schools, hospitals, hotels, restaurants, malls and other retail establishments. Energy consumption in the commercial sector totals about 7.7 quads annually, including 3.1 quads of natural gas, slightly less than the commercial consumption of electricity. The primary commercial sector uses for energy are space heating (36 percent), lighting (19 percent), cooling (12 percent), water heating (8 percent), cooking (6 percent) and drying (3 percent). Gas is dominant in the space and water heating, cooking and drying segments. Gas now also accounts for 13 percent of the commercial cooling market.

Commercial gas cooling has multiple applications. Gas cooling products are making inroads in the marketplace. The three basic types of gas cooling equipment are engine-driven chillers, absorption chillers and desiccant dehumidifiers. Engine-driven chillers use a gas engine rather than an electric motor to drive a compressor. These systems are particularly attractive because they offer the option of recovering waste heat that can be used to generate hot water or steam. Sales of commercial gas engine-driven chillers jumped from 7,000 tons in 1994 to almost 50,000 tons in 1996.

Absorption cooling produces a cooling effect by evaporating a refrigerant. These systems, which use water or ammonia rather than a synthetic refrigerant, commonly are used to cool large commercial buildings such as hotels, offices and hospitals. The number of heat exchanger "stages" of absorption systems can be increased, thereby increasing system efficiency. Double-stage absorption systems increase efficiency by 50 to 60 percent compared with single-stage systems. Triple-stage systems currently under development offer potential savings of an additional 50 percent over those of the double-stage systems.

Gas-based desiccant dehumidification systems reduce humidity in commercial establishments, thereby reducing the energy required for cooling. When humid air is cooled, about half the energy of conventional cooling systems is actually used just to dry the air. Desiccants dry the air prior to cooling. The clean, dry air produced by desiccants can eliminate frost buildup in the frozen-food section of supermarkets, reduce airborne spores and bacteria in hospitals, prevent mold and mildew problems in hotels, and improve indoor air quality in offices and retail establishments.

Desiccants combined with a gas-powered chiller can bring excellent energy efficiency to new cooling markets such as grocery stores.

The government hopes to double combined heating and power by 2010. Almost all energy-related processes waste some energy, often in the form of heat. Sometimes this energy can be captured and used for other processes. The capture and use of energy that otherwise would be wasted ultimately leads to conservation of our energy resources and also reduces the environmental impacts that stem from energy production, transportation, conversion and use. Combined heat and power (CHP) and combined cooling, heating and power (CCHP) refer to integrated systems that can provide these multiple products with one energy input, usually natural gas.

Natural gas is ideally suited for CHP and CCHP applications. Heat released by gas power generators or engine-driven chillers can be used to run cooling equipment such as desiccant dehumidifiers or absorption chillers, or to run space or water heaters. The energy efficiency of these systems is being recognized by building managers seeking to reduce energy costs and by government officials with environmental objectives. For example, the Assistant Secretary of Energy Efficiency and Renewable Energy of the U.S. Department of Energy has challenged industry to double CHP capacity by 2010. He sees similar prospects for CCHP.

Distributed generation is available for a variety of commercial establishments. CHP and CCHP are both forms of distributed generation that have multiple energy products. However, other forms of distributed generation offer a single output — electricity — that is produced on-site. Reciprocating engines, turbines and fuel cells can all be used to generate electricity at commercial sites. These options offer increased freedom from power disruptions, consistent high-quality electricity and control over the energy supply.

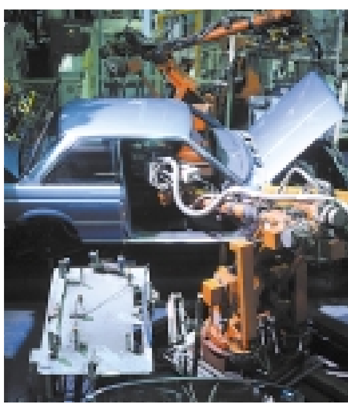
The movement of distributed generation technologies into the commercial sector is a natural evolution. Related technologies have prospered in the industrial sector for decades. Over time, units have become smaller and more efficient and reliable. Whereas the economic threshold for stand-alone turbines 20 years ago may have been 20 megawatts, today's microturbines use 30 or fewer kilowatts. Thus, today we see not only turbines the size of a house providing electricity to an industrial facility, but also engines or turbines the size of a refrigerator meeting the electricity needs of fast food restaurants and drug stores. Such evolution will inevitably continue.

Getting Down to Business: Industrial Markets Lead the Gas Resurgence

Natural gas is the primary source of energy in the industrial sector, accounting for nearly 40 percent of the total energy consumed. Gas is used as a boiler fuel, as a feedstock and as the energy source for a variety of industrial processes. Key gas-consuming industries include chemicals, steel, paper, glass and oil refining. Industrial gas consumption in 1998 was 10.1 quads. The current projection estimates industrial gas consumption of 11 quads by 2020; the accelerated projection forecasts 13 quads. These totals include gas consumed for cogeneration and other forms of distributed generation.

The industrial sector has led the resurgence in gas demand growth since the mid-1980s. During the past decade, industrial natural gas consumption increased by 2.5 quads — by far the leading source of gas demand growth throughout the period. In fact, the growth in industrial gas consumption over the past 10 years was more than four times the growth in gas consumption by electric utilities.

Cogeneration, a form of distributed generation, has been the key driver in industrial demand growth. Much of the energy demand in the industrial sector is based on the



need for heat and electricity. Both electricity and usable heat can be produced in a single process called cogeneration. Because cogeneration equipment captures and uses heat that would otherwise be wasted, it is far more efficient and clean than conventional separate processes.

The Public Utility Regulatory Policies Act (PURPA) of 1978 recognized the benefits of cogeneration, and it provided financial incentives to cogenerators, including the mandatory purchase by electric utilities of any surplus electricity generated. PURPA provided a significant stimulus to cogeneration projects, about two-thirds of which are fueled by gas. Cogenerators currently produce about 10 percent of the electricity consumed in the United States. (More than 80 percent of the operational capacity was constructed post-PURPA.) Gas-fired cogeneration accounted for roughly 40 percent of the 2.5-quad growth in gas demand from 1988 to 1998.

Growth in industrial cogeneration will slow over the forecast period as the electric industry is restructured and PURPA benefits are eliminated, and also because most of the large sites with favorable electricity and steam balances have been taken.

Despite saturation in the cogeneration market, industrial gas demand will see continued strong growth. Cogeneration growth will slow somewhat over the next 20 years. However, numerous technological advances have emanated from the cogeneration boon, producing new breeds of gas turbines, reciprocating engines and heat-recovery equipment. These advances have laid the groundwork for other forms of industrial distributed generation as well as for increased penetration of cogeneration and distributed generation in smaller-scale residential and commercial applications.

Radical improvements in high-efficiency industrial gas equipment offer significant benefits to plant operators and the nation. In the early 1970s, the first oil embargo pushed energy prices up sharply at the same time Americans were increasingly focused on improving energy efficiency and environmental progress. As a result, since then industrial energy users have sought to upgrade the performance of the energy-consuming equipment in their factories.

This upgrading has produced a new breed of gas equipment and processes that, although often overlooked, offer significant benefits to plant operators and the nation. For example, direct-contact water heaters, used primarily in the textile industry, allow a gas flame to come into direct contact with the fluid being heated rather than merely heating the air or a containment vessel. As a result, far less energy is wasted. In fact, the efficiency of this heating process is greater than 99 percent (compared with the 30- to 35-percent efficiency equipment it normally replaces). Similarly, gas-fired infrared burners, used in a host of industrial processes, are three times as efficient as traditional gas burners. Sophisticated, high-tech equipment such as this will be required for gas to maintain its role as the primary industrial energy source.

Natural Gas Powers Up New Electricity Generating Units – Large and Small

Because of its many economic and environmental benefits, natural gas has become the fuel of choice for electricity generation. In the 1990s, there was a dramatic shift to natural gas for the generation of electricity. Large coal and nuclear generating plants were the clear choice of electric utility planners in the 1970s and 1980s, but a combination of economic, environmental and technological factors have resulted in a pronounced movement to gas. In fact, virtually all new generating capacity being added today will rely on gas.

Gas-fired combined-cycle technology is the overwhelming choice in these new generating plants. Combined-cycle plants offer extremely high efficiency, clean operation, low capital costs and shorter construction lead times. The efficiency of combined-cycle units is now approaching 60 percent compared with roughly 34 percent efficiency for traditional boiler units – regardless of the fuel source.

Higher efficiency means lower fuel bills and less pollution. For example, replacing a coal generating unit with a gas-fired combined-cycle plant could eliminate sulfur dioxide emissions (the primary cause of acid rain), cut carbon dioxide (the principal greenhouse gas) by as much as two-thirds and cut nitrogen oxides (the primary cause of smog) by as much as 95 percent. Also, not only is the lead time for construction of a combined-cycle unit shorter than that of a new coal-fired plant, but construction can be implemented in a modular fashion. So rather than constructing one large coal or nuclear unit today and hoping that the forecasted demand for electricity will be realized, smaller gas units can be constructed as warranted — without the economic penalties associated with building "small" coal or nuclear plants.

Gas consumption by central-station electricity generating plants will more than double over the next 20 years, although the increase may be lower than projected by some forecasters. Gas consumption at central-station electricity generating plants (including electric utility plants and independent power producers) is currently at 3.3 quads per year. The accelerated projection indicates consumption will more than double by 2020 – to 6.7 quads per year. Although this growth is far above historic levels for this sector, the total is somewhat less than the current projection of 7.8 quads and significantly less than the 9.2

quads forecast by the U.S. Energy Information Administration in its 1999 Annual Energy Outlook.

While the accelerated projection includes a very high penetration rate for gas in new generating facilities, capacity additions are somewhat limited. These limitations are due to the assumed life extensions of both nuclear and coal plants, increasing the use of coal and nuclear plants, growth in distributed generation and some construction of new coal plants in the later years of the forecast.

By 2020 the operating licenses of half of all nuclear generating plants will expire, but not all of these plants will be closed. About 100 gigawatts of nuclear generating capacity are operating in the United States today, providing 20 percent of the country's electricity. The operating licenses of many of these plants will expire over the next 15 to 20 years. In fact, if no operating licenses are extended, nuclear generating capacity would be cut in half by 2020. However, as a result of industry restructuring, significant consolidation is occurring within the nuclear industry. This consolidation, combined with environmental pressures to reduce greenhouse gas emissions, will likely result in efforts to renew the licenses of many nuclear plants. The accelerated case includes an assumption that two-thirds of the nuclear units scheduled to retire will be granted license extensions.

The role of coal will stay fairly constant, and it will remain the nation's primary source of electricity. Currently, coal provides 56 percent of the electricity generated in the United States, and this percentage remains essentially constant throughout the forecast period for the accelerated scenario. Since electricity consumption will continue to increase and the coal share is stable, coal consumption is forecast to actually increase from the 900 million ton level today to 1.1 billion tons by 2020.

Growth in renewable energy will be robust but not a panacea. Renewable energy such as wind and solar power accounts for approximately 12 percent of the electricity generated today, increasing to nearly 15 percent by 2020 in the accelerated projection. At first glance, this growth appears somewhat modest. However, it must be considered that the lion's share of the renewable mix today is attributable to hydroelectric generation. No new hydro capacity is anticipated in the forecast period due to concerns related to fish habitat. Thus, the non-hydro renewable growth is impressive – more than doubling over the next 20 years.

Electricity generation will begin to shift from central-station facilities to distributed-generation facilities. In the accelerated projection, 20 percent of the new generating capacity added throughout the forecast period is accounted for by distributed generation, providing about 5 percent of all electricity generated in 2020. It should be noted that over the past decade cogeneration, a form of distributed generation that produces both electricity and useful heat, accounted for 25 to 30 percent of the total generating capacity added. *(See "Gas Puts Electricity on the Doorstep" for more details about distributed generation.)*

Gas Puts Electricity on the Doorstep

"Distributed generation" refers to the placement of small-scale power-generation units at or near the site where the electricity will be used. These units can generate as little as 5 kilowatts of electricity, which is enough for the average single-family home, or 50 kilowatts or more for factories. In fact, on-site natural gas generation is very popular at industrial facilities.

Walgreens recently installed a natural gas microturbine.

Natural gas is a particularly attractive fuel for distributed generation, and it powers most of the numerous distributed generation technologies. The systems available today range from fuel cells that generate electricity for individual homes to gas-fueled turbines and reciprocating engines that produce electricity for a factory.

Compared with electricity generation at central-station power plants, distributed electricity generation produces fewer pollutants, is more energy-efficient and can be more reliable. For instance, distributed generation eliminates the loss of electricity, roughly 8 percent, that occurs when electricity moves from the central-station power plant through the power line grid to the point of use.

Gas-fueled distributed generation also is resistant to power outages, produces high-quality electricity required for very high-tech applications and gives the consumer greater control over energy use.

Use of Natural Gas Vehicles Revs Up

Natural gas vehicles lead the accelerated projection's transportation growth. Gas consumption in the transportation sector increases from 1.1 quads in the current projection to 2.8 quads in the accelerated scenario. The lion's share of the growth, more than 1.5 quads, is attributable to natural gas vehicles (NGVs) — transit buses, trucks, vans and cars. Gas used to power the compressors that move gas through transmission and distribution lines increases to 1 quad in 2020, up modestly from 0.7 quads today. The accelerated projection also includes a small amount of gas used by railroads in the form of liquefied gas.

About 80,000 NGVs are operating in the United States today, dwarfed by more than 200 million gasoline and diesel vehicles. Most NGVs are fueled at some 1,225 compressed natural gas stations throughout the United States, a number that has increased four-fold since 1991. NGVs are the most commercially advanced of the alternatively fueled vehicles — methanol, ethanol, propane and electricity.

Twenty-two percent of all new transit bus orders are for natural gas buses.

Fleet vehicles in areas with air quality concerns offer the most promise. The benefits of NGVs are most pronounced in congested urban areas that have air quality concerns, and federal, state and local organizations have recognized the potential benefits of NGVs in these areas. Promotional federal initiatives include the Clean Air Act, the Clean Cities Program, the Congestion Mitigation Air Quality Program, the Energy Policy Act and the Advanced Natural Gas Vehicle Program.

A number of factors make fleet vehicles — buses, taxis, delivery vehicles — the prime target for natural gas. Because natural gas generally costs less than gasoline, these high-mileage vehicles can realize large savings in fuel costs. Also, fleet vehicles tend to be centrally located. Thus, fleets can locate near refueling stations, or they can install their own facility.

Natural gas vehicles offer tremendous benefits but face serious hurdles. Emissions from cars, trucks and buses are one of our most serious sources of pollution, contributing to urban smog, visibility problems and greenhouse gas emissions. Highway vehicles account for roughly one-third of all carbon dioxide and nitrogen oxides emissions, and half of all carbon monoxide emissions. Using natural gas rather than gasoline can produce major reductions in a number of vehicular emissions. In addition to being cleaner than conventional vehicles, NGVs reduce the nation's extreme dependence on imported oil, and the fuel cost is generally less than the cost of gasoline or diesel fuel.

Despite these benefits and the fact that a survey of fleet operators by the Natural Gas Vehicle Coalition showed that NGVs are their favorite type of alternatively fueled vehicle, market growth for these vehicles has not been dramatic. The primary obstacle is that vehicle production levels are limited, making the purchase price of an NGV higher than the price of a comparable conventionally fueled vehicle. Even for high-mileage vehicles, it is difficult to offset the extra thousands of dollars on an NGV's price tag with the savings in fuel costs of 10 to 20 cents per gallon. Once the demand for NGVs reaches a level that can sustain full production, prices will fall. Currently, the natural gas fueling infrastructure is also limited, but the fueling infrastructure will expand as NGVs gain in popularity.

Natural gas can be used in a compressed or liquefied form to fuel vehicles. NGVs can use either compressed or liquefied natural gas. Natural gas can be compressed at high pressure — up to 3,600 pounds per square inch — and stored in a high-pressure cylinder in the trunk or under the vehicle. Alternatively, natural gas can be cooled to -260°F at which point it is liquefied and can be stored in insulated tanks. In each method the fuel reaches the engine in a gaseous state. The liquefied natural gas option offers an advantage in that it allows more energy storage per unit of space — 600 times more natural gas can be stored in liquefied form. Thus, less room is required of the trunk or other tank area, and driving range can effectively be increased.

Technological focus will be on purchase price and driving range. NGVs have made numerous technological advances during the past decade. The units available today are clean, safe and efficient vehicles that perform much the same as gasoline vehicles. However, a few further technological advances could greatly improve public acceptance.

Experts are working to reduce the purchase price of NGVs, to expand their driving range without sacrificing trunk or other usable space, and to take full advantage of the energy efficiency and environmentally friendly characteristics of natural gas. Finally, a simplified process that converts gas to a liquid, the "syntroleum process," is expected to be commercially viable by 2005. Successful introduction of a viable gas-to-liquid technology would provide significant incentive for using natural gas as transportation fuel.

Meeting the Natural Gas Supply Challenge

The natural gas resource base in North America is vast and diverse. This statement, while simple, is actually poorly understood and often misinterpreted when quantified. Estimates of the natural gas resource base made at one time are often a better measure of how the resource base has changed over time than an absolute value. Clearly, the North American resource base is capable of sustaining consumption well into the 21st century and beyond.

PHOTO COURTESY OF HDI

Horizontal drilling is a relatively new technology for extracting natural gas.

Virtually all of the natural gas consumed in the United States in produced in North America. Most (roughly 85 percent) is produced in the United States. Canada provides most of the remainder (about 97 percent of U.S. imports, or about 3 Tcf in 1998). Mexico's large natural gas resource base and its high production capability make it a potential gas supply source. This diversity, both in terms of the supply source and geographic distribution, adds strength to the flexible, economic and reliable nature of natural gas in today's energy mix.

Note: All Tcf have been converted to quads to ease comparisons.

Although the gas resource base is often characterized as "finite," estimates of its size continue to grow. Because experts' ability to evaluate and measure the gas resource base is imprecise, characterization of this resource base as "finite" can be misleading. As the tools and technologies used in the evaluation process improve, resource base estimates of virtually all estimators have increased over time. For example, at year-end 1998, the Potential Gas Committee (PGC) estimated the United States' future supply of natural gas at 1,241 quads, which is more than 60 years of supply at current domestic production rates. However, PGC has made detailed resource evaluations every two years for more than 30 years based on the input of hundreds of petroleum geologists and engineers. Curiously, its 1998 estimate exceeds its 1990 estimate (1,207 quads) by 34 quads even though more than 149 quads were produced from the total resource base over that timeframe. In other words, the future supply estimate for 1998 was more than 15 percent larger than the estimate made in 1990 even though significant production had occurred.

PGC is not alone in expanding its estimate of the gas resource base. The National Petroleum Council released a major report in December 1999 with heavy involvement by natural gas producers, pipelines, distribution companies and the federal government. The report notes that in comparison with its 1992 study, "Taking into account the 124 Tcf [128 quads] that have been produced in the lower 48 states since then, the estimate of the resource base has increased 23 percent since the last study. The increase is largely due to technology breakthroughs that have opened new frontiers such as the Deepwater Gulf of Mexico and have provided improved information and better tools for evaluating — and more fully recovering — resources."

The accelerated projection requires 20 percent more gas than does the current projection, most of which can be supplied through expanded domestic production. Total consumption in the accelerated scenario is projected to reach 35 quads by 2020 compared with 29 quads under the current projection. Of the 35 quad total, 29.5 — or 84 percent — is supplied through domestic U.S. production. This share is little different from that of today's 85 percent.

Domestic natural gas production has grown 23 percent from the demand-constrained level of 16.1 quads in 1986 to more than 19.8 quads in 1997. A significant portion of that new production is accounted for by resource environments not even on the production radar screen in the 1980s, such as deepwater (water depths greater than 1,000 feet) in the Gulf of Mexico. These new production trends, which include incremental additions from coalbed methane as well as deeper onshore production in traditional producing areas like the Rocky Mountains, are highly dependent on continued advances in drilling and production technologies and are expected to gain momentum during the study period.

Sustaining growth in annual natural gas reserve additions to meet the growing appetite for clean fuels is an economic challenge as well as a technology challenge for the 21st century. Continued growth in natural gas reserves will likely occur as existing deepwater discoveries further develop and the information regarding the nature of those reservoirs is refined. In fact, it is likely that entirely new deepwater fields will be discovered and brought online within the study period. Extending resource life in existing fields both onshore and in the shallow water environments of the Gulf of Mexico also will present technological challenges but, based on recent resource enhancement history, are attainable.

Canada will remain the primary source of imported natural gas. Production of natural gas in Canada is currently just under 6.2 quads annually, about half of which is exported to the United States. With a resource base estimated at more than 618 quads, the Canadian resource life index is more than 100 years at current production levels.

Under the accelerated scenario, imports from Canada are projected to increase from about 3.1 quads annually in 1998 to approximately 5.2 quads by 2020. Thus, the share of the overall U.S. supply mix attributable to Canada increases slightly — from roughly 13 percent of the total to 16 percent.

To meet the required levels of production necessary to satisfy demand growth in both Canada and the United States, the Canadian producing community will face challenges similar to those faced by U.S. producers. Technological advances will be needed to complete drilling projects in hostile environments, rig activity will need to increase, and exploration initiatives in frontier as well as established areas must gain momentum.

Liquefied natural gas will play an increasing, yet still modest, role. LNG is a significant factor in the world energy market. Natural gas in Africa, the Middle East, Australia, Indonesia and the United States is liquefied, transported by ship, re-gasified and distributed in Pacific Rim countries, Europe and the United States. Currently, there are four major LNG import facilities in the United States, operating well below capacity.

While the high levels of LNG imports projected by energy forecasters in the 1970s have not materialized, this does not reflect failed LNG technology or economics. Rather, it is a testament to the strength of the U.S. supply response to the removal of artificially low regulated prices.

The accelerated projection assumes the full operation of all existing U.S. terminals but no construction of new facilities. Existing facilities account for roughly 1 quad of gas supply in 2020.

Alaskan natural gas, including more than 35 Tcf of previously discovered gas resources and vastly more potential, offers additional supply insurance to the lower 48 states. Alaskan natural gas, similar to foreign LNG, offers major gas supply potential but remains largely untapped due to an inability to compete with lower 48 and Canadian supplies. The economics of transporting a portion of those supplies southward are changing, however, as the natural gas infrastructure from Canada grows toward Alaska. Alaska currently exports about .07 quads annually in the form of LNG to Pacific Rim nations and consumes more than .46 quads annually. Additional resource potential exists onshore and offshore in Alaska, including a speculative but significant undeveloped potential from coalbed methane.

"New sources" of supply such as coalbed methane are contributing to the gas mix today while methane hydrates and other options offer promise for tomorrow. Vast quantities of methane gas are locked in coal seams, but this gas was not economically recoverable until recently. In fact, coalbed methane was not even included in PGC's resource base assessments before 1988. However, we have now discovered ways to efficiently access this gas, and 6 percent of U.S. gas production now comes from coalbed methane. Methane hydrates is another potentially huge resource that is not currently economically recoverable *(see "Getting Methane Out of Bed")*.

Meeting the demand level of the accelerated projection will require a continuation of the inventions and innovations experienced by the industry in recent years. Although significant advances in exploration and production technology will be required to meet the demand levels of the accelerated projection, these developments should be viewed as a continuation of the current trend. Recent advances in computer technology have yielded breakthroughs in data processing, integration and imaging, which in turn have vastly improved reservoir modeling.

Advances in drilling technology have been equally impressive. Wells are routinely drilled today to depths of more than 17,000 feet — depths considered radical in 1980. Drilling in 600 feet of water was "routine" in 1980. Today, a depth of 2,000 feet is not unusual. Further, while vertically was the only direction to drill 20 years ago, horizontal drilling is now commonplace and effective.

Continued advances will be required as resource exploration and development onshore in deeper geologic zones under extreme temperature and pressure conditions are mirrored in hostile deepwater environments offshore. Innovations in the design, materials and fabrication of these systems will be required to ensure adequate future natural gas supplies. If the advances in the past 30 years of petroleum exploration and development in North America are any indication, the industry will continue to create innovative technology developments for oil and gas extraction.

Getting Methane Out of Bed

Coalbed methane offers a perfect illustration of how technological advances can dramatically alter the size of the natural gas resource base.

Methane, the chief component of natural gas, adheres to the inner surface of coal. For years, coal-mine operators have "produced" methane — not as fuel but to get rid of it because it poses a safety problem in the mines. While the methane in coal beds was recognized as a possible source of gas supply, it could not be recovered and added to the nation's natural gas supply using existing technologies. So coalbed methane was classified as an "unconventional" source of gas supply.

Then, technological improvements in the early 1980s made recovery of the nation's vast quantities of coalbed methane possible. Within a few years, coalbed methane was removed from the "unconventional" category and reclassified as a mainstream source of gas supply by the energy experts who tabulate the size of the nation's gas resource base. Today, coalbed methane makes up 6 percent of U.S. gas production.

In the future, this same story may be repeated for methane hydrates, which consist of methane molecules, water and small amounts of other gases in a crystalline ice-like substance. The hydrates are found in permafrost areas and in ocean sediments when certain pressure and temperature conditions are present. Worldwide, methane hydrates offer a potential gas resource that is estimated at millions of Tcf/quads. The technological hurdles associated with extracting methane from hydrates are now being investigated.

Expanding Natural Gas Delivery Systems

The natural gas infrastructure is designed to deliver gas with maximum safety, reliability, flexibility and efficiency. The natural gas production and delivery system includes production wells, processing plants to remove impurities, long-distance underground pipelines and smaller local distribution lines, compressor stations to move gas through the system, various kinds of gas storage facilities and peaking facilities to supplement gas supply on the coldest days. The system is safe: the safest way to transport energy, according to the U.S. Department of Transportation. It is highly efficient: 90 percent of the energy produced reaches the ultimate consumer in a usable form in contrast to electricity, which loses more than 70 percent of its useful energy from the point of production to the point of consumption. It is highly reliable, largely underground and therefore not subject to weather-induced interruptions. It is a system largely taken for granted.

Safety and reliability will not be compromised in an unbundled environment. The natural gas industry has moved demonstrably toward an open, competitive market during the past two decades. First gas pipelines and now utilities have opened their systems to competition, not unlike the phone system. Gas purchasers, both local gas utilities and ultimate consumers, may now buy gas from a variety of sources. In fact, more than three-fourths of the

gas consumed today can be purchased from someone other than the local gas utility. In addition, many of the services traditionally performed by local utilities in a monopoly environment are becoming subject to competition — meter reading, billing, etc.

Underground natural gas lines leave little mark on the surrounding environment.

Clearly, the movement toward customer choice and other forms of unbundling will continue. However, it is also clear that as new players enter the market, performing functions once restricted to pipelines or utilities, the public will expect a continuation (or enhancement) of the level of service they have historically received. For example, distribution systems have been constructed and operated to ensure that all customers will receive safe, reliable and economic gas even on the coldest day of the past 100 years. As the nation moves toward significantly higher demand levels under much evolved market conditions, consumers will mandate that this level of service not be compromised.

The natural gas industry is extensive and capital intensive. The in-place assets of the natural gas industry total more than $250 billion, including a 1.3 million-mile transmission and distribution system valued at nearly $150 billion. Of the 1.3 million-mile total, nearly 1 million miles is accounted for by distribution main. The system also includes more than 400 storage facilities, located primarily in proximity to ultimate markets. Gas is injected into these facilities in off-peak periods and withdrawn in periods of peak demand. The natural gas industry operates in all 50 states, with more than 150,000 gas utility employees in addition to exploration and production employees.

Obtaining the necessary investment to fund gas industry growth presents a challenge but not an insurmountable hurdle. To accommodate the demand of the accelerated projection, significant industry investment will be required. For example, transmission and distribution line mileage must increase by about 30 percent at a cost of more than $150 billion. The distribution segment additions will cost nearly twice as much as those of the pipeline additions. Although these investment levels are certainly significant, they are not dramatically different from the levels experienced in the 1990s — a modest increase for distribution and a modest decrease for transmission.

The investment required for the necessary exploration and production activity assumed in the accelerated scenario will certainly be greater than the requirement for transmission and distribution system expansion. More wells will need to be drilled, and more drilling rigs will be required. Although the number of oil and gas wells drilled per year may have to double — to nearly 50,000 per year — this is well below the peak levels of the early 1980s, which ranged from 70,000 to 90,000 wells per year.

Because the drilling fleet has aged, a significant investment also will be required for upgrades. Capital expenditures in the $40 billion per year ($1998) range may be necessary, and acquiring this level of capital will be difficult when competing for dollars with alternative "high-tech" investment options. Again, however, when compared with the investment levels of the mid-1980s, future investment requirements appear less extreme. A critical difference between the production segment and the transmission and distribution segments is that drilling activity slowed significantly in the 1990s and thus the expanded activity required under the accelerated projection is more dramatic when viewed against today's activity level.

Despite technological advances, regulatory hurdles still could impede expansion of the natural gas infrastructure. Perhaps more critical than the dollars required to construct the infrastructure necessary in the accelerated projection is the timely siting and permitting of gas industry facilities. The siting and permitting of gas pipelines, distribution main and storage facilities is often unnecessarily contentious and time consuming. Recognition of technological advances, such as ultra-quiet new pipeline compressors or plastic pipe that can operate at higher pressure, thereby potentially reducing the need for new pipe, can help speed up or lessen the need for infrastructure expansion.

Similarly, large portions of the gas resource base are not open to development due to environmental regulations that are decades old. This includes gas on federal lands in the Rockies, offshore areas in the eastern Gulf of Mexico, and much of the East and West coasts. Obviously, drilling technologies and practices have advanced since the implementation of these restrictions.

The Price Is Right: Gas Prices Can Remain Competitive Despite Higher Demand

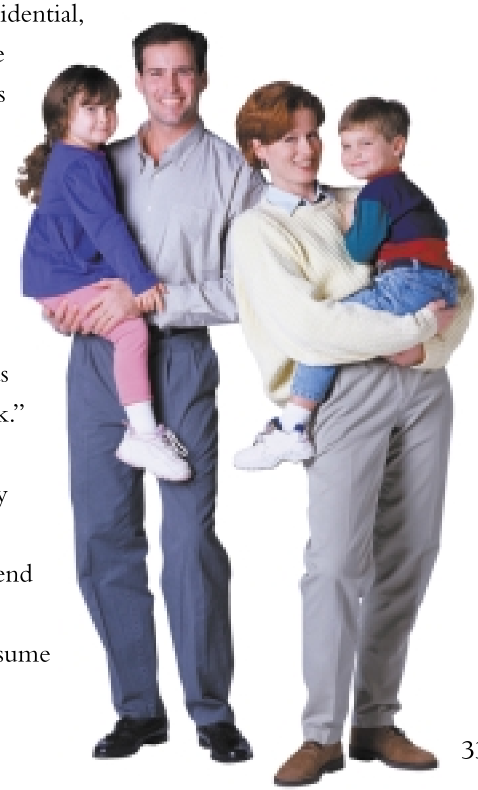
Energy forecasters believe natural gas demand at or beyond 30 quads can be satisfied with only modest price increases. Among the organizations that estimate long-range natural gas and other energy prices are the U.S. Energy Information Administration (EIA), the American Gas Association (AGA), GRI and the National Petroleum Council (NPC). The gas consumption forecast of each of these organizations exceeds 30 quads per year by 2015, and none differs by more than 10 percent from the accelerated projection level of 32.6 quads.

Wellhead gas prices, which hover in the $2 per million Btu (MMBtu) range today, are projected by three of the four organizations to increase modestly in real terms by 2015, ranging from $2.29 to $2.63. (NPC does not include a specific price estimate for 2015; its estimate for 2010 is $2.95. NPC's price estimate is discussed below.)

Each of the forecasts projects that prices to the ultimate consumer will increase less than the wellhead price. That is, efficiency improvements in gas transmission and distribution will continue to offset some of the higher costs of gas exploration and production. There is also uniform agreement among the forecasts that prices to the largest-volume customers — electric utility plants — will increase more than the prices to residential, commercial and industrial customers. In fact, residential and commercial prices are shown to remain unchanged or to decline in real terms in most of the forecasts, despite the higher price of gas at the wellhead.

Washington Policy and Analysis believes that the demand levels of the accelerated projection can be satisfied with wellhead prices in the mid-$2 per MMBtu range (real dollars, adjusted for inflation) in 2015. Residential, commercial and industrial prices should be relatively constant in real terms with prices for central-station electricity generation somewhat higher.

Continued resource base expansion and technological improvements will ensure long-term price stability. Long-term price projections for natural gas have customarily resembled a "hockey stick." They tend to rise very modestly in the short- to mid-term, but at some point they turn sharply upward. One of the primary reasons for this pattern is that forecasters tend to take an engineering approach to quantifying the gas resource base. They assume



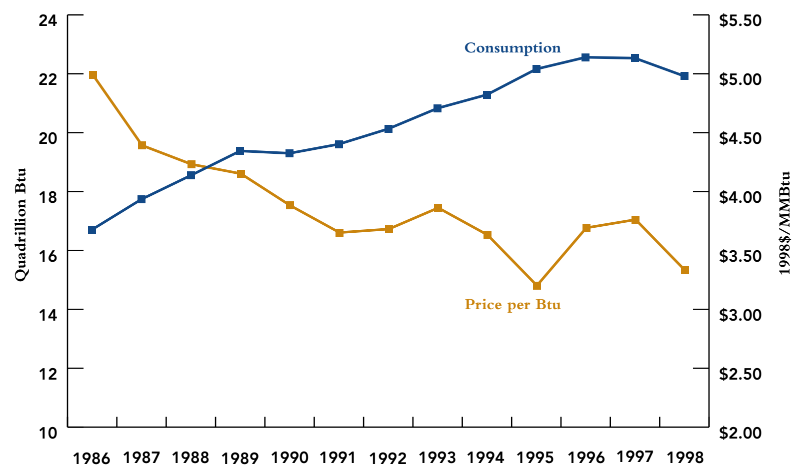
that their initial estimate of the resource base is accurate, and therefore, over time, this resource base will decline, pushing prices up. In fact, all estimates of the gas resource base performed over time by the same estimators and using the same methods have increased, often dramatically.

Resource base estimates tend to heavily influence price forecasts. For example, NPC's recently released work indicates that if its resource base estimate were increased by 260 quads, the 2010 gas price estimate would decline by $0.93 per MMBtu — a reduction of roughly one-third. Interestingly, NPC's 1999 resource base estimate was 176 quads greater than its 1992 estimate, and 304 quads greater when taking into account the 128 quads produced since the 1992 estimate was made.

Additionally, forecasters have historically underestimated the impact of new technologies on gas exploration, production, delivery and use. Forecasters tend to assume that the most recent round of invention and innovation will be the last for a while. That is, the technological leap of the computer is viewed as an endpoint rather than as a starting point. Again, underestimating technological progress affects price. NPC estimates that if it had employed a higher rate of technological improvement for gas production the 2010 gas price estimate would be reduced by $0.32 — about 10 percent. In this analysis it is not assumed that the resource base expansion and technological progress experienced in recent years is an anomaly.

In the deregulated era, natural gas prices have fallen significantly. The natural gas industry has undergone a lengthy process of deregulation, and, as a result, natural gas prices have fallen significantly in real terms (adjusted for inflation). That is, gas prices have gone up far less than the gross domestic product (GDP) index that includes a bundle of goods and services purchased by consumers. For example, from 1987 through 1998 the GDP index increased by 36 percent while the price of gas increased by only 3 percent. All gas consumers, regardless of size or class of service,

Comparison of Gas Consumption and Gas Price



enjoyed significant real price declines over this period. The declining cost of the commodity, when coupled with higher-efficiency equipment that requires less gas to operate, is doubly beneficial for consumers.

While wellhead prices may exhibit short-term volatility, efficiency gains in transmission and distribution continue to exert steadily downward price pressure. While the price of gas at the wellhead can exhibit significant volatility in the short run, moving up or down based on changing weather or various market factors, gas consumers are largely insulated from these movements for a number of reasons. The consumer's bill has two primary components: the cost of the gas commodity and the cost of delivering the commodity. Gas pipelines and local gas utilities have become increasingly efficient in the delivery process, and the real price of the delivery component fell by about 35 percent from 1987 through 1998. (Obviously, this trend cannot continue indefinitely.) The wellhead cost of gas also declined over this timeframe — by more than 13 percent — although the movement in wellhead prices was more erratic and less pronounced than the transmission and delivery charge.

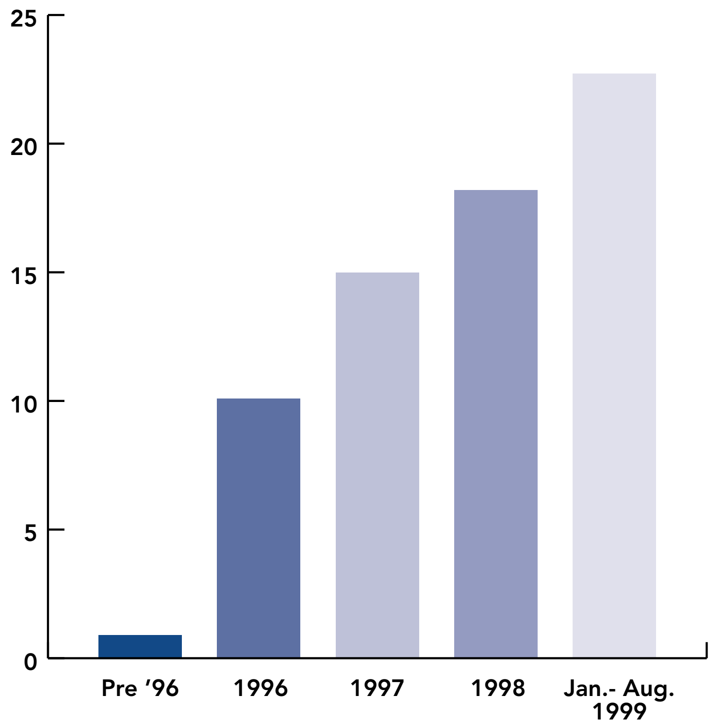
Consumers also are insulated because gas suppliers generally hold a mixed portfolio of gas supplies, including gas from various long-term and short-term contracts. They can purchase gas when market conditions are favorable and store this gas until needed. The free market for gas is still in its infancy, and as we move forward through the forecast period the array of available new technologies and market strategies that can ultimately lower prices will continue to expand.

Natural gas competes primarily with electricity, oil and coal, all of which are expected to have relatively flat or declining real prices throughout the forecast period. Natural gas is not sold in a market vacuum. It competes with a variety of other energy forms — primarily with electricity, oil and propane in the residential and commercial markets; with oil, electricity and coal in the industrial market; and with oil, coal, nuclear energy and various renewables in the market for electricity generation. Over the forecast period, electricity markets will be deregulated, the oil market will become increasingly a world market, coal and nuclear will fight to retain their dominance in generating electricity, and renewable energy forms will become more competitive. The market for energy will be a market of increased competition and innovation with prices that decline or rise very modestly in real terms.

New gas applications can help level the load of gas suppliers. One positive aspect of some of the new gas technologies included in the accelerated projection, such as gas cooling and distributed generation, is that they can help level gas demand. The extreme demand peaks and valleys caused by the need for space heating can be smoothed, allowing for more efficient (i.e., less costly) use of the delivery system.

Residential Customer Choice Program Announcements

(Cumulative Number of Homes Eligible — Millions)



Having It Your Way: Customer Choice

More than three-fourths of the natural gas market has been opened to competition. In the past, natural gas was sold from gas producers to long-distance gas pipeline companies, who sold this gas to utilities, who sold this gas to the ultimate consumer.

This process began to change in the 1980s when large-volume gas customers — industrial facilities and electric utility plants — began to purchase gas directly from producers or from gas marketers. The gas delivery process was unchanged — pipelines and utilities still delivered gas to the customer, but they did not buy and sell the gas commodity. “Customer choice” in the gas industry, as in the telephone industry before it, was seen as a means to put downward pressure on prices while offering new services to customers through increased competition.

This opportunity for customer choice has expanded dramatically, and the move is now prevalent in commercial and residential markets as well. In fact, customer choice is now available to two-thirds of the commercial market and 44 percent of the residential market — and growing.

Appendix: Underlying Policy Assumptions for the Accelerated Projection

Seven policy assumptions were incorporated in the development of the accelerated scenario, which forecasts that U.S. consumption of natural gas could increase by more than 60 percent and reach 35 quads by 2020. It is difficult to isolate individual assumptions and project the specific gas demand impact of each, but the overall collection of assumptions fosters an environment conducive to the realization of the accelerated scenario and its resulting benefits.

Energy markets will be free and competitive, and natural gas utilities will be allowed to compete fairly in these markets. Energy markets have been opened to competition, and it is assumed that consumers will be increasingly free to buy their energy and energy-related services from whichever suppliers they choose, including gas utilities that wish to offer these services.

It is further assumed that regulatory authorities will understand that as gas markets are opened to competition, the balance between risks and rewards must be maintained for gas utilities. If this were not the case, gas utilities would be put at a serious market disadvantage, which would limit market expansion potential.

The historic reputation of the natural gas industry for safety and reliability will not be compromised. Safety and reliability have always been the highest priority of the natural gas industry. If this were not so, industry growth would not have been possible. As the nation moves toward an increasingly deregulated energy market, new questions arise.

For example, gas utilities have traditionally had an "obligation to serve" all customers regardless of their ability to pay. Where will this responsibility rest? Will it be with the regulated gas utility that now only transports gas, or will it shift to the unregulated marketing company that sells the gas commodity to the consumer? Another question involves governmental funding of energy assistance programs for low-income households. If this funding is reduced as gas utilities face increasing competitive pressure, who will ensure the safety of the poor in extreme weather *(see "Keeping Cool — and Warm")*?

It is assumed that these kinds of issues will be addressed and that safety and reliability will not be compromised.

Energy efficiency and environmental regulations will be comprehensive, equitable and balanced. Many energy/environmental regulations are flawed and even counter-productive because they are not "comprehensive" enough. For example, energy efficiency regulations that look solely at the efficiency of the energy-consuming equipment and not at the efficiency of the entire process of providing the energy can push consumers toward equipment that ultimately wastes more energy, emits more pollutants and is more costly.

Similarly, environmental regulations can be counterproductive when they are not equitable. In fact, some regulations are more stringent for cleaner-burning fuels than for dirtier-burning fuels, thereby promoting the consumption of the dirtier fuels.

Finally, environmental regulations can lack balance in that the costs and benefits are not appropriately weighted. It is possible, for instance, to set standards for indoor air quality that are so stringent that they virtually rule out the possibility of natural gas usage in new, tightly constructed houses. Or, in some areas the standards for new fuel-burning equipment are so strict that they tend to encourage energy users to retain older, dirtier-burning equipment rather than upgrade to newer equipment that is cleaner and more economical.

The federal government, in recognition of increased potential national benefits, will promote rather than discourage increased natural gas consumption, and it will step up RD&D activities. Given the potential significant national benefits of the accelerated projection, it is assumed that the federal government will promote and support increased use of natural gas. This could include, for instance, tax incentives to extend gas service to areas not currently served. The projection also assumes increased federal funding of gas-related research and development — for system safety as well as for end-use equipment innovation.

The potential of new technologies will be fully recognized in regulations that govern the natural gas industry. As gas industry technologies and practices evolve over time, it is assumed that regulations governing the industry will evolve as well. Plastic pipe provides a good example. Today's plastic pipe can safely operate at higher pressures than older pipe can withstand. If safety regulations did not recognize this advance, the market would be dampened for some forms of gas-based distributed electricity generation systems that require high gas pressures.

In addition, the regulatory arena appears to be moving toward creating more flexible, less prescriptive regulations. It is assumed that this movement will prove to be effective in providing safe and reliable service and that it will continue.

Access to the natural gas resource base will not be unduly restricted. Today, access to significant portions of the gas resource base are totally or partially restricted. The restrictions ban exploration and production activities in the eastern Gulf of Mexico, most of the offshore West Coast, all of the offshore East Coast and portions of the Rocky Mountains. Most of the restrictions are environmental in nature and have been in place for several decades.

In light of the drilling and waste-disposal technologies now in use as well as advances in operating practices, it is assumed that these restrictions will be reevaluated and lifted over the next 20 years.

The costs of providing gas service to new electricity generating plants will not be borne by residential, commercial and industrial customers. Providing gas service to new electric power plants requires that gas pipelines and/or gas utilities invest in facilities and make operational changes, such as adding new line, contracting for storage capacity and upgrading the ability to serve severe load swings.

It is assumed that the costs incurred to serve new generating plants will be borne by power plant operators and not by other existing gas customers. If this is not the case, then gas demand among residential, commercial and industrial customers will be artificially constrained.

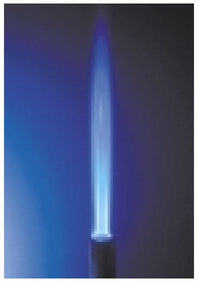
Keeping Cool — and Warm

In 1981 Congress created the Low-Income Home Energy Assistance Program (LIHEAP) to help low- and fixed-income households pay their fuel and utility bills. More than 4 million households, most with annual household incomes of less than $8,000, receive financial assistance under LIHEAP. Almost half of the recipients use natural gas for heating or cooling.

Since its heyday in 1985 when funding reached $2.1 billion, dollars allocated to LIHEAP have decreased by nearly 50 percent. Current funding can assist only 13 percent of the eligible households.

LIHEAP serves the most vulnerable groups in society — the elderly on fixed incomes, the disabled and households with small children. LIHEAP also helps many low-income working families stay off welfare and alleviates the tough budget choices they have to make every month: paying for utilities versus other necessities such as rent, food and medicine.

Glossary of Terms



Btu: A British thermal unit is the amount of energy required to raise the temperature of one gram of water 1°C. An average residential gas customer consumes about 100 million Btu per year.

CCHP: Combined cooling, heating and power systems consume a fuel, usually natural gas, and produce heat, cooling and electricity.

Cogeneration: An energy system that consumes a fuel, usually natural gas, to produce both heat and electricity. Cogeneration systems are very efficient because they capture and use energy that otherwise would be wasted.

Combined-cycle system: An energy system that consumes a fuel, usually natural gas, to produce electricity. Combined-cycle systems are very efficient because they capture and use heat that otherwise would be wasted.

Distributed generation: Electricity generation that occurs at or near the site of ultimate consumption as opposed to most electricity which is generated at a remote site and transported by long-distance transmission lines to the consumer.

Fuel cell: A piece of equipment that converts chemical energy into electricity and hot water through an electrochemical process rather than through combusting the fuel source.

Fossil fuel: A fuel source, primarily oil, coal and natural gas, that originates from decayed fossils.

Liquefied natural gas: Natural gas that is liquefied by reducing the temperature to -260°F, usually to allow for transportation by ship. Upon reaching its final destination, LNG can be re-gasified and injected into the pipeline system.

Methane hydrates: Methane, the primary component of natural gas, can be trapped in crystalline ice-like substances with water and small amounts of other gases. If this methane can be economically freed, it can be added to the natural gas supply base.

Microturbine: A very small turbine, fueled by natural gas or some other energy source, that generates electricity for use in homes or commercial establishments.

Natural gas resource base: The amount of gas that supply experts believe remains in the ground ready to be produced.

Quad: A unit of energy of 1 quadrillion British thermal units. Total U.S. energy consumption is roughly 90 quads per year.

Tcf: A trillion cubic feet of natural gas, equivalent in energy content to 1.03 quads.

Throughput: The amount of gas traveling through the natural gas delivery system.

Total energy efficiency: Refers to the energy that is used or lost in the processes of energy production, processing, conversion, transmission, distribution and use.

Wellhead: The point of gas production. Natural gas prices are often cited "at the wellhead" as opposed to the point of consumption which also includes the cost of transporting gas from the wellhead to the consumer.

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