This paper describes the Gas Research Institute's Baseline Projection for 1993 and two alternative scenarios, one in which energy demand is constrained by economic and policy factors and one built upon very optimistic assumptions about natural gas supplies and prices. All three scenarios focus upon the influence of technology: the requirements for new technology, the anticipated contribution of technological change, and its impact on gas demand and supply.

Cet article expose les projections de base pour 1993 de l'Institut pour la recherche sur le gaz ainsi que deux scénarios de rechange. Dans l'un de ces cas de figure, la demande d'énergie est limitée par des facteurs économiques et de politique tandis que l'autre se fonde sur des hypothèses optimistes au sujet des réserves de gaz naturel et des prix. Les trois scénarios mettent principalement l'accent sur l'influence de la technologie: les besoins en nouvelles technologies, la contribution projetée du changement technologique, et son impact sur la demande et l'approvisionnement en gaz naturel.

The Future of Natural Gas Markets and Two Extreme Views

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Introduction

The strategic planning and appraisal of Gas Research Institute (GRI) R&D programs and projects depend upon a consistent analytical framework that establishes a likely projection of future energy supply and demand and defines the probable role of the gas industry during the time frame in which the GRI R&D program is expected to have its impact. The framework that forms the scenario and data base for these planning decisions is called the baseline projection.

In many situations, the level of gas demand and supply which will be achieved in the future will be dependent on the direction and emphasis placed on gas technology development. This paper presents the 1993 Edition of the GRI Baseline Projection and two alternative scenarios. The alternative scenarios describe two extreme views of the energy future. In one scenario, despite energy prices that remain very low, energy demand is severely constrained by economic and policy factors. In the other, an optimistic assumption about gas supplies and prices is carried to an extreme degree. The main focus in all three scenarios is on the implications for technology: the requirements for new technology, the anticipated contribution of technology, and the impact of technology on demand and supply.

The initial part of the paper provides a summary of the results of the 1993 Edition of the GRI Baseline Projection. The discussion of the alternative scenarios follows this summary.

Primary Energy Consumption

Total primary energy consumption (Table 1) in the baseline projection is projected to increase at about 0.8% annually significantly less than the projected 2.1% per year growth in GDP over the long term. The projection of energy consumption includes a steady improvement in energy efficiency over time.

Petroleum: The trend in the world oil price outlook has been significantly reduced for the 1993 edition of the projection. The projected price for the year 2000 is $21 in 1992 dollars, which is about $28 in the nominal dollars seen in 2000. For 2010, the real price is $27. For comparison, in the 1992 edition of the projection, the 2010 price in real dollars was about $38 per barrel.

At these prices, US petroleum consumption is projected to increase at a rate which is slightly less than that of total primary energy demand. Petroleum consumption is projected to grow from roughly 33 quads in 1991 to over 37 quads by 2010. The increase in consumption is moderated by a strong improvement in efficiency. The entire increase in petroleum consumption occurs in the industrial, electric utility, and transportation sectors.

Coal: Coal consumption is projected increase from about 19 quads in 1991 to almost 22 quads by 2010, or by 15%. The projected slow growth reflects the impact of increasingly stringent environmental restrictions and load management programs by electric utilities designed to slow growth in electricity demand.

Gas: Gas consumption is projected to increase sharply from 1991 levels in the projection. Primary gas consumption is projected to grow at an average annual rate of 1.2%. This rate of growth is about 50% greater than the growth in overall primary energy consumption. Total primary gas demand is projected to grow from 19.9 quads in 1991 to 24.9 quads in the year 2010. Total delivered gas consumption (including gas synthetics and coal gas) is projected to grow from 20.0 quads in 1991 to 25.0 quads by 2010.

Table 1: US Primary Energy Consumption (Quads)

	Actual 1991	1995	2000	2010
Petroleum	32.9	33.2	35.2	37.4
Gas	19.9	21.2	22.2	24.9
	(20.0)	(21.3)	(22.3)	(25.0)
Coal	18.9	19.6	19.8	21.8
Nuclear	6.5	7.0	7.1	6.9
Hydro	3.1	3.0	3.0	3.0
Other	3.1	3.2	3.5	4.0
Total	84.3	87.2	90.9	98.0

Source: 1993 Edition of *GRI Baseline Projection*

Gas Demand by Application

Figure 1 displays the annual use of gas in 1991 disaggregated among the major energy service applications, rather than the usual end-use sectors. It also shows the projected increase in annual demand between 1991 and 2010.

Disaggregating gas demand by application relates it more closely to the competitive influences and the types of technologies involved. Electric power generation, including utilities, independent power producers (IPPs), and cogenerators represents the most significant potential for demand growth. The figure also reveals, however, that the more traditional applications, which are often neglected in current discussion, are and will remain the mainstay of the gas industry's total volume. Some traditional applications also represent higher value uses, because the competition is with more costly alternatives such as electricity and high grade distillate fuels. The space conditioning application is an important example.

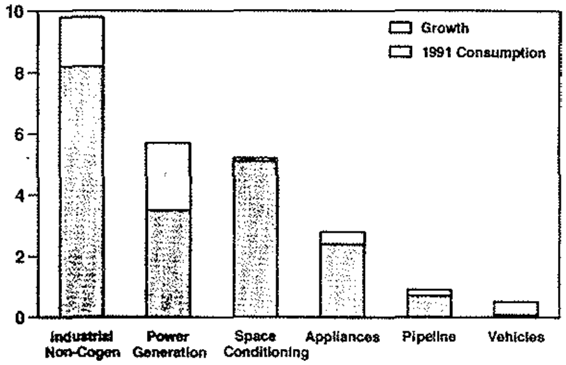

Figure 1: Gas Demand by Application in 2010 (Quads)

This application is often erroneously referred to as a captive market which it is not.

Viable alternatives to gas space conditioning are available to each customer. It is true that once an investment in heating or cooling equipment has been made by a residential or commercial customer, that customer is unlikely to replace the equipment prematurely because of moderate fuel price fluctuations. Nevertheless, thousands of new investments are being made each year based upon contemporary fuel prices and the available equipment options. Over a ten-year period, 40% of the total gas space conditioning load will be subject to new user choices. If the commodity price is noncompetitive, or certainly if the available gas equipment fails to meet policy standards and consumer preferences, this high value market share could rapidly erode. The same factors, of course, apply to the somewhat smaller gas appliance application.

Industrial applications for gas, exclusive of cogeneration, are a more complex and diversified set of uses. They are both historically important and provide potential for significant growth. Some of these uses have been very competitive, based almost entirely upon fuel price. Gas may gain a competitive advantage in some uses, such as boiler fuel, as coal and oil encounter greater costs and constraints arising from emission standards. In other process heating applications, however, even gas will increasingly be viewed as a problem because of costly requirements for emissions monitoring and severe fines for errors. Where electricity is a viable alternative, its competitive position will be improved.

The characteristics and capabilities of the available gas technologies will be the deciding factor as often as the fuel price in choices that will decide the future market shares for industrial applications.

Vehicle applications and the incremental growth in electric power generation are equally dependent upon technological advances. Gas turbines and methane vehicle technologies will have to be improved to keep pace with future emission standards. The operation of numerous large turbine power plants in conjunction with normal pipeline system services probably presents technical problems yet to be resolved. Similarly, vehicle engine, fuel storage, and refueling technologies need much more development. If the optimistic outlook for these new applications is to be realized over the long term, the advanced technologies must become available.

Natural Gas Supply and Prices

Supply

The outlook for domestic natural gas production (Table 2) is more optimistic in the 1993 edition of the projection, despite the lower price track. Domestic production accounts for a greater proportion of projected supply. Both Canadian and liquefied natural gas (LNG) imports will play a role, but pipeline imports from Alaska do not enter the supply slate before the year 2010. Mexico is expected to be a net importer of US gas (416) throughout the projection.

GRI is not unique in adopting an optimistic view of future gas supply. Many projections currently being published are far more optimistic than the GRI baseline projection. All of the analyses that predict adequate gas supplies for growing consumption at low prices rest upon an assumption of strong technology improvement, whether they explicitly state that assumption or not.

Table 2 : Gas Supply Trends in the 1993 Edition of the GRI Baseline Projection (Quads)

	Actual 1991	1995	2000	2010
Current Practice				
Domestic Production	18.4	18.6	17.7	16.4
Canadian Imports	1.7	2.4	2.1	2.5
LNG Imports	0.1	0.3	0.5	0.9
Supplemental Sources	0.2[a]	0.1	0.1	0.1
	20.5	21.4	20.4	19.9
New Technology				
Lower-48 Adv. Tech.	0.0	0.4	2.1	5.1
Pipeline Imports	0.0	0.0	0.2	0.4
	0.0	0.4	2.3	5.5
Total Supply	20.5	21.7	22.7	25.4

[a] Includes 0.1 quad of net gas injections into storage.

There are adequate justifications for such an assumption. There has been a trend of strong improvement in recent years. There also is an inventory of advanced practices and new technologies which have been proven in oil and gas applications in the field but which are not yet widely employed. They hold promise of much greater future contributions. Horizontal drilling techniques and slim hole technologies are prominent examples.

Table 2 illustrates the critical significance of the technology assumption. If technology were frozen at today's state, that is, if success ratios for finding gas did not improve, if drilling costs did not decrease, and if recovery from a given formation remained at the current level of capability, total gas supply would fall by about 5.5 quad by 2010. To serve the demand, the gas price track would have to be higher. Probably, the projection would balance at a higher gas price and reduced market share.

GRI believes the assumptions of technological progress that are included in this projection are reasonably attainable, but not guaranteed without continued gas industry investment.

Gas Prices

For several years, GRI has been revising the price outlook downward. Figure 2 compares the gas acquisition price tracks from 1988 and 1993 baseline projections. The points on the graph show actual base-year prices.

The first and most obvious reason for revising the outlook is that the expected price for 1991 from the '88 projection has not materialized. This historical correction is embedded in the base year for the new projection. If nothing else were revised, this correction alone results in about a third of the price reduction in the year 2010.

The second stage to be considered is the near-term outlook. Long-range models do not deal adequately with the transitory and cyclical factors that dictate fluctuations in gas prices from month to month and year to year, such as recessions, weather patterns, deliverability surpluses, and the psychology of the marketplace. These factors do not always average out over a short period of time. The probable path of prices for the next few years, although it will be influenced by the underlying long-term trend, will also be affected by such near-term factors.

In the 1988 baseline projection, a rapid increase in gas demand was expected to occur in the immediate future. The then current price, based upon historical experience, was judged to be below the replacement cost of the new supplies that would be needed. A rapid increase in producer investment was expected to result in a price increase of about one dollar within the '87 to '91 period, most of it in a rapid step as supply tightened.

Today, despite the recent surge in gas prices, a similar judgment about the near-term outlook would be difficult to support. There is no gas market that seems likely to provide a rapid increase in demand in the next few years, deliverability seems adequate to support consumption at gradual rates of increase for some time with moderate producer activity, and estimates of the cost of adding the next increments of production to the supply slate have been greatly reduced. The recent surge in

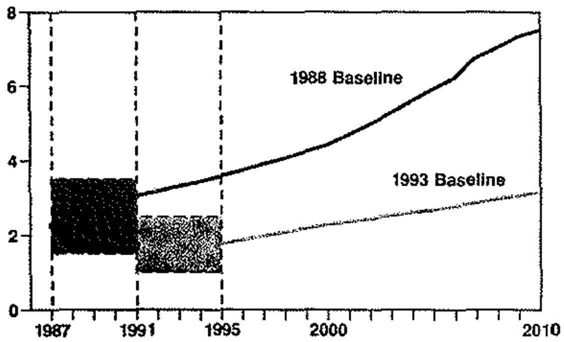

Figure 2: Comparison of Gas Acquisition Price Trends (1992$/MMBtu)

price reflects a near-term correction from extremely depressed price levels which did not accurately reflect demand/supply fundamentals. The likelihood of continued increases of the magnitude seen in recent months is minimal. In fact, in the near term a downward correction after the winter months probably has a higher probability.

Finally, the long-term outlook has also been revised. Here the factors are more fundamental and analytical in nature. Until the year 2000, the projected rate of increase in the acquisition cost is not significantly different from the earlier projection; but after that time, the rapid escalation shown in the earlier projection has been greatly moderated. The reduced costs of drilling and the increases in success ratios in both finding and recovering gas resources that have been demonstrated in recent years have been introduced into the analysis. Further improvements stemming from new technologies and improved practices are anticipated in the future. Estimates of the gas resource base in the lower-48 states have also been revised upward. The combined impacts of these changes reduce the rate of investment necessary to provide the required supply, and defer the introduction of high cost supplies, such as Alaskan gas.

In the 1993 projection, the average acquisition price for 2000 is $2.29 per million Btu in 1992 dollars. That converts to $3.08 per million Btu in 2000 dollars, the actual cash price that would be paid in 2000. By 2010, the price is projected to reach $3.16 per million Btu in 1992 dollars. For comparison, the projected price in the 1988 baseline for 2000 is $4.41 and for 2010 it is $7.51 per million Btu, both in 1992 dollars.

Alternative Scenarios

The previously published 1992 Edition of the GRI Baseline Projection emphasized that the prices of energy commodities will probably remain relatively low. Nevertheless, the demand for energy of all kinds will be constrained by public policy initiatives that mandate efficiencies of energy use and discourage growth in energy intensive activities. This is a paradoxical scenario. In projections driven by economics, it is expected that reduced energy prices will result in expanded economic activity, will encourage greater demand for energy services, and will reduce the incentive for investments in energy efficiency.

In a sense, the policies that place costly environmental management burdens on energy uses or that mandate efficiency standards greater than those which would be chosen in the marketplace represent a shadow price. They make the consumption of energy appear more expensive to the consumer than the commodity prices themselves would indicate.

In the 1993 Edition of the GRI Baseline Projection, low prices and constrained consumption are emphasized more than they were last year. There is a widely held point of view, however, that even more extreme conservation and lower prices are likely.

As part of producing the 1993 baseline projection, two extreme scenarios have been analyzed to evaluate these critical uncertainties. In one of the scenarios, more aggressive constraints are imposed upon energy demand, both through conservation and through low economic growth. In the other scenario, the outlook for low gas acquisition costs is carried to a greater extreme.

Constrained Energy Demand Scenario

The extreme scenario of a constrained energy demand future that was chosen incorporated more aggressive energy efficiency trends than the baseline projection, lower economic growth, and a lower oil price outlook. The average rate of GDP growth over the term of the projection was, for example, only 1.6% per year. The results of this scenario are compared with the baseline projection in Figure 3.

Of course, other high efficiency scenarios could have been examined. Some have suggested that a more energy efficient economy will be more productive and competitive and will, therefore, support strong economic activity. Others contend that policies which constrain energy use or compel conservation investments that would not be made in an unconstrained market will tend to stifle economic growth. The choice of this scenario is not intended to comment upon that issue.

Low world oil prices might stimulate strong global economic growth, but a worldwide policy initiative to limit energy use would be likely to constrain oil price increases. The past few years have seen major policy initiatives which constrain energy use along with a prolonged period of low economic performance. Recent experience has also confirmed that stagnant economic growth and soft oil prices are a possible combination. This scenario is simply one of several rational futures in which energy demand is constrained to an extreme degree.

The analysis resulted in no increase in total energy demand throughout the projection. Natural gas consumption grew only slightly. In general, gas demand growth in the commercial and industrial sectors was offset by forced efficiency gains in residential uses and by restricted market opportunity and reduced competitive advantage in electric power generation.

These results should not be surprising. The technical capability to increase the efficiency of energy use is even greater than the economically rational assumptions used in this scenario. In a world of constant real price, oil will continue to be the fuel of choice in existing oil capable equipment unless it is explicitly excluded by policy. Energy efficiency standards certainly must be expected to have the ultimate

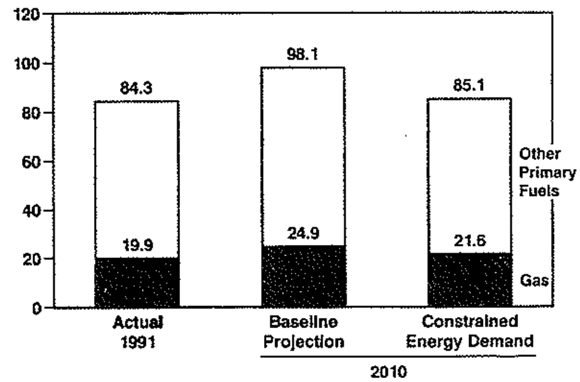

Figure 3: Primary Energy Demand (Quads)

effect of reducing the demand for gas as well as for the alternatives in many end-use applications.

The impact of the constraints on energy demand are particularly well displayed by the consumption of fuel for the generation of electricity as shown in Figure 4. Although the prospect in most conventional projections is for continued strong growth in the demand for electricity, the focus of most demand side management programs now being initiated is on reducing electricity consumption. There are substantial opportunities to increase the efficiency of electric services. Because of the high capital cost of new generating capacity, there also are financial incentives for both utilities and consumers to make investments in conservation.

There is little doubt that very large investments are going to be made in initiatives to reduce electricity demand. It is less certain that these investments will have the impact that is expected of them, as there is no historical experience to verify the expectations. The outlook for electric power demand growth is a critical area of uncertainty in all efforts to forecast the energy future. This scenario clearly emphasizes the critical significance of that uncertainty to the gas industry.

The initial impact of the constrained energy scenario is to hold annual growth in electric power consumption to about 0.5%. In that situation, new generating capacity will only be required to replace retirements, to upgrade

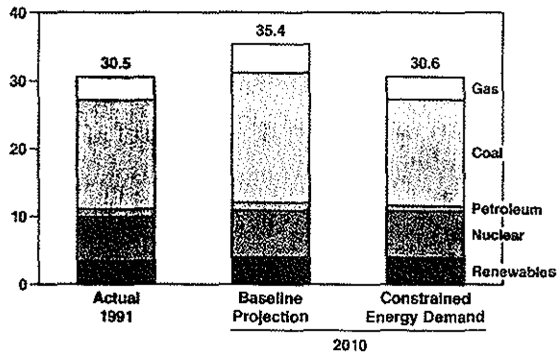

Figure 4: Energy Consumption for Electricity Generation (Quads)

existing facilities, to conform to changes in peak load or regional consumption patterns, or to comply with policy directives.

As the figure indicates, nuclear, hydroelectric, and renewable generation would operate much as they do in the Baseline Projection. Future petroleum use would be reduced, but in a low oil price situation there would be little incentive to convert existing oil-fired capacity to natural gas. Existing coal-fired capacity and that already on order would probably operate about as expected. The use of natural gas would be largely limited to existing facilities and new peaking capacity.

This scenario, of course, does not contemplate new policy initiatives that would require coalor oil-fired power plants to be converted to gas. It assumes that compliance with any new environmental requirements will be possible for the existing facilities.

Optimistic Gas Supply Scenario

Although the gas acquisition cost track in the 1993 Edition of the GRI baseline projection is significantly below that of earlier projections, there are people who maintain that those prices are still unreasonably high. The optimistic gas supply scenario was intended to explore the implications of very low future gas prices.

The baseline gas price projection is developed analytically by estimating the cost, including an appropriate rate of return on producer investment, of finding and producing the gas required in a balanced supply and demand scenario. There are a number of factors that might affect the cost track for a given supply requirement. They are judgments about the physical nature of the undiscovered resource base, the success ratio in exploration and development, and the future cost of carrying out the necessary activity. Each of these judgments includes numerous detailed assumptions, and each is subject to a range of optimism about the future.

For the optimistic gas supply scenario, a very low track for future gas acquisition costs was specified. The acquisition cost in the scenario reaches only $2.28 in the year 2010 in real terms ($4.78 in nominal dollars), as compared to $3.16 in the baseline projection.

Using the demand side model, a supply requirement was developed for gas at that price as shown in Figure 5. Compared to the baseline projection, the reduced gas prices result in an increase in gas demand of about 0.7 quad in the year 2000 and 2.2 quads in 2010. The increase is small in the near term because growth in gas demand is largely dependent upon the addition of new gas-using equipment to the stock.

The pace of addition of new energy service equipment is insensitive to the price of gas. It is dependent upon such factors as electricity demand growth, industrial production, housing starts, and commercial building occupancy. Reduced gas prices, therefore, are only reflected in greater market share as choices for new equipment are made over time. These choices, in turn, are heavily influenced by the economics and characteristics of the available equipment, not only by the relative fuel prices.

Using the GRI Hydrocarbon Model, the possibility of providing the supply for this scenario at the lower prices was explored. Of course, the higher demand could not be accommodated by the model using the baseline projection assumptions for the pace of technological progress. With those assumptions, this price track would result in a supply constrained future. More gas would be demanded than the price would bring forth. Prices would have to rise until a supply demand balance was

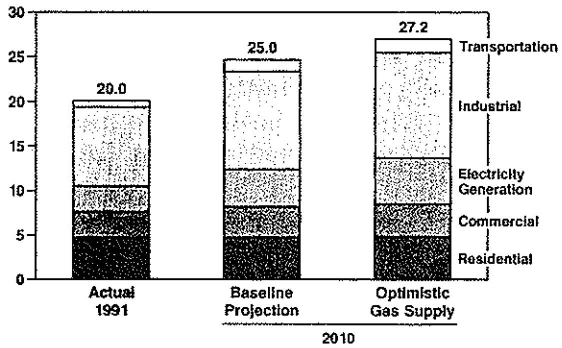

Figure 5: Gas Demand by Sector (Quads)

achieved.

To develop a balanced scenario around the specified price track, greater optimism about the future of gas production is needed. As a first adjustment, the expectations for improved success ratios and cost reductions that are reflected in the model were carried to the greatest degree of optimism that seemed rational. As one example, it is assumed that drilling services can be profitable with drilling costs reduced by 25% in real terms over the term of the projection.

As shown in Figure 6, even these advances in technology and practices failed to provide adequate supply to balance the scenario shown on this slide. The scenario can only be balanced by also adding a greater degree of optimism concerning the undiscovered resource base.

The conclusion to be drawn is that scenarios of very low gas prices coupled with large growth in consumption are difficult to support. In all probability, such a future is only possible if the current estimates of the undiscovered natural gas resource base prove to be much too conservative and the future improvement in the industry's ability to find and develop new supplies outstrips the strong rate of improvement that has been demonstrated in recent years.

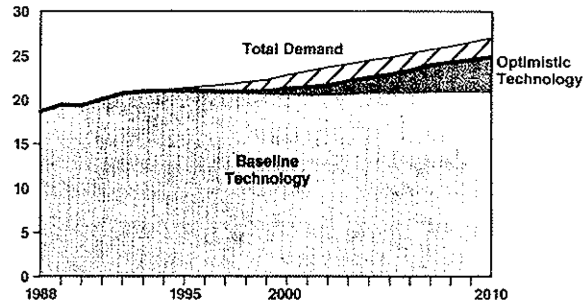

Figure 6: Optimistic Gas Supply Scenario: Technology Assumptions (Quads)

Conclusions

The extreme scenarios add emphasis to conclusions that are evident in the baseline projection itself. These conclusions are of strategic importance to the gas industry as well as to GRI.

Demand

The first conclusion is that at moderate prices, and especially in a high efficiency outlook, demand is likely to be the constraint on the expanded role that natural gas can play in the energy mix. This conclusion is not counterintuitive. Gas prices have been low for several years and existing market opportunities are probably pretty much saturated.

Any significant increase in the use of gas will have to be associated with investment in new gas-using equipment--turbines, vehicles, appliances, space conditioning devices, or industrial facilities. The only important exception might be substitution of gas, at discount prices, for coal in existing power plants.

New demand, therefore, depends first upon growth in the need for energy services through household formation, increased industrial production, and similar socio-economic factors. Then it depends upon the choice of gas-using equipment to serve those needs.

Unless the available gas-using equipment measures up to consumer preferences, meets policy standards, and can compare favorably with the alternatives, growth in gas demand will be confined to low value uses where the customer is indifferent to anything but fuel price.

Today's equipment simply will not meet tomorrow's requirements. Gas turbines will face increasingly stringent limitations on NO_x and other emissions. Gas appliances will have to keep pace with efficiency standards. Equipment controls will have to be compatible with computerized communications systems, and methane vehicles will have to become as convenient as conventional options. Continuing technological progress will be necessary to support gas demand growth, no matter how optimistic the other assumptions of the future might be.

Supply

The second conclusion concerns gas supply. The baseline projection supports the view that healthy demand growth can be accommodated at moderate gas prices. Gas resources are physically adequate to support much greater rates of growth.

The baseline projection, however, shares an assumption with all of the contemporary views of gas supply that the rapid pace of technological improvement of the past few years will continue. If technology in exploration and development were frozen at today's level of achievement, the baseline projection price track would not support the demand growth. The scenario would become a supply constrained scenario at a lower level of gas consumption.

Some further technological achievement is, of course, nearly certain to occur. The pace of improvement in drilling cost reduction, recoverability, and success ratios expected in the baseline projection, however, exceeds this "inertia" already built into the system. Maintaining that pace will require continued efforts in R&D and technology transfer. Some contemporary projections assume an even greater pace of technological progress than the GRI baseline projection does. As the low price scenario graphically illustrates, if prices are extremely low or if gas demand exceeds the baseline projection, a more aggressive pace of technological improvement will be necessary to provide the supply.

The baseline projection expects technological progress to keep pace with the need; but, beyond the near term, this expectation is not a certainty. With major companies cutting corporate R&D programs, with the frontier emphasis increasingly focused on the technological problems of oil in areas outside of the US, and in a period of cost cutting and expediency throughout the industry, the assumption of strong technological progress over the next twenty years may be questionable.

The final conclusion is that nobody but the gas industry itself has the incentive and the capability to underwrite the technological progress that will be required. Only gas industry support for R&D and deployment of new technologies will make the optimistic assumptions realities.