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Accelerated Depletion: Assessing Its Impacts on Domestic Oil and Natural Gas Prices and Production

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Preface

The analysis in this report was undertaken at the request of the Office of Fossil Energy, U.S. Department of Energy (DOE). In the request, the Principal Deputy Assistant Secretary asked the Energy Information Administration (EIA) to analyze the potential impacts of accelerated depletion on domestic oil and natural gas prices and production, as noted in the first letter in Appendix A. A case depicting accelerated depletion of domestic oil and natural gas supply was also requested, as well as several sensitivity cases evaluating key variables that could counteract the effects of accelerated depletion: world oil prices, advances in technology, and increased access to Federal lands. A second letter outlining the detailed assumptions followed the first.

The energy projections presented here are from the National Energy Modeling System (NEMS), an energy-economy model of U.S. energy markets designed, developed, and maintained by EIA. NEMS is used each year to provide the projections in the *Annual Energy Outlook* (*AEO*). The same general methodologies and assumptions underlying the *Annual Energy Outlook 2000*, published in December 1999, were used in this analysis. Some minor modifications were made to reflect recent changes in fuel prices, environmental constraints that limit access to resources, and changes in assumptions related to the technology of unconventional gas recovery. The modifications are outlined in Appendix E.

Chapter 1 of this report provides background discussion of what is meant by accelerated depletion and how it is measured, as well as the framework and methodology of the analysis. The results are summarized in Chapter 2. Appendix A contains the letters requesting the analysis. Appendix B provides detailed results from the accelerated depletion cases. Appendix C compares the results of this analysis and the National Petroleum Council (NPC) study, *Natural Gas: Meeting the Challenges of the Nation's Growing Natural Gas Demand*, released in December 1999. Appendixes D, E, and F give more detailed information on key model equations and assumptions. Appendix G relates the cases developed in this analysis in response to reported increases in the rate at which production from wells in the Gulf of Mexico is declining.

The legislation that established the EIA in 1977 vested the organization with an element of statutory independence. EIA does not take positions on policy questions. It is the responsibility of EIA to provide timely, high-quality information and to perform objective, credible analyses in support of deliberations by both public and private decisionmakers. Accordingly, this report does not purport to represent the official positions of the U.S. Department of Energy or the Administration.

Contents

Appendixes

Tables

Tables (Continued)

Figures

Executive Summary

This study was undertaken by the Energy Information Administration (EIA) at the request of the Principal Deputy Assistant Secretary for Fossil Energy of the Department of Energy. The request followed a letter to Secretary of Energy Bill Richardson from six trade organizations for oil and gas producers: the American Petroleum Institute, Domestic Petroleum Council, Independent Petroleum Association of America, U.S. Oil and Gas Association, National Ocean Industries Association, and Natural Gas Supply Association.

In their letter, the six organizations raised concerns about the effects of depletion on future oil and natural gas supply. Recent interest in the effects of depletion follows reports which suggest that future production may be more difficult than previously thought. Several reports have highlighted the sharp change in the decline rate for wells on the continental shelf in the Gulf of Mexico. While natural gas wells drilled in 1972 declined from their peak at an average rate of 17 percent per year, natural gas wells drilled in 1996 have been declining at an annual rate of 49 percent. At the same time, the ratio of natural gas production to the level of proved reserves—resources that have been identified and are ready to be developed—have increased from 15.7 percent in 1991-1992 to 18.0 percent in 1997-1998. In addition to the effects of depletion, exploratory drilling for oil and gas was also extremely low in 1999 as a result of unusually low prices. In 1999 the average number of rigs drilling for oil and natural gas was only 625, the lowest level in decades. Although the short-term effect of lower drilling activity already is being reversed as a result of higher prices for oil and gas in 2000, accurate future projections must account for the long-term effects of depletion on oil and gas production.

The projections of future oil and gas prices and production presented in EIA's *Annual Energy Outlook 2000* (*AEO2000*) are produced by the National Energy Modeling System (NEMS), which is designed to capture the expected impact of depletion on future production and prices, based on historical trends. Although the *AEO2000* projections incorporated the effects of depletion, this study develops a series of alternate scenarios that project more pronounced effects from depletion than suggested by the long-term historical trend. The scenarios described below show that changing the projected effects of depletion causes changes in projected U.S. oil and natural gas prices and production, as expected.

Background

Depletion is a natural phenomenon that accompanies the development of all nonrenewable resources. Taken most broadly, depletion is a progressive reduction of the overall stock (or volume in the instance of oil and natural gas) of a resource over time as the resource is produced. In the oil and gas industry, depletion may also more narrowly refer to the decline of production associated with a particular well, reservoir, or field. As existing wells, reservoirs, and fields are depleted, new portions of the resource base must be tapped to replace those that can no longer be produced at economical levels.

Oil and natural gas fields vary in both size and ease of development. In general, the first fields developed from the resource base in a given geographic area are relatively large and accessible. Subsequent fields in the same area are on average smaller, may be more costly to develop, and may not allow the same level of production as the fields they are replacing. Thus, as time progresses, more effort is required to produce the same amount of oil and gas from the same exploration area. Historically, this trend has been counterbalanced by a trend of increasing initial production from oil and gas wells, made possible by advances in drilling technology. On the other hand, higher initial production rates have also been accompanied by more rapid declines in the later stages of production. As a result, more exploration and development activity is needed to maintain production levels. If drilling does not increase, production will inexorably fall; but if drilling increases sufficiently, production can actually increase despite the finding of smaller and potentially less productive fields.

In addition to technology advances, the periodic opening of entire new areas to exploration and development has balanced the effects of resource depletion in the past. While a myriad of technological improvements have allowed oil and gas resources to be discovered more efficiently and developed less expensively and have extended the economic life of existing fields, declines in the available resources in traditional oil and gas producing areas have led to development of oil and gas resources in such "frontier" areas as Alaska and the deep waters of the Gulf of Mexico.

Methodology

In NEMS, the effects of resource depletion, technology advances, and access to new resources on oil and gas production are modeled in the Oil and Gas Supply Module (OGSM).[1] For this analysis, NEMS was used to generate a series of projections based on different assumptions about the effects of depletion on future production and prices. Sensitivity cases were developed to evaluate the effects on changes resulting from accelerated depletion of U.S. oil and gas resources that might result from higher imports of natural gas, higher or lower world oil prices, different rates of improvement in technology, and increased access to unconventional natural gas resources in the Rocky Mountains. A total of 12 cases were examined. The assumptions used to define the Reference Case, the Accelerated Depletion Case, and all but one of the sensitivity cases were provided by the Office of Fossil Energy, in consultation with representatives of the six trade groups requesting the study. Appendix A includes a description of the cases provided by industry representatives and the Office of Fossil Energy.

- **Reference Case.** The Reference Case, depicting business as usual, is similar to the Reference Case for the *Annual Energy Outlook 2000* (*AEO2000*), with some minor changes in the assumed conventional natural gas resource base in the Rocky Mountain region and the technology assumptions for unconventional gas production. The world oil price and natural gas wellhead prices in 1999 and 2000 were also revised to be consistent with short-term projections from EIA's April 2000 *Short-Term Energy Outlook*[2] (see Appendix E for more detail).

- **Accelerated Depletion.** The Accelerated Depletion Case, reflecting the issues raised by the six trade groups, shows a faster decline in production than the Reference Case. Future oil and gas discoveries are assumed to be one-third smaller and new fields are projected to produce more rapidly than in the Reference Case. Assumptions about the rate of technological change and accessible oil and gas resources are the same as in the Reference Case. The Accelerated Depletion Case is a hypothetical case designed to highlight the potential impacts of lower reserve additions and faster depletion rates on natural gas and oil prices, production, imports, and consumption.

- **Accelerated Depletion with High and Low World Oil Prices**. These two cases show how domestic production and prices with accelerated depletion are affected by different world oil price paths. The high and low oil price cases are the same as those used in *AEO2000*. The High World Oil Price Case assumes that the world oil price rises to $28.04 per barrel in 2020, compared with $22.90 in the Reference Case and $14.90 in the Low World Oil Price Case (all prices in 1998 dollars).

- **Accelerated Depletion with Rapid and Slow Technology Growth.** These two cases show the interaction of accelerated depletion with changes in the expected rate of technological development. The rate of technological improvement is captured by changes in future costs, drilling accuracy, and the amount of oil and gas added to proved reserves with each well drilled. For conventional oil and natural gas, NEMS uses a composite rate of technology growth and does not project the introduction of specific technologies. The rate of technological growth used in the Reference Case is based on past trends. In the Rapid Technology Growth Case, technology advances are assumed to increase the rates of improvement in costs, accuracy, and reserve additions per well by 50 percent over those in the Reference Case; in the Slow Technology Growth Case, the improvement rates are assumed to be 50 percent slower.[3] While the fields found in the Accelerated Depletion Cases are smaller than those found in the Reference Case, changing the technology influences how quickly and thoroughly these fields are developed. Rapid technology growth causes the projected volume of reserve additions per well to be higher than the Accelerated Depletion Case over time and closer to the path set in the Reference Case; in other words, faster technology growth can partially offset depletion effects. Slower than expected technology growth causes projected volumes of reserve additions to be lower than the Accelerated Depletion Case, or make depletion effects worse. All other parameter values are the same as in the Reference Case, including the technology parameters for other modules, parameters affecting foreign oil supply, and assumptions about imports and exports of liquefied natural gas and natural gas trade with Canada and Mexico. The path of the world oil price is the same as in the Reference Case.

[1]NEMS is an integrated model that balances supply and demand for each fuel and consuming sector on an annual basis. A synopsis of NEMS, the model components, and the interrelationships between the components is available in Energy Information Administration, *The National Energy Modeling System: An Overview*, DOE/EIA-0581(2000) (Washington, DC, March 2000).

[2]Energy Information Administration, *Short-Term Energy Outlook*, DOE/EIA-0202(00/2Q) (Washington, DC, April 2000), www.eia.doe.gov/pub/forecasting/steo/oldsteos/apr00.pdf.

[3]Although the Rapid and Slow Technology Growth Cases are designed to highlight the uncertainty associated with the effects of technological development, they do not provide a formal confidence interval. In *AEO2000*, the rates of technological growth for the technological sensitivity cases were adjusted by 33 percent, rather than the 50 percent used for this analysis in order to acknowledge the broad range of uncertainty around future technological change.

- **Accelerated Depletion with Improved and Reduced Productivity Technology.** Changes in reserve additions per well have a greater effect on prices and production than do changes resulting from other types of technological change. In these two cases, the effect of technology improvement is captured only for changes in reserve additions per well drilled, without changing assumptions about future costs or drilling accuracy. Therefore, the projections from the Improved and Reduced Productivity Technology Cases vary less from the Reference Case projections than do those from the Rapid and Slow Technology Cases. Nevertheless, the Improved and Reduced Productivity Technology Cases capture most of the effects of the broader cases, in which all technology rates are adjusted. In the Improved and Reduced Productivity Technology Cases, the rate of growth in the amount of oil and natural gas added to proved reserves per well is adjusted by plus or minus 50 percent. Other rates of technological change are the same as in the Reference Case. The path of the world oil price is also the same as in the Reference Case.

- **Accelerated Depletion with High Rocky Mountain Access.** This case illustrates the effects of increasing the amount of natural gas available for development in the Rocky Mountain States by assuming the elimination of environmental and other constraints on production in the region. The question of access is limited to the Rocky Mountain region, where resources are sizable. In the Reference Case, 97 trillion cubic feet out of a total of 251 trillion cubic feet of unconventional gas resources is assumed not to be accessible to development before 2020. In the High Rocky Mountain Access Case, the inaccessible portion is assumed to be only 18 trillion cubic feet. The world oil price path is the same as in the reference case.

- **Accelerated Depletion with High Rocky Mountain Access and Improved Productivity Technology.** This case combines the assumptions of the two previous cases to show how increased Rocky Mountain access and improved productivity technology could ameliorate the effects of accelerated depletion.

- **Accelerated Depletion with High Rocky Mountain Access and Rapid Technology Growth.** This case combines the assumptions of the Rapid Technology Growth and High Rocky Mountain Access Cases to show how increased access and faster technology growth could offset some of the effects of declining production due to accelerated depletion.

In addition to the 11 cases provided by the Office of Fossil Energy, one other case was developed to address the uncertainty regarding the potential for additional imports of natural gas, primarily from Canada and Mexico:

- **Accelerated Depletion with High Natural Gas Imports.** This case combines the assumptions of the Accelerated Depletion Case with an assumed increase in the volume of natural gas imported from other countries. In the Accelerated Depletion Case, despite higher price projections, pipeline imports of natural gas from Canada are limited by constraints on pipeline capacity, and imports of liquefied natural gas (LNG) are limited by constraints on gasification plant capacity. In this case, more natural gas imports and a more rapid increase in imports are allowed in response to the higher domestic prices that result from accelerated depletion than are allowed in the Reference and Accelerated Depletion Cases. Other assumptions about world oil prices, technology growth, and access to Rocky Mountain resources are the same as in the Reference Case.

Summary of Results

Accelerated Depletion Leads to Higher Prices and Lower Production than in the Reference Case, with the Greatest Differences in the Later Years of the Projections

The Accelerated Depletion Case assumes that each new well developed in the future will add less to U.S. oil and gas reserves than assumed in the Reference Case. As the projections progress, adding oil and gas reserves becomes increasingly more difficult in the Accelerated Depletion Case than in the Reference Case, and the oil and gas reserves available for production are increasingly lower than in the Reference Case. Newly added reserves in the Accelerated Depletion Case are assumed to be produced more intensively than in the Reference Case (that is, the ratio of production to reserves for new additions is higher), but the cumulative effect of smaller reserve additions is a lower overall level of production for both oil and natural gas (Table ES1 and Figures ES1 and ES2). By 2020, natural gas production in the lower 48 States is projected to be 22.5 trillion cubic feet, 13 percent lower than the 26 trillion cubic feet per year projected in the Reference Case. Lower 48 crude production in 2020 is projected to be 4.7 million barrels per day, compared with 5.0 million barrels per day in the reference case. The difference in projected production levels between the two cases is more pronounced for natural gas than for oil because of the difference in the two fuel markets.

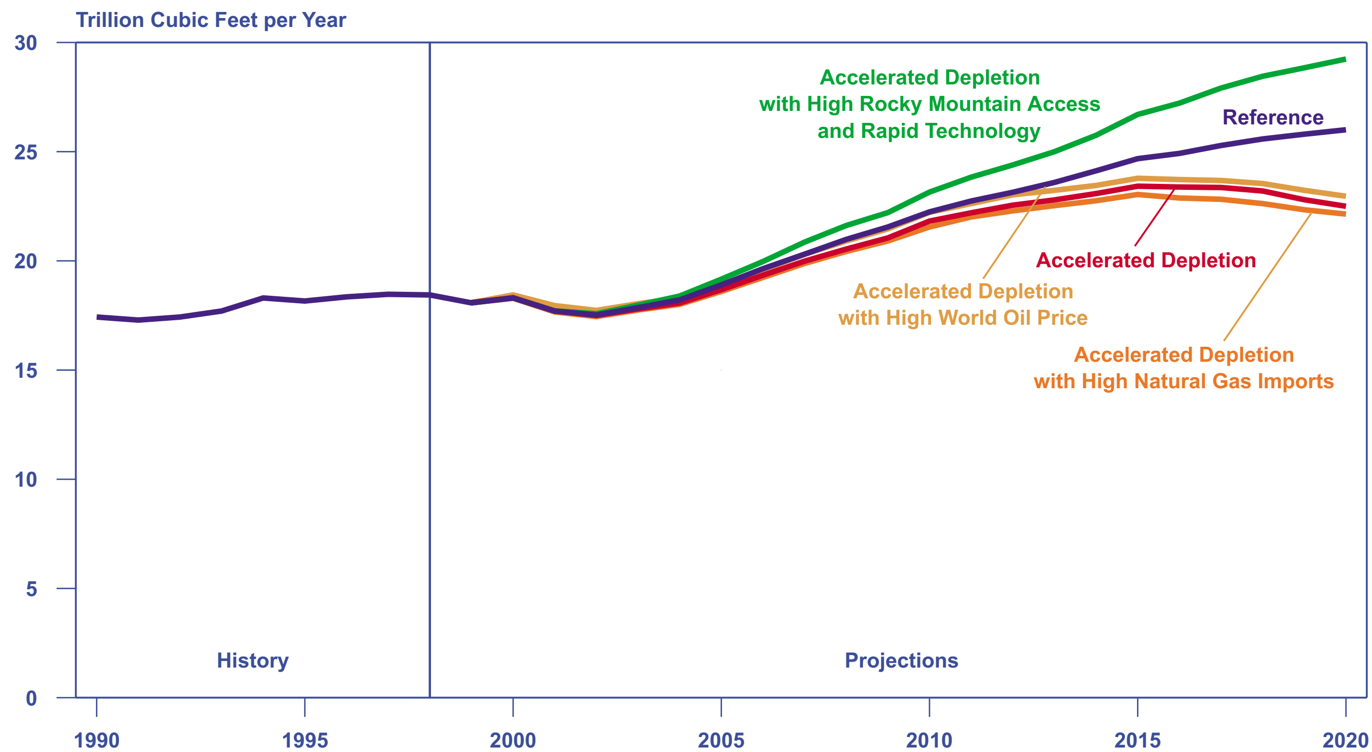
In the U.S. natural gas market, prices are determined largely by the domestic supply and demand balance. Unlike oil, there is not a corresponding world price for natural gas, because of the differences in infrastructures which connect producers to consumers. Tighter supply

Table ES1. Projected Lower 48 Crude Oil and Natural Gas Production in Twelve Cases, 2005-2020

Analysis Case	2005	2010	2015	2020
Lower 48 Natural Gas Production (Trillion Cubic Feet per Year)				
Reference	18.9	22.2	24.7	26.0
Accelerated Depletion	18.7	21.8	23.4	22.5
Accelerated Depletion with High Natural Gas Imports	18.6	21.6	23.0	22.1
Accelerated Depletion with High World Oil Price	18.9	22.2	23.8	23.0
Accelerated Depletion with Low World Oil Price	18.6	21.7	22.9	21.9
Accelerated Depletion with Rapid Technology	19.2	23.2	26.3	28.4
Accelerated Depletion with Slow Technology	18.4	21.0	21.9	20.3
Accelerated Depletion with Improved Productivity Technology	19.0	22.8	25.2	25.8
Accelerated Depletion with Reduced Productivity Technology	18.6	21.6	22.8	21.9
Accelerated Depletion with High Rocky Mountain Access	18.7	22.0	23.8	23.2
Accelerated Depletion with High Rocky Mountain Access and Improved Productivity Technology	19.0	22.9	25.5	26.4
Accelerated Depletion with High Rocky Mountain Access and Rapid Technology	19.2	23.2	26.7	29.2
Lower 48 Crude Oil Production (Million Barrels per Day)				
Reference	4.3	4.5	4.8	5.0
Accelerated Depletion	4.3	4.2	4.5	4.7
Accelerated Depletion with High Natural Gas Imports	4.3	4.2	4.5	4.7
Accelerated Depletion with High World Oil Price	4.5	4.5	4.9	5.3
Accelerated Depletion with Low World Oil Price	4.0	3.9	3.9	4.1
Accelerated Depletion with Rapid Technology	4.4	4.6	5.0	5.3
Accelerated Depletion with Slow Technology	4.1	4.0	4.0	4.0
Accelerated Depletion with Improved Productivity Technology	4.4	4.6	5.0	5.3
Accelerated Depletion with Reduced Productivity Technology	4.1	4.0	4.0	4.1
Accelerated Depletion with High Rocky Mountain Access	4.3	4.2	4.5	4.7
Accelerated Depletion with High Rocky Mountain Access and Improved Productivity Technology	4.4	4.6	5.0	5.3
Accelerated Depletion with High Rocky Mountain Access and Rapid Technology	4.4	4.6	5.0	5.3

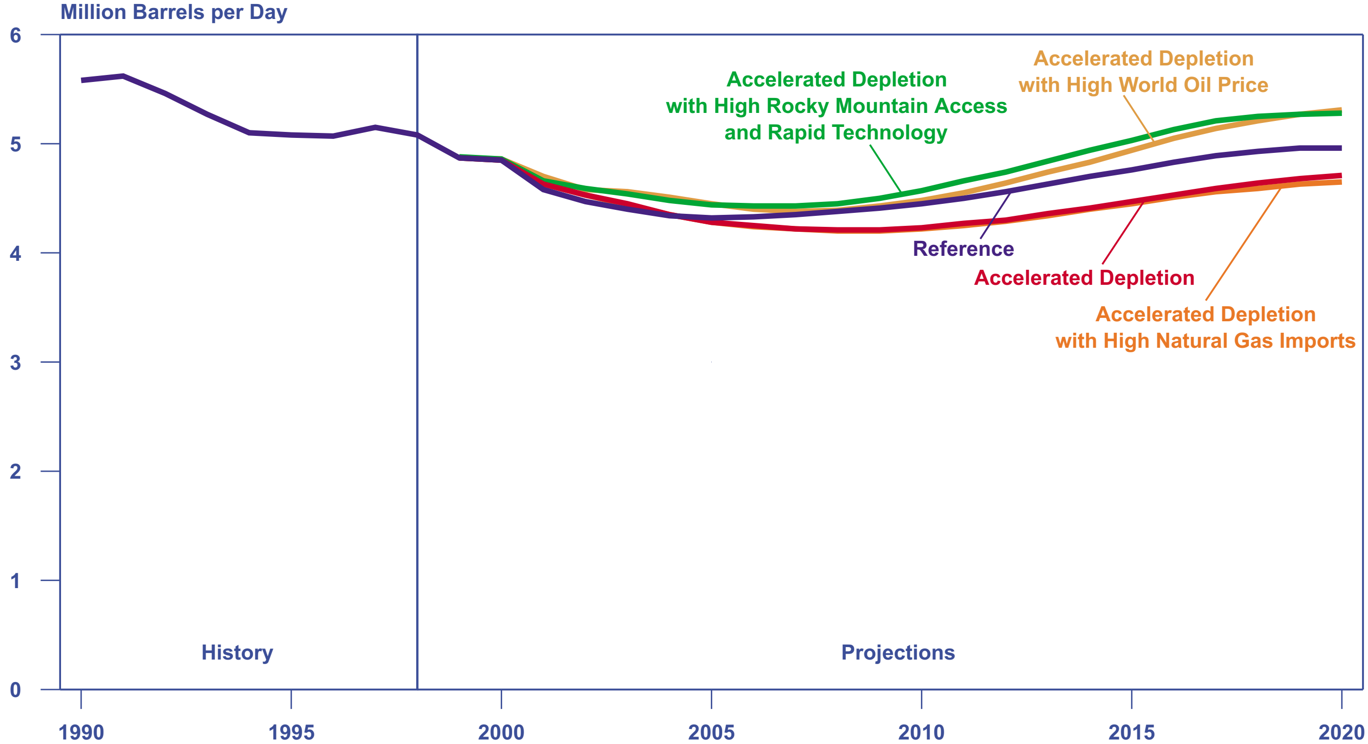
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE. D051200A, OGDEPL.D051200A, DEPL2.D071700A, OGHWOP.D051200A, OGLWOP.D051200A, OGRTECH.D051200A, OGSLOW.D051200A, OGFRHTEC.D051200A, OGFRLTEC.D051200A, OGACCESS.D051200A, OGACCFR.D051200A, and OGRAPID.D051200A.

Figure ES1. Lower 48 Natural Gas Production in Five Cases, 1990-2020



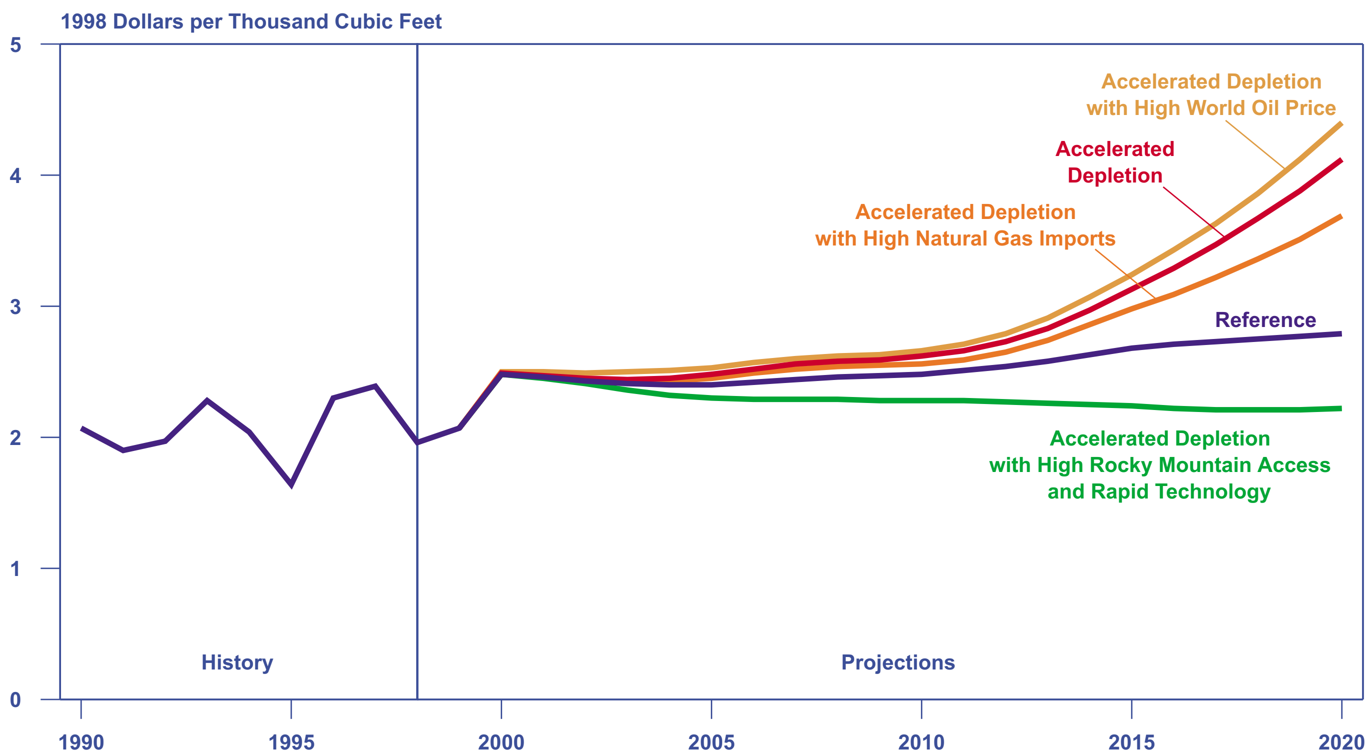
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE. D051200A, OGDEPL.D051200A, DEPL2.D071700A, OGHWOP.D051200A, and OGRAPID.D051200A.

Figure ES2. Lower 48 Crude Oil Production in Five Cases, 1990-2020



Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE. D051200A, OGDEPL.D051200A, DEPL2.D071700A, OGHWOP.D051200A, and OGRAPID.D051200A.

Figure ES3. Lower 48 Natural Gas Wellhead Prices in Five Cases, 1990-2020



Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE. D051200A, OGDEPL.D051200A, DEPL2.D071700A, OGHWOP.D051200A, and OGRAPID.D051200A.

Table ES2. Projected Lower 48 Average Natural Gas Wellhead Prices in Twelve Cases, 2005-2020

Analysis Case	2005	2010	2015	2020
(1998 Dollars per Thousand Cubic Feet)				
Reference	2.40	2.48	2.68	2.79
Accelerated Depletion	2.48	2.62	3.13	4.12
Accelerated Depletion with High Natural Gas Imports	2.45	2.56	2.98	3.69
Accelerated Depletion with High World Oil Price	2.53	2.66	3.24	4.40
Accelerated Depletion with Low World Oil Price	2.30	2.47	2.95	3.60
Accelerated Depletion with Rapid Technology	2.31	2.30	2.32	2.37
Accelerated Depletion with Slow Technology	2.57	2.83	3.59	4.56
Accelerated Depletion with Improved Productivity Technology	2.37	2.39	2.65	2.99
Accelerated Depletion with Reduced Productivity Technology	2.49	2.66	3.33	4.24
Accelerated Depletion with High Rocky Mountain Access	2.46	2.57	3.01	3.90
Accelerated Depletion with High Rocky Mountain Access and Improved Productivity Technology	2.35	2.37	2.57	2.81
Accelerated Depletion with High Rocky Mountain Access and Rapid Technology	2.30	2.26	2.24	2.22

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A, OGDEPL.D051200A, DEPL2.D071700A, OGHWOP.D051200A, OGLWOP.D051200A, OGRTECH.D051200A, OGSLOW.D051200A, OGFRHTEC.D051200A, OGFRLTEC.D051200A, OGACCESS.D051200A, OGACCFR.D051200A, and OGRAPID.D051200A.

in the Accelerated Depletion Case causes both production and consumption projections to be lower than in the Reference Case, and wellhead prices are uniformly higher (Figure ES3). The difference in prices between the two cases increases over the 20 years of the forecast. By 2020, the lower 48 wellhead price of natural gas in the Accelerated Depletion Case is 48 percent higher than in the Reference Case: $4.12 per thousand cubic feet (in constant 1998 dollars), compared with $2.79 per thousand cubic feet (Table ES2). As a result, gas consumption in 2020 is projected to be about 9 percent lower in the Accelerated Depletion Case than in the Reference Case, as consumers either switch to other energy sources or consume less energy altogether.

In the U.S. oil market, the lower 48 wellhead price is determined largely by the world oil price. The lower 48 wellhead price of oil in the Accelerated Depletion Case is projected to be roughly the same as it is in the Reference Case, because world oil prices are not significantly affected by changes in U.S. production. Although domestic oil production is expected to be lower in the Accelerated Depletion Case, oil prices are not expected to rise, because there are ample available imports to meet domestic consumption.

Total energy use in the Accelerated Depletion Case is projected to be 119.8 quadrillion Btu in 2020, compared with 121.0 quadrillion Btu in the Reference Case. In addition to lower natural gas use, higher prices for natural gas in the Accelerated Depletion Case are expected to cause consumers to use more coal and oil than they do in the Reference Case. Projected coal consumption in 2020 is about 3 percent higher in the Accelerated Depletion Case than in the Reference Case, as coal penetrates the electricity generation market with slightly higher prices. The projected use of crude oil and petroleum products is also higher by about 2 percent because of higher natural gas prices. Net imports of crude oil and petroleum products in 2020 are projected to be 16.9 million barrels per day in the Accelerated Depletion Case, compared with 15.8 million barrels per day in the Reference Case, because projected oil consumption is higher and production of oil and natural gas plant liquids is lower.

Higher Natural Gas Imports Reduce Domestic Natural Gas Prices and Production from the Levels Projected in the Accelerated Depletion Case

In the Accelerated Depletion with High Natural Gas Imports Case, several assumptions were changed to show how more imports could influence the projections in the Accelerated Depletion Case. Three changes were made to the Reference Case assumptions to show how higher projected prices in the Accelerated Depletion Case might increase imports of natural gas, and what effect the increase would have on the rest of the market. First, the total capacity for imports from Canada was increased. By 2020, pipeline capacity for gas imports from Canada was assumed to be 20 percent higher than in the Reference and Accelerated Depletion Cases. Second, it was assumed that Mexico would become a net exporter of gas to the United States, rather than a net importer as in the Reference and Accelerated Depletion Cases, with higher prices stimulating an increase in Mexico's production of natural gas for export to the United States. In the Reference and Accelerated Depletion Cases, the United States is projected to export 200 billion cubic feet of gas to Mexico in 2020; however, in the Accelerated Depletion with High Natural Gas Imports Case, Mexico is projected to export 90 billion cubic feet per year to the United States in 2020. Third, U.S. imports of LNG in the Accelerated Depletion with High Natural Gas Imports Case are projected to increase to 450 billion cubic feet per year in 2020, compared with only 330 billion cubic feet in the Reference Case and 370 billion cubic feet in the Accelerated Depletion Case. Total U.S. imports of natural gas are projected to be 6.36

trillion cubic feet in 2020, compared with 5.52 trillion cubic feet in the Accelerated Depletion Case.

Higher imports lead to lower domestic prices for natural gas than are projected in the Accelerated Depletion Case, as more plentiful supplies allow consumers to buy more gas at lower prices. In the Accelerated Depletion with High Natural Gas Imports Case, the lower 48 wellhead price of natural gas in 2020 is projected to be $3.69 per million cubic feet—$0.90 higher than in the Reference Case but $0.43 lower than in the Accelerated Depletion Case. As a result, lower 48 production of natural gas is projected to be lower, at 22.1 trillion cubic feet per year in 2020, than in the Accelerated Depletion Case (22.5 trillion cubic feet in 2020). Because the change in assumptions is limited to imports of natural gas, the projected level of domestic oil production in the High Natural Gas Imports Case is nearly the same as in the Accelerated Depletion Case.

The assumptions for the Accelerated Depletion with High Natural Gas Imports Case do not extend the projected effects of accelerated depletion to either Mexican or Canadian resources. Although those resources are also subject to depletion, development of a methodology to introduce similar accelerated depletion assumptions into the Mexican and Canadian markets is beyond the scope of this analysis.

World Oil Prices Influence Accelerated Depletion Results

The projected effects of accelerated depletion on U.S. wellhead prices and domestic production vary when higher or lower world oil prices are assumed. Higher oil prices lead to increased demand for natural gas as a substitute for oil, resulting in higher gas prices and higher domestic production. In the Accelerated Depletion with High World Oil Price Case, lower 48 gas production is projected to reach 23.0 trillion cubic feet in 2020—only about 0.5 trillion cubic feet higher than in the Accelerated Depletion Case and still 3.0 trillion cubic feet lower than in the Reference Case. At the same time, the natural gas wellhead price is projected to reach $4.40 per thousand cubic feet in the Accelerated Depletion with High World Oil Price Case, 28 cents higher than in the Accelerated Depletion Case, as higher oil prices induce fuel switching from oil to gas, causing demand and prices for natural gas to increase (Figure ES3).

Although total oil use is projected to be lower in the Accelerated Depletion with High World Oil Price Case than in the Accelerated Depletion Case because of higher prices, the same higher prices stimulate an increase in domestic oil production at the expense of imports. U.S. production reaches 5.3 million barrels per day in 2020, 0.6 million barrels per day higher than in the Accelerated Depletion Case and 0.3 million barrels per day above the Reference Case production level (Figure ES2). In contrast, natural gas production in the Accelerated Depletion with High World Oil Price Case is consistently lower than in the Reference Case, and in 2020 it is only slightly higher than in the Accelerated Depletion Case.

In the Accelerated Depletion with Low World Oil Price Case, demand for natural gas is lower than in the Accelerated Depletion Case, as consumers substitute oil for gas. The wellhead price of gas in 2020 is 52 cents per thousand cubic feet (13 percent) lower than in the Accelerated Depletion Case, and gas production in 2020 is 0.6 trillion cubic feet (3 percent) lower. Although more oil is consumed while prices are lower, the effect on oil production is a projected reduction of 0.6 million barrels per day from the 2020 production level in the Accelerated Depletion Case with reference prices. Lower production in the case with low oil prices is accompanied by higher imports to meet a higher level of demand for cheaper oil.

Changes in the Rate of Technology Advances Influence the Results of Accelerated Depletion

In the Accelerated Depletion with Rapid Technology Case, faster innovation is expected to effectively counter many of the negative effects of depletion. Although new fields are smaller, technology allows new fields to be found more cheaply and developed more thoroughly at lower cost; thus, more oil and gas is available from U.S. fields each year at any given price. By 2020, the effects of increased potential production in the Accelerated Depletion with Rapid Technology Case cause the projected wellhead price of natural gas to be $1.75 per thousand cubic feet lower than in the Accelerated Depletion Case (Figure ES3), while natural gas production is projected to be nearly 6 trillion cubic feet per year higher in 2020. Oil production in 2020 is projected to be 0.6 million barrels per day higher in the Rapid Technology Case than in the Accelerated Depletion Case, as U.S. fields are able to produce more at the prevailing world price.

Focusing only on the effects of technology on reserve additions per well, the Accelerated Depletion with Improved Production Technology Case does not show as great an offset in the negative effects of accelerated depletion as does the more general Accelerated Depletion with Rapid Technology Case. However, unlike the Accelerated Depletion with Rapid Technology Case, natural gas production in the Improved Productivity Technology Case is projected to be lower than in the Reference Case in 2020, while oil production is projected to be higher (Table ES1). The natural gas wellhead price in the Rapid Depletion with Improved Productivity Technology Case is projected to be $2.99 per thousand cubic feet in 2020, more than a dollar lower than in the Accelerated Depletion Case with reference technology (Table ES2), and gas production in 2020 is projected to be 3.3 trillion cubic feet per year higher in 2020 than in the

Accelerated Depletion Case. Crude oil production in the Improved Productivity Technology Case is nearly the same as in the Rapid Technology Case in 2020.

Both the Accelerated Depletion with Reduced Productivity Technology and Accelerated Depletion with Slow Technology Cases project lower production and higher prices than those in the Accelerated Depletion Case, because less oil and gas is available for development. In the Accelerated Depletion with Slow Technology Case, the wellhead price of natural gas is projected at $4.56 per thousand cubic feet in 2020, about 11 percent higher than in the Accelerated Depletion Case; U.S. natural gas production in 2020 is projected to be 2.2 trillion cubic feet per year lower than in the Accelerated Depletion Case; and domestic oil production is projected to be 0.7 million barrels per day lower than in the Accelerated Depletion case.

Increasing Access to Rocky Mountain Lands May Partially Offset the Effects of Accelerated Depletion

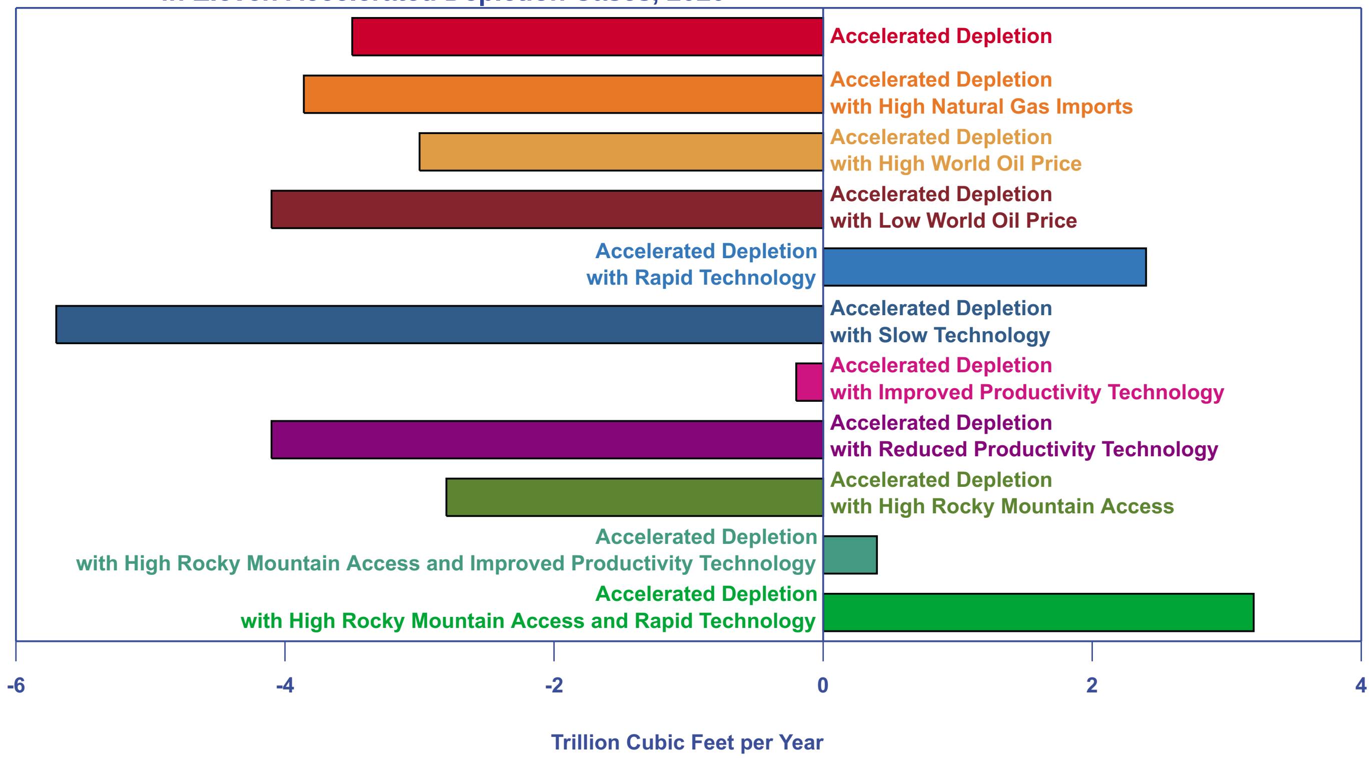
Increased access to natural gas resources on Federal lands in the Rocky Mountain region is projected to lead to higher natural gas production. Increased access would allow producers to develop unconventional gas resources that currently are off limits. In the Accelerated Depletion with High Rocky Mountain Access Case, lower 48 natural gas production in 2020 is projected to be 23.2 trillion cubic feet per year, or about 3 percent higher than in the Accelerated Depletion Case (Table ES1). The expected effect on national average wellhead prices is somewhat larger. Prices in the Accelerated Depletion with High Rocky Mountain Access Case in 2020 are projected to be about $0.22 per thousand cubic feet (5 percent) lower than in the Accelerated Depletion Case (Table ES2).

Combining Increased Access with Faster Introduction of Technology May Completely Offset the Effects of Accelerated Depletion

The combination of faster development of technology and increased access to unconventional gas resources in the Rocky Mountains is expected to result in higher natural gas production at lower prices. Lower 48 natural gas prices in the Accelerated Depletion with High Rocky Mountain Access and Rapid Technology Case are projected to be $2.22 per thousand cubic feet in 2020, and lower 48 natural gas production is projected to be 29.2 trillion cubic feet per year—compared with $4.12 per thousand cubic feet and 22.5 trillion cubic feet per year in the Accelerated Depletion Case (Tables ES1 and ES2). Indeed, the projected wellhead gas price in 2020 in the Accelerated Depletion with High Rocky Mountain Access and Rapid Technology Case is 20 percent below the Reference Case projection (Figure ES3).

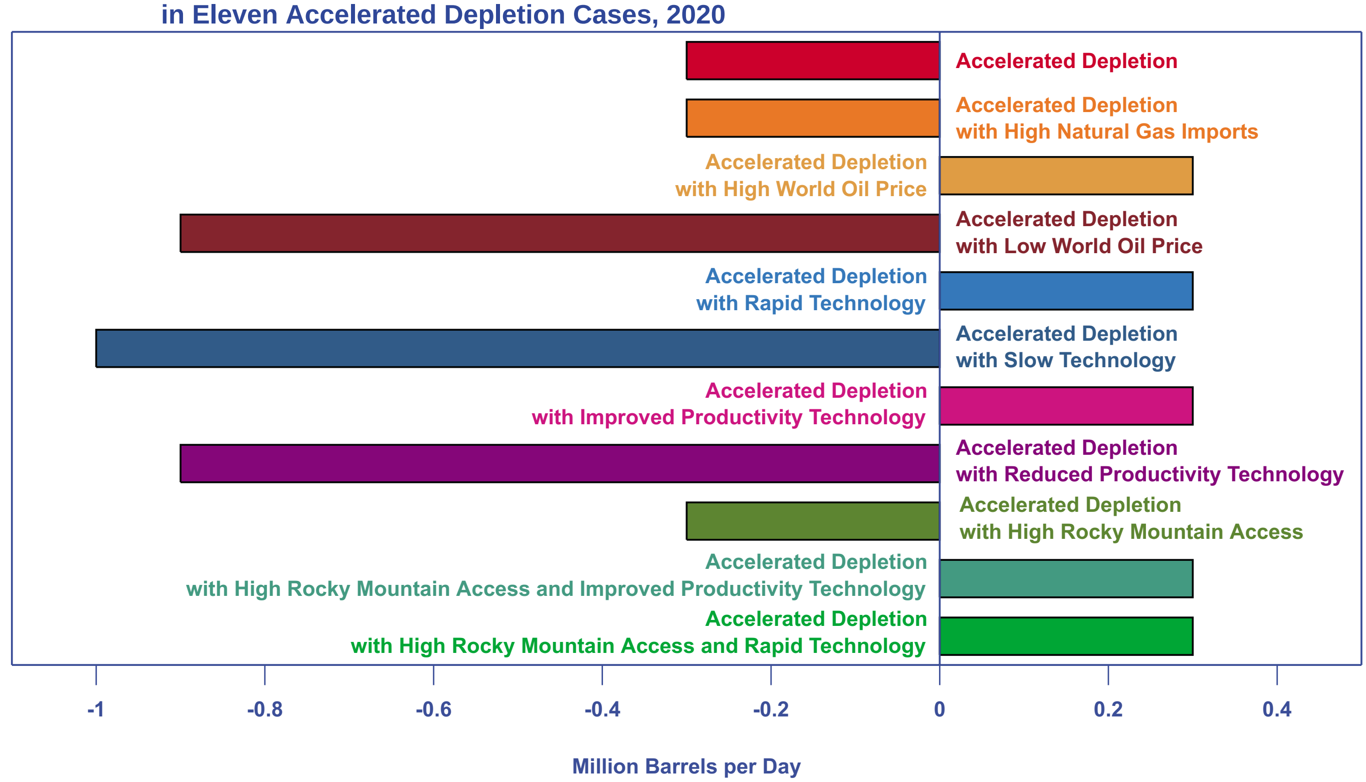
The differences between the Accelerated Depletion Case and the Accelerated Depletion with High Rocky Mountain Access and Improved Productivity Technology Case are similar to those described above but less pronounced, because the improved productivity technology assumptions are more limited than the rapid technology assumptions. Natural gas prices and production in the Accelerated Depletion with High Rocky Mountain Access and Improved Productivity Technology Case are projected to be roughly the same as in the Reference Case in 2020.

Figure ES4. Differences from Reference Case Projections of Lower 48 Natural Gas Production in Eleven Accelerated Depletion Cases, 2020



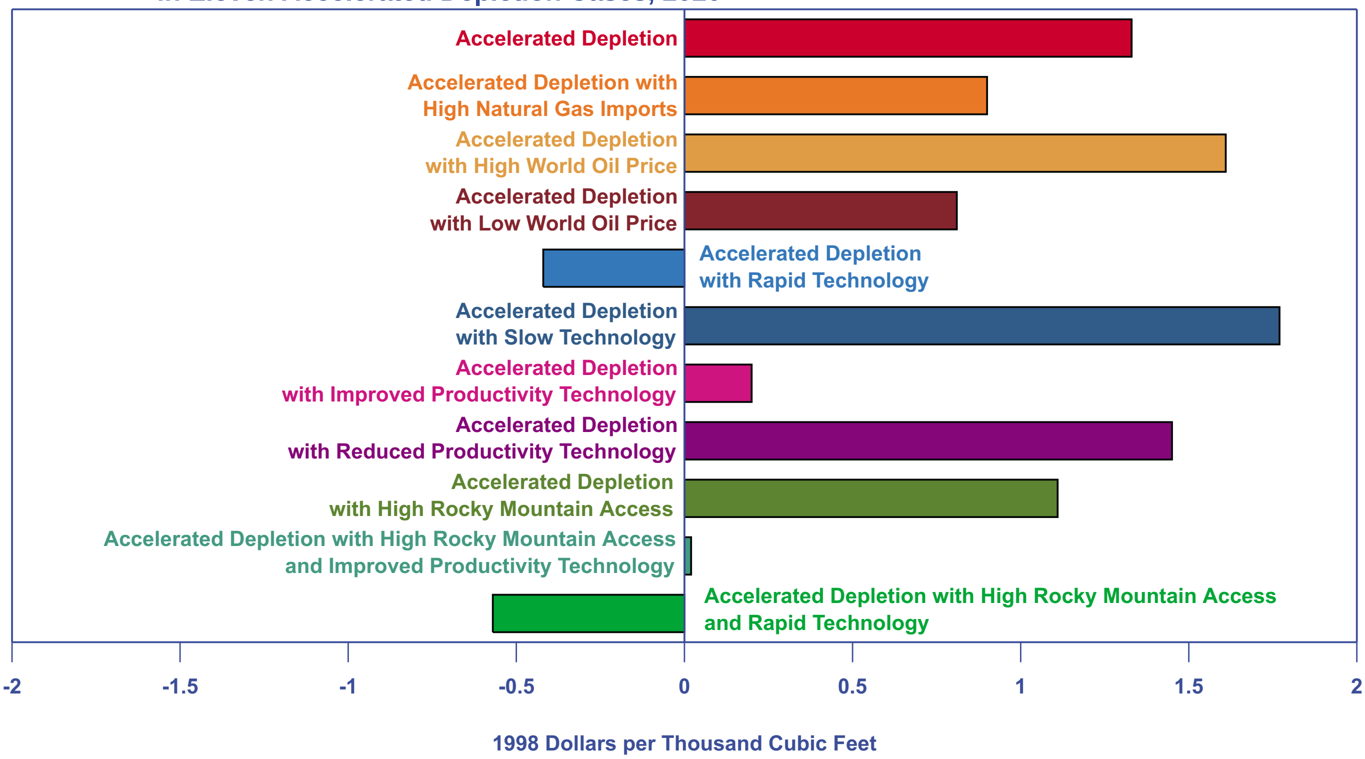
Sources: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE. D051200A, OGDEPL.D051200A, DEPL2.D071700A, OGHWOP.D051200A, OGLWOP.D051200A, OGRTECH.D051200A, OGSLOW.D051200A, OGFRHTEC.D051200A, OGFRLTEC.D051200A, OGACCESS.D051200A, OGACCFR.D051200A, and OGRAPID.D051200A.

Figure ES5. Differences from Reference Case Projections of Lower 48 Oil Production in Eleven Accelerated Depletion Cases, 2020



Sources: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE. D051200A, OGDEPL.D051200A, DEPL2.D071700A, OGHWOP.D051200A, OGLWOP.D051200A, OGRTECH.D051200A, OGSLOW.D051200A, OGFRHTEC.D051200A, OGFRLTEC.D051200A, OGACCESS.D051200A, OGACCFR.D051200A, and OGRAPID.D051200A.

Figure ES6. Differences from Reference Case Projections of Lower 48 Natural Gas Prices in Eleven Accelerated Depletion Cases, 2020



Sources: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE. D051200A, OGDEPL.D051200A, DEPL2.D071700A, OGHWOP.D051200A, OGLWOP.D051200A, OGRTECH.D051200A, OGSLOW.D051200A, OGFRHTEC.D051200A, OGFRLTEC.D051200A, OGACCESS.D051200A, OGACCFR.D051200A, and OGRAPID.D051200A.

Conclusions

The results of this analysis show how projections of future U.S. oil and gas prices and production are affected by changes in the assumptions made about the effects of resource depletion. As compared with the Reference Case for the analysis, the accelerated depletion assumption, by itself, leads to a lower projection for domestic natural gas production in 2020 (Figure ES4), a lower projection for domestic oil production (Figure ES5), and a higher projection for natural gas prices (Figure ES6). In addition, variations in assumptions about the future path of world oil prices, the availability of natural gas imports, the rate of technological innovation, and increased access to unconventional gas resources on Federal lands are shown to influence the projected effects of an assumed increase in the rate of resource depletion. Greater availability of natural gas imports is projected to moderate the price increase resulting from accelerated depletion and also to reduce lower 48 gas production relative to the projections in the Accelerated Depletion Case. Higher world oil prices are projected to raise production of both U.S. crude oil and natural gas in the Accelerated Depletion Case, although oil production is more sensitive to the world oil price than natural gas, due to the limits of substitutability between the two fuels. More rapid technology growth offsets the effects of accelerated depletion. Increased access to Rocky Mountain resources leads to more production of natural gas and lower prices.

When the effects of more rapid technology growth and increased access are considered together, production levels are projected to be higher than in the Reference Case. This result suggests that, for at least the next two decades, the potential negative effects arising in the event of accelerated depletion could be offset by an increase in the rate at which new technologies are introduced in the oil and gas industry and by a relaxation of current restrictions on drilling on Federal lands. While the accelerated depletion cases illustrate that depletion could increasingly affect U.S. oil and natural gas supplies in the decades to come, they should be considered as illustrative projections, not forecasts. If, in the future, the effects of resource depletion follow more closely the path laid out in the Accelerated Depletion Case than that in the Reference Case, it is likely that U.S. energy markets would be slightly more reliant on coal and imported oil.

1. Scope and Methodology of the Study

This study was undertaken by the Energy Information Administration (EIA) at the request of the Principal Deputy Assistant Secretary for Fossil Energy, U.S. Department of Energy (DOE). The request followed a letter to Secretary of Energy Bill Richardson from six trade organizations for oil and gas producers: the American Petroleum Institute, Domestic Petroleum Council, Independent Petroleum Association of America, U.S. Oil and Gas Association, National Ocean Industries Association, and Natural Gas Supply Association.

In their letter, the six organizations raised concerns about the effects of depletion on future oil and natural gas supply. Recent interest in the effects of depletion follows reports which suggest that future production may be more difficult than previously thought. Several reports have highlighted the sharp change in the decline rate for wells on the continental shelf in the Gulf of Mexico. While natural gas wells drilled in 1972 declined from their peak at an average rate of 17 percent per year, natural gas wells drilled in 1996 have been declining at an annual rate of 49 percent.[1] At the same time, the ratio of natural gas production to the level of proved reserves—resources that have been identified and are ready to be developed—have increased from 15.7 percent in 1991-1992 to 18.0 percent in 1997-1998. In addition to the effects of depletion, exploratory drilling for oil and gas was also extremely low in 1999 as a result of unusually low prices. In 1999 the average number of rigs drilling for oil and natural gas was only 625, the lowest level in decades. Although the short-term effect of lower drilling activity already is being reversed as a result of higher prices for oil and gas in 2000, accurate future projections must account for the long-term effects of depletion on oil and gas production.

The projections of future oil and gas prices and production presented in EIA's *Annual Energy Outlook 2000* (*AEO2000*) are produced by the National Energy Modeling System (NEMS), which is designed to capture the expected impact of depletion on future production and prices, based on historical trends. Although the *AEO2000* projections incorporated the effects of depletion, this study develops a series of alternate scenarios that project more pronounced effects from depletion than suggested by the long-term historical trend. The scenarios described below show that changing the projected effects of depletion causes changes in projected U.S. oil and natural gas prices and production, as expected.

Background

Definition

Depletion is a natural phenomenon that accompanies the development of all nonrenewable resources. Taken most broadly, depletion is a progressive reduction of the overall stock (or volume in the instance of oil and natural gas) of a resource over time as the resource is produced. In the oil and gas industry, depletion may also more narrowly refer to the decline of production associated with a particular well, reservoir, or field. Typically, production from a given well increases to a peak and then declines over time until some economic limit is reached and the well is shut in.

The economic characteristics of a resource change over time, as depletion leads producers to abandon older fields and develop new ones. The process of developing domestic oil and natural gas resources leads producers to find and develop the larger, more economical fields first. Later fields tend to be less desirable, because they are farther away from existing infrastructure or smaller in size. Thus, as time progresses more effort is required to produce the same level of the resource from the same exploration area.

Depletion and its effects are highly influenced by technology. In the past, technology advances in oil and gas extraction have allowed more accurate drilling and extraction of a higher percentage of oil and gas from each field, extending the economic life of the average well. Advanced technology has also allowed resources to be developed that were not economically viable before, such as deep sea fields, unconventional natural gas, and oil and gas from very deep reservoirs. These trends are expected to continue into the future.

Technology has two contradicting effects on depletion. On one hand, technology offsets the effects of depletion and allows production to grow, even though the resources that are most accessible and inexpensive to produce are used first. On the other hand, technology allows the resource base to be drawn down more quickly, causing existing resources to be depleted more

[1] David Pursell, *Depletion: The Forgotten Factor in the Supply and Demand Equation: Gulf of Mexico Analysis* (Houston, TX: Simmons and Company International, 1998).

rapidly than they otherwise would have been. Although technology can make some domestic oil and gas resources economical to produce that were not before, technology cannot change the underlying size of the resource.

In the past, analysts have drawn a distinction between gross depletion and net depletion of a field.[2] Gross depletion—also referred to as "cashless decline"—is the decline in production from a well or field if no additional investment is made to sustain production. Net depletion is the decline in production after investments have been made (such as recompletions, infill drilling, and secondary and tertiary recovery techniques) to prolong production.

Depletion Fundamentals

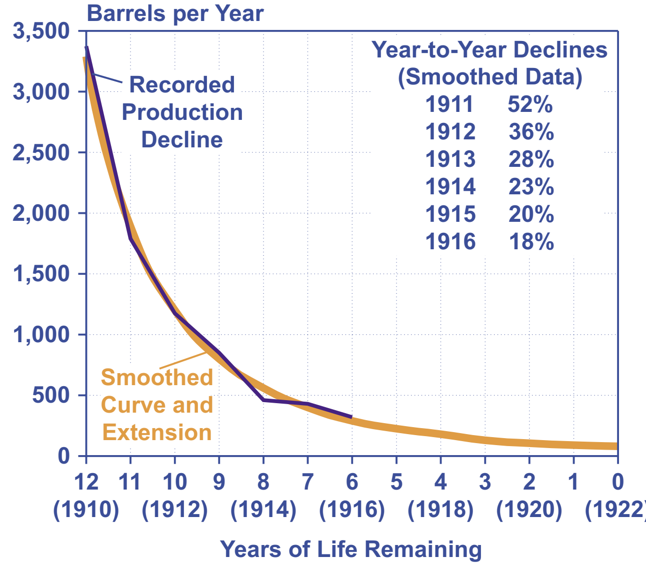
In the 1820s subsurface natural gas was discovered and exploited in the United States, and Colonel Drake drilled his famous rock oil well in 1859. This started the depletion of oil and gas resources in the United States. Since that time, U.S. oil production has matured, peaked, and declined from its highest levels. Natural gas production has yet to reach its ultimate peak. As domestic production has matured, increasingly sophisticated techniques have been developed to measure how much oil and gas is produced and how much remains.

The production decline curve of an individual well in the Oklahoma's Glenn pool illustrates the depletion trajectory of a well in unrestricted production (Figure 1). Although it is taken from a U.S. Department of Interior Bulletin printed in 1924, its message is fundamental and timeless: production rates start high, then decline hyperbolically over time. If all the world's resources were easily accessible and development were not complicated by changes in demand, prices, costs, and technology, the production of the world's resources would resemble this simple decline curve and would be mathematically simple to model. Obviously, depletion is considerably more complicated than this; however, production from oil and gas wells will generally follow a pattern of hyperbolic decline.

Interaction of Depletion and Prices

Regional production is the sum of production from individual wells. Assuming that, within a given region, larger fields with correspondingly higher levels of production are found first, developed, and replaced with smaller fields, then production will tend to decline with time if drilling is roughly constant. However, changes in prices influence drilling. The expectation of higher prices causes more money to be spent to develop wells, whereas the expectation of lower prices causes

Figure 1. Production Decline Curve for Yearly Production from an Individual Well in the Glenn Pool, 1910-1922



Source: U.S. Department of the Interior, *Bulletin 228* (1924).

exploratory activity to decline. Therefore, economics affect regional production paths.

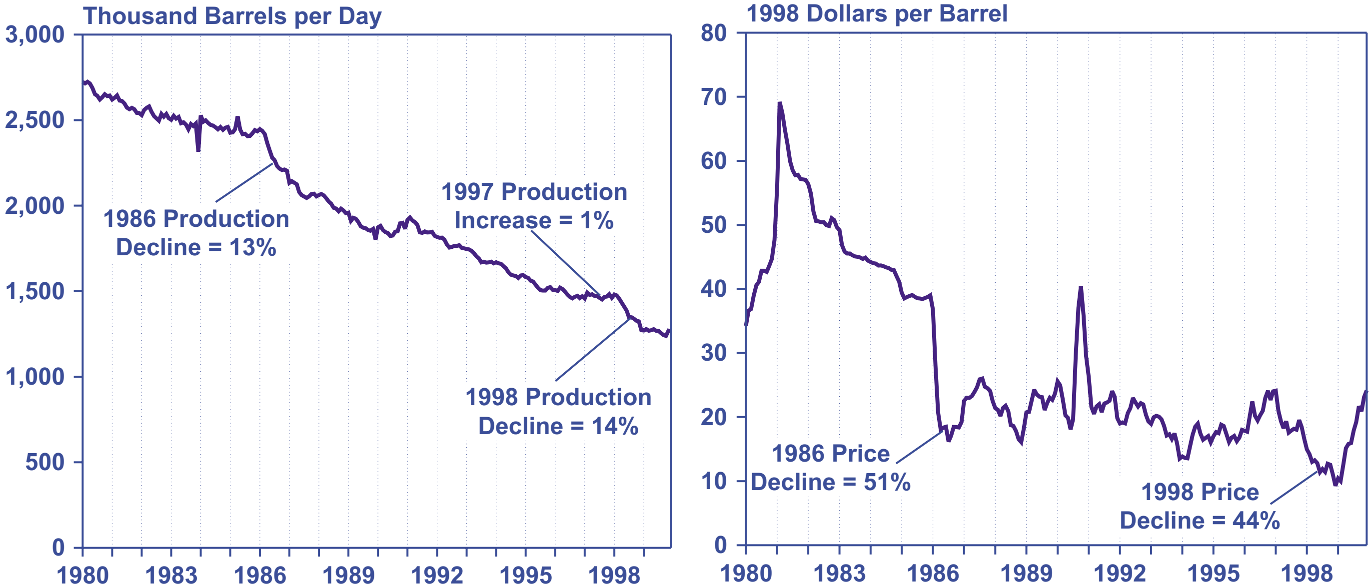
The relationship between prices and regional production can be seen by looking at oil production in Texas from 1980 to 1999 (Figure 2), when Texas fields are considered to have been mature. Production during the period is characterized by the flatter section of a hyperbolic decline curve. In the early 1980s, Texas oil production was declining by a couple of percent per year, even with very high prices and continued drilling. At the end of 1985 production was actually increasing, but during 1986 oil prices fell by 51 percent, and oil production fell by 13 percent.

The 1990-1991 price spike that accompanied the Gulf War led to a modest increase in production; however, there was an overall gradual decline accompanying relatively stable prices from 1986 to 1996, and production from Texas proceeded along the flatter section of the hyperbolic curve described above. In 1997, higher prices led to a 1-percent increase in oil production. Then, in 1998, with a 44-percent drop in prices, Texas oil production fell by 14 percent.

As illustrated in Figure 2, there is not a one-to-one correspondence between changes in prices and changes in production. The relationship is complicated by other factors, such as changes in production costs resulting from changes in the price of inputs (such as labor and materials) and changes in taxes. In addition, production increases may be limited by the availability of drilling rigs and skilled labor in the short run. Thus, although depletion of the resource base may eventually lead to

[2]For example, see R.E. Snyder,"Oil and Gas Prices: What Else is Important?" *World Oil*, Vol. 220, No. 1 (January 1999), p. 31.

Figure 2. Texas Oil and Condensate Production and Texas First Purchase Price, 1980-1999



Source: Energy Information Administration, Office of Oil and Gas, Reserves and Production Division (Dallas, TX).

lower production from a field or region, the rate of decline can be affected or even reversed in the short run by changes in underlying economic factors.

Field Size Distribution

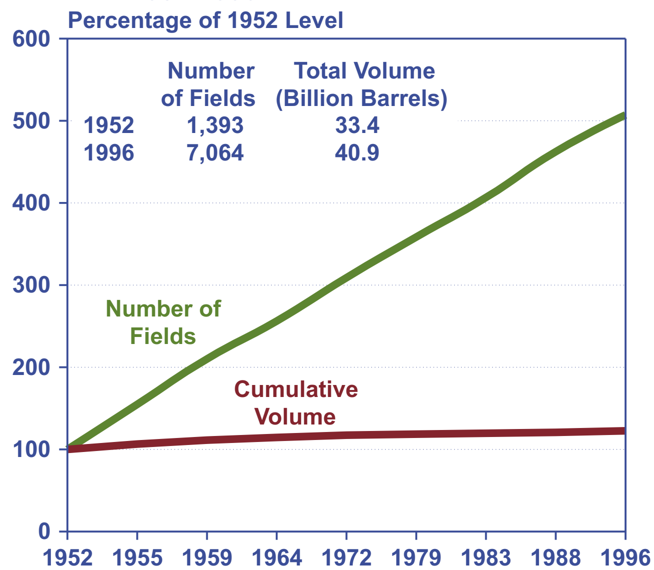
The history of oil and natural gas production in the United States shows that the largest fields are more likely to be discovered first. Large fields will produce for a very long time because of their large supply of resources. As they are exploited exploration continues, and smaller fields typically are discovered and exploited. The smaller fields, individually, do not have the volume of resources that the larger fields do, but there are many more of them.

The effects of adding progressively smaller fields as a region is developed are illustrated by the development history of the Permian Basin, a producing region in West Texas and Eastern New Mexico (Figure 3). By 1952, more than 33 billion barrels of oil had been found in the Permian Basin. Nearly 1,400 fields had been discovered; however, more than 17 billion barrels, or more than one-half of the total volume of oil found, was concentrated in the 20 largest fields. From 1952 to 1996, when the volume of oil discovered in Permian Basin fields grew by just 7.5 billion barrels (to a total of nearly 41 million barrels), the total number of fields discovered was over 7,000, or more than five times the number discovered before 1952.

The experience in the Permian Basin is reflected in domestic oil and gas production as a whole. In 1998, the 20 largest oil fields accounted for about 45 percent of U.S. proved reserves. The 15 largest were discovered before 1990 and were on average 50 years old in 1998. Only 3 of the top 20 fields were discovered after 1990—one in Alaska and two in the offshore Gulf. Of the 20 largest natural gas fields, accounting for about 29 percent of all U.S. proved reserves, only was found after 1990.[3]

Exploration in previously undeveloped regions has historically helped to offset the effects of depletion. For

Figure 3. Trends in Cumulative Volume of Oil and Number of Fields Discovered in the Permian Basin, Selected Years, 1952-1996



Source: Energy Information Administration, Office of Oil and Gas, Reserves and Production Division (Dallas, TX).

[3]Energy Information Administration, *U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves, 1998 Annual Report*, DOE/EIA-0216(98) (Washington, DC, December 1999), pp. 58-61.

instance, fields in Alaska and offshore in the deep waters of the Gulf of Mexico are now major sources of production that were not available when oil production was at its peak. Of course, each step of regional development has also served to diminish the existing frontier.

Resource Recovery Rates

The trends of drilling improvements and smaller field size suggest that the initial recovery rates of future wells will be higher than they have been historically. Specifically, the initial recovery rate—the percentage of a well's total ultimate production recovered in the first few years of drilling—is enhanced by better technology but diminished by the incremental deterioration of available resources. Thus far, the positive effects of technological improvements have increased the average recovery rate for new wells at a pace that exceeds the decline in the quality of fields brought into development.

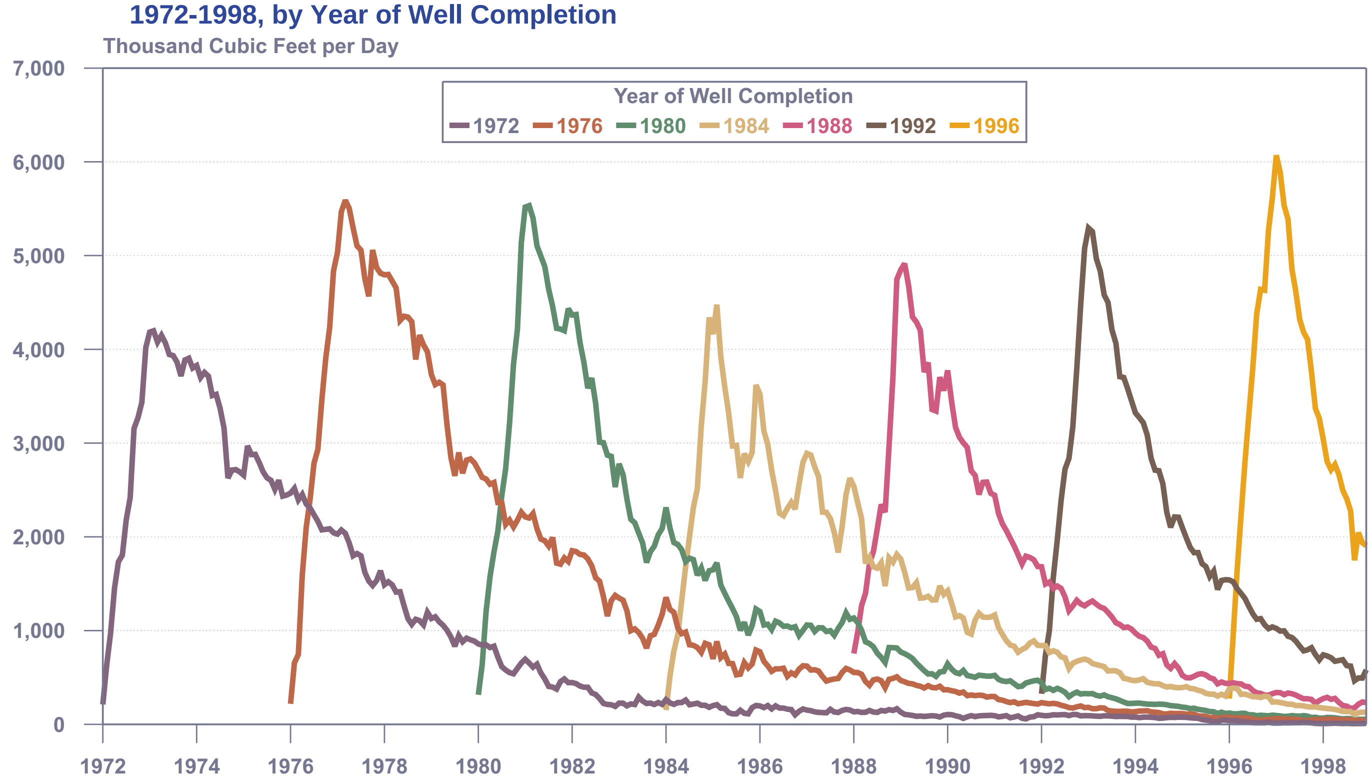
Natural gas production from wells in the Federal waters of the Gulf of Mexico (Figure 4) illustrates how initial flow rates have increased over time. Wells drilled in 1972, on average, reached a peak production level of 4.2 billion cubic feet per day. Wells drilled in 1996 reached an average peak of nearly 6.1 billion cubic feet per day. On the other hand, 2 years after peaking, production from wells drilled in 1972 average 63 percent of their peak level, whereas those drilled in 1996 averaged only 31 percent. The cumulative average volume of production after the first 3 years of production was actually about 10 percent higher for wells drilled in 1996, but the average ultimate recovery (represented by the area under the curve for each year) has varied from year to year without following a specific trend. (See Appendix G for a discussion of how the trends of higher initial flow rates and more rapid declines in production are incorporated in the methodology for this study.)

While the frontier for new resources is diminishing, increased innovation has, thus far, served to offset depletion at least partially, keeping production stronger than it would have been in the absence of the innovations. Technological progress is expected to continue to enhance exploration, reduce costs, and improve production technology. But eventually, as field sizes grow smaller, the ultimate recovery from discovered fields will shrink. Thus, despite technological improvements, ultimate recovery from the average field of the future will be smaller than from the average field today.

Resources and Reserves

EIA annually collects and publishes data on proved reserves in the United States. The distinction between proved reserves and total resources is important for

Figure 4. Average Daily Production from Natural Gas Wells in the Federal Offshore Gulf of Mexico, 1972-1998, by Year of Well Completion



Source: Energy Information Administration, Office of Oil and Gas, Reserves and Production Division (Dallas, TX).

understanding how the NEMS Oil and Gas Supply Module (OGSM) works, as described in the next section.

The total quantity of oil or gas trapped within the boundaries of a reservoir or field makes up its total resources. The amount of total resources in a field—or in the world—is uncertain. Estimates of oil and gas resources by field are routinely based on information from geologists and engineers who measure the porosity and permeability of rock formations, construct geological maps, estimate the extent and thickness of formations suspected or known to contain oil, and compile many other types of data. The estimates are a "best guess" given the available data, and they are revised as more knowledge becomes available. There is no time frame or probability associated with estimates of total resources in place.

In contrast, proved reserves of crude oil and natural gas are the estimated quantities that, on a particular date, are demonstrated with reasonable certainty by geological and engineering data to be recoverable in the future, from known reservoirs under existing economic and operating conditions. Unlike a resource estimate, there is a probability associated with a proved reserves estimate. Generally, there is at least a 90 percent probability that, at a minimum, the estimated volume of proved reserves in the reservoir can be recovered under existing economic and operating conditions.

Each year, production is taken from proved reserves, reducing both proved reserves and the total resource. As the proved reserves are being reduced, exploration and development add to the remaining proved reserves. Technological advances may make it easier to discover resources and reclassify them as proved reserves, but reserve additions—the volume of resource added to proved reserves each year—are fundamentally determined by the amount and success of drilling activity. Although the level of proved reserves may fluctuate because of the conflicting effects of depletion, technological advance base, and the amount of drilling, the total size of the resource remains unchanged.

Historically, the amount of oil and natural gas produced in a given year is related to the level of proved reserves of each (although the relationships have varied from year to year and evolved over time). The relationship between production and proved reserves, quantified as the P / R ratio, is the basis for future production estimates in the OGSM, which calculates each year's production as a fraction of the proved reserves of a given fuel in a given region. Proved reserves are only a subset of the total remaining resources available in a field, and are therefore consistently lower than the best guess in the amount of oil or gas remaining in a field.

Recent events have illustrated that reserves and reserve additions can fluctuate from long-term trends. After the sharp declines in revenues in 1998, reserve additions of oil and natural gas were unusually low. Oil reserve additions, which were 125 percent of production in 1997, were only 24 percent of the total volume of oil produced in 1998; gas reserve additions fell from 104 percent in 1997 to 83 percent in 1998.[4] The larger decline in the rate of oil reserve additions reflects the change in oil prices between 1997 and 1998, which fell faster than natural gas prices.

Although EIA has not released its reserve report for 1999,[5] there is at least one report that indicates that reserve additions in 1999 were higher than in 1998 and returned to the pattern that has prevailed since 1991.[6] The extreme decline in reserve additions during 1998 can be attributed to extremely low prices, as well as the continuing economic restructuring of the industry, characterized by mergers, acquisitions and spinoffs. Restructuring can be a drain on the industry's cash flow and may hinder development. The recent low reserve additions are the result of short-term market conditions, and suggest that future year-to-year drops in reserves will not be as strong.

Impact of Depletion on North American Supply and Demand for Crude Oil

Most of the oil basins in the United States are mature. The fields in U.S. basins require extensive capital investment (such as secondary and tertiary enhanced recovery) to maintain current production rates or, in some cases, merely to minimize rapidly increasing depletion rates. In other words, they are experiencing net depletion after capital investment. One example is Prudhoe Bay, the Nation's largest field, where production is falling by about 10 percent per year despite large investments in enhanced oil recovery technology.[7]

Although depletion limits domestic production, its effect on mature U.S. oil fields has little impact on worldwide oil supply or prices. Because crude oil is relatively easy to transport to distant locations, the market responds to worldwide supply and demand. Therefore, U.S. prices for crude oil are largely determined by the

[4]Energy Information Administration, *U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves, 1998 Annual Report,* DOE / EIA-0216(98) (Washington, DC, December 1999), pp.19 and 27.

[5]The report is expected in December 2000.

[6]John S. Herold, Inc., *Herold 33rd Annual Reserve Replacement Cost Analysis—Top 50 U.S. Companies* (Stamford, CT, May 2000).

[7]Energy Information Administration, *Performance Profiles of Major Energy Producers 1998,* DOE / EIA-0206(98) (Washington, DC, January 2000), p. 107.

world market rather than North American supply and demand.

Demand in the United States is met through domestic production and imports, mostly from countries with less mature fields that can produce oil at lower costs. When prices are high, U.S. producers try to expand production, developing new fields and making investments in technology to offset the trend toward declining production in mature fields. When prices are low, such investments are less profitable. Imports are higher when prices are lower, and the effects of depletion on U.S. production increase as investment in technology declines.

Impact of Depletion on North American Supply and Demand for Natural Gas

Because of the regional nature of gas markets, the price of natural gas is much more susceptible to North American field depletion than the price of oil. The decline in oil production from lower 48 onshore fields that accompanies depletion can be offset by increased imports. In contrast, the role of imports in natural gas markets is limited by the difficulty of transporting natural gas from fields outside North America. Although natural gas can be imported from other producing regions of the world in the form of liquefied natural gas, it is expensive and not expected to be a likely major alternative in meeting future gas needs.

There is currently much debate surrounding depletion in the Gulf of Mexico. The debate usually centers not on the overall size of the resource (which appears to be quite large) but on whether there has been sufficient capital investment in the region to allow producers to meet natural gas demand in the future.

In 1998, gas production from offshore fields in the Gulf of Mexico averaged 15.1 billion cubic feet per day, or 28 percent of total U.S. production.[8] There is evidence that the average decline in production from existing wells from year to year in the absence of additional drilling has been increasing over time, from slightly less than 16 percent in 1991-1992 to more than 18 percent in 1997-1998. When only producing proved reserves are considered, the corresponding increase is about 27 percent in 1991-1992 to more than 32 percent in 1997-1998.[9]

According to one estimate, in the absence of additional wells, production in 1999 from the shelf portion of the Gulf of Mexico is expected to show a decrease of about 29 percent, or 4.1 billion cubic feet per day, from 1998 production. The same estimate projects that maintaining production on the shelf area would require roughly 1000 additional wells, each producing on average 6.0 million cubic feet per day.[10] When the annual depletion-related decline in production from traditional areas can no longer be replaced, it will have to be replaced by production from deep water Gulf of Mexico or sub-salt shallow water natural gas sources. This will require continued capital investment in new field development, pipeline infrastructure, and drilling technology.

Access Limitations

Access to Federal lands is a critical factor in any evaluation of the effects of resource depletion on the future supply and prices of natural gas. A significant portion of the Nation's resource base is found on Federal lands or in Federal waters where development is restricted or prohibited by statute or environmental regulations. The Rocky Mountains and the Nation's offshore regions, areas of high potential for future gas production, have significant access restrictions. This analysis assumes that 45 percent of the potential gas resource in the Rocky Mountain region (approximately 108 trillion cubic feet) is located beneath Federal land that is either closed to exploration or under restrictive provisions. According to a recent report released by the National Petroleum Council (NPC), an additional 31 trillion cubic feet of natural gas is inaccessible as the result of a moratorium passed by Congress, which closed the East Coast of the United States to oil and gas development.[11] The West Coast and the Eastern Gulf of Mexico have also been constrained with similar developmental restrictions, affecting another potential 46 trillion cubic feet of natural gas. Simply put, access issues limit the industry's ability to exploit known resources. Increased access to restricted Federal land and waters could provide new fields to replace older fields and serve as a potential countermeasure to the effects of depletion on total U.S. production.

Role of Technology

Industry observers have recognized the effect of technology on oil and gas resource depletion. Some argue that advances in technology have accelerated depletion; others contend that they have helped to counter accelerating depletion. Innovative production techniques to prolong production, such as well recompletions, secondary and tertiary enhanced recovery techniques, and expanded production of unconventional resources,

[8]Energy Information Administration, *Natural Gas Annual 1998*, DOE/EIA-0131(98) (Washington, DC, October 1999), Table 3, p.12. The daily figure is calculated by adding yearly State and Federal offshore figures for Texas, Louisiana, and Alabama and dividing by 366.

[9]Advanced Resources International, internal memorandum, 1999.

[10]R.E. Snyder, "Oil and Gas Prices: What Else is Important?" *World Oil*, Vol. 220, No. 1 (January 1999), p. 31.

[11]National Petroleum Council, *Meeting the Challenges of the Nation's Growing Natural Gas Demand*, Vol. I (Summary Report) (Washington, DC, December 1999), p. 13.

have reduced net depletion rates at the well and field levels.

Advanced exploration and drilling techniques, such as 3-D seismic imaging, directional drilling, and multiple wells from single boreholes,[12] have had a major impact on depletion. These technologies reduce the cost of finding new pools, reduce the risk of dry holes and dry hole costs, and allow new pools to be developed and produced more quickly. One analyst estimated that in the early to mid-1990s technological development reduced the finding costs of crude oil by about 15 percent per year.[13]

Lower exploration, drilling, and dry hole costs increase the return on capital by lowering costs. More rapid production of resources from a field increases the return on capital because earnings are realized sooner in the project's life, and therefore, discounted less. The reduction of risk and increased returns on capital have two effects. First, higher returns on capital attract and stimulate drilling activity. Second, higher returns make some fields that are too expensive to develop under "normal" circumstances economically feasible, because reduced costs may allow firms to make profits where they could not before.

On the other hand, some analysts have countered these assertions by stating that more rapid development and production of a field by definition increases the rate of depletion. If an operator produces a field more quickly, the argument goes, the rate of depletion must rise. While the rate of depletion increases with technological progress, the adverse effects of depletion are diminished, and higher levels of production can be maintained for longer periods of times. This analysis examines the ameliorating effects of technological development on depletion.

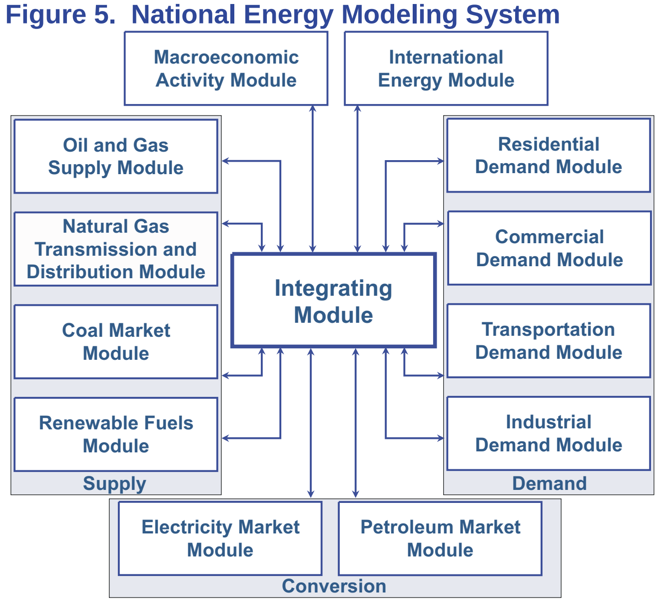
Overview of the National Energy Modeling System/Oil and Gas Supply Module

The analysis of the accelerated depletion cases was conducted by EIA using NEMS.[14] NEMS is an integrated model that balances supply and demand for each fuel and consuming sector on an annual basis. It is organized and implemented as a modular system, including four supply modules, four demand modules, a macroeconomic activity module and an international energy module (Figure 5). The time horizon for NEMS projections is roughly 20 years—currently through 2020. NEMS is used to produce the forecasts for EIA's *Annual Energy Outlook* and for other appropriate projects, such as the 1999 *Analysis of the Impacts of an Early Start for Compliance with the Kyoto Protocol*.[15]

The interrelationships among depletion, technological improvements, and domestic oil and natural gas production are modeled in NEMS in the OGSM. The OGSM represents domestic supply of crude oil and natural gas from conventional and unconventional sources at a regional level. Oil and natural gas exploration and development projections are based on the expected profitability of projects, subject to anticipated future prices, costs, and technological change.

The finite nature of oil and natural gas resources is modeled in the OGSM. In the *Annual Energy Outlook 2000* (*AEO2000*),[16] the technically recoverable oil resource

Figure 5. National Energy Modeling System



Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

[12] 3D seismic imaging is a technique that uses sound waves and advanced computing technology to model the three dimensional shape of underground reservoirs, and horizontal drilling is a development process that extracts oil and gas by drilling through a reservoir horizontally, to maximize the number of feet of resource that is drilled through from a single well, thereby improving production. For more information about these techniques and other technologies that have aided oil and natural gas production see US Department of Energy, *Environmental Benefits of Advanced Oil and Gas Exploration and Production Technology*, DOE / FE-0385 (Washington, DC, October 1999).

[13] M.N. Fagan, "Resource Depletion and Technical Change: Effects of U.S. Crude Oil Finding Costs from 1977 to 1994," *The Energy Journal*, Vol. 18, No. 4 (1997), p. 101.

[14] A synopsis of NEMS, the model components, and the interrelationships between the components is available in Energy Information Administration, *The National Energy Modeling System: An Overview*, DOE / EIA-0581(2000) (Washington, DC, March 2000).

[15] Energy Information Administration, *Analysis of the Impacts of an Early Start for Compliance with the Kyoto Protocol*, SR / OIAF / 99-02 (Washington, DC, July 1999).

[16] Energy Information Administration, *Annual Energy Outlook 2000*, DOE / EIA-0383(2000) (Washington, DC, December 1999).

base for the United States was estimated at 140 billion barrels, of which 24 billion barrels were considered proved reserves ready for production. Proved reserves of natural gas were estimated at 167 trillion cubic feet, out of a technically recoverable resource base of 1,259 trillion cubic feet. The OGSM resource estimates are based on estimates of technically recoverable resources from the U.S. Geological Survey (USGS) and the Minerals Management Service (MMS) of the Department of the Interior. Supplemental adjustments to the USGS nonconventional resources were made by Advanced Resources International (ARI), an independent consulting firm, and adjustments to the MMS offshore Gulf of Mexico resources were based on estimates from the National Petroleum Council.

The impacts of depletion are explicitly incorporated into the OGSM framework through three key elements: production-to-reserves (P/R) ratios, reserve additions per well (finding rates), and expected return on investment in drilling projects. In the OGSM, production is estimated each year as a fraction of proved reserves—the P/R ratio. The P/R ratio generally increases over time, reflecting the higher extraction rate for new wells. The projected change in the P/R ratio used in the *AEO* reference case is based on historical trends. Finding rates are assumed to decline as drilling progresses and remaining undiscovered and undeveloped resources decline. The decline can be partially offset by improvements in technology, but eventually the impacts of depletion will outweigh the technology improvements.

The OGSM determines expected drilling returns on the basis of a discounted cash flow algorithm, which is based on representative well production profiles. Each profile represents a schedule of the average projected production from a well over its economic lifetime, which is assumed to be 20 years. Production from a well is greatest in the first full year of the production life then declines, reflecting both depletion and the desire to produce as much as possible early in order to maximize the return on investment. Initial flows also decrease over time as a result of the natural progression of the discovery process from larger, more profitable fields to smaller, less economical ones. Although representative well profiles are used to determine the expected return on drilling projects, the number of producing wells and their vintage are not tracked in the OGSM.

Accelerated Depletion Cases

For this analysis, NEMS was used to generate a series of projections based on different assumptions about the effects of depletion on future production and prices. Sensitivity cases were developed to evaluate the effects on changes resulting from accelerated depletion of U.S. oil and gas resources that might result from higher imports of natural gas, higher or lower world oil prices, different rates of improvement in technology, and increased access to unconventional natural gas resources in the Rocky Mountains. A total of 12 cases were examined. The assumptions used to define the Reference Case, the Accelerated Depletion Case, and all but one of the sensitivity cases were provided by the Office of Fossil Energy, in consultation with representatives of the six trade groups requesting the study. Appendix A includes a description of the cases provided by industry representatives and the Office of Fossil Energy.

- **Reference Case.** The Reference Case, depicting business as usual, is similar to the Reference Case for the *Annual Energy Outlook 2000* (*AEO2000*), with some minor changes in the assumed conventional natural gas resource base in the Rocky Mountain region and the technology assumptions for unconventional gas production. The world oil price and natural gas wellhead prices in 1999 and 2000 were also with revised short-term projections from EIA's April 2000 *Short-Term Energy Outlook*[17] (see Appendix E for more detail).
- **Accelerated Depletion.** The Accelerated Depletion Case, reflecting the issues raised by the six trade groups, shows a faster decline in production than the Reference Case. Future oil and gas discoveries are assumed to be one-third smaller and new fields are projected to produce more rapidly than in the Reference Case. Assumptions about the rate of technological change and accessible oil and gas resources are the same as in the Reference Case. The Accelerated Depletion Case is a hypothetical case designed to highlight the potential impacts of lower reserve additions and faster depletion rates on natural gas and oil prices, production, imports, and consumption.
- **Accelerated Depletion with High and Low World Oil Prices**. These two cases show how domestic production and prices with accelerated depletion are affected by different world oil price paths. The high and low oil price cases are the same as those used in *AEO2000*. The High World Oil Price Case assumes that the world oil price rises to $28.04 per barrel in 2020, compared with $22.90 in the Reference Case and $14.90 in the Low World Oil Price Case (all prices in 1998 dollars).
- **Accelerated Depletion with Rapid and Slow Technology Growth.** These two cases show the interaction of accelerated depletion with changes in the expected rate of technological development. The

[17] Energy Information Administration, *Short-Term Energy Outlook*, DOE/EIA-0202(00/2Q) (Washington, DC, April 2000), www.eia.doe.gov/pub/forecasting/steo/oldsteos/apr00.pdf.

rate of technological improvement is captured by changes in future costs, drilling accuracy, and the amount of oil and gas added to proved reserves with each well drilled. For conventional oil and natural gas, NEMS uses a composite rate of technology growth and does not project the introduction of specific technologies. The rate of technological growth used in the Reference Case is based on past trends. In the Rapid Technology Growth Case, technology advances are assumed to increase the rates of improvement in costs, accuracy, and reserve additions per well by 50 percent over those in the Reference Case; in the Slow Technology Growth Case, the improvement rates are assumed to be 50 percent slower.[18] While the fields found in the Accelerated Depletion Cases are smaller than those found in the Reference Case, changing the technology influences how quickly and thoroughly these fields are developed. Rapid technology growth causes the projected volume of reserve additions per well to be higher than the Accelerated Depletion Case over time and closer to the path set in the Reference Case; in other words, faster technology growth can partially offset depletion effects. Slower than expected technology growth causes projected volumes of reserve additions to be lower than the Accelerated Depletion Case, or make depletion effects worse. All other parameter values are the same as in the Reference Case, including the technology parameters for other modules, parameters affecting foreign oil supply, and assumptions about imports and exports of liquefied natural gas and natural gas trade with Canada and Mexico. The path of the world oil price is the same as in the Reference Case.

- **Accelerated Depletion with Improved and Reduced Productivity Technology.** In these two cases, the effect of technology improvement is captured only for changes in reserve additions per well drilled, without changing assumptions about future costs or drilling accuracy. Therefore, the projections from the Improved and Reduced Productivity Technology Cases vary less from the Reference Case projections than do those from the Rapid and Slow Technology Cases. In the Improved and Reduced Productivity Technology Cases, the rate of growth in the amount of oil and natural gas added to proved reserves per well is adjusted by plus or minus 50 percent. Other rates of technological change are the same as in the Reference Case. The path of the world oil price is also the same as in the Reference Case.

- **Accelerated Depletion with High Rocky Mountain Access.** This case illustrates the effects of increasing the amount of natural gas available for development in the Rocky Mountain States by assuming the elimination of environmental and other constraints on production in the region. The question of access is limited to the Rocky Mountain region, where resources are sizable. In the Reference Case,97 trillion cubic feet out of a total of 251 trillion cubic feet of unconventional gas resources is assumed not to be accessible to development before 2020. In the High Rocky Mountain Access Case, the inaccessible portion is assumed to be only 18 trillion cubic feet. The world oil price path is the same as in the reference case.

- **Accelerated Depletion with High Rocky Mountain Access and Improved Productivity Technology.** This case combines the assumptions of the two previous cases to show how increased Rocky Mountain access and improved productivity technology could ameliorate the effects of accelerated depletion.

- **Accelerated Depletion with High Rocky Mountain Access and Rapid Technology Growth.** This case combines the assumptions of the Rapid Technology Growth and High Rocky Mountain Access Cases to show how increased access and faster technology growth could offset some of the effects of declining production due to accelerated depletion.

In addition to the 11 cases provided by the Office of Fossil Energy, one other case was developed to address the uncertainty regarding the potential for additional imports of natural gas, primarily from Canada and Mexico:

- **Accelerated Depletion with High Natural Gas Imports.** This case combines the assumptions of the Accelerated Depletion Case with an assumed increase in the volume of natural gas imported from other countries. In the Accelerated Depletion Case, despite higher price projections, pipeline imports of natural gas from Canada are limited by constraints on pipeline capacity, and imports of liquefied natural gas (LNG) are limited by constraints on gasification plant capacity. In this case, more natural gas imports and a more rapid increase in imports are allowed in response to the higher domestic prices that result from accelerated depletion than are allowed in the Reference and Accelerated Depletion Cases. Other assumptions about world oil prices, technology growth, and access to Rocky Mountain resources are the same as in the Reference Case.

[18] Although the Rapid and Slow Technology Growth Cases are designed to highlight the uncertainty associated with the effects of technological development, they do not provide a formal confidence interval. In *AEO2000*, the rates of technological growth for the technological sensitivity cases were adjusted by 33 percent, rather than the 50 percent used for this analysi s in order to acknowledge th ebroad range of uncertainty around future technological change.

2. Summary of Results

Accelerated Depletion Case

Assumptions

Although depletion is incorporated in the Oil and Gas Supply Module (OGSM) of the National Energy Modeling System (NEMS), the Accelerated Depletion Case was developed explicitly to address the issues raised by the six trade associations in their communication with the Department of Energy. The assumptions embodied in the Accelerated Depletion Case differ significantly from those used in the Reference Case and in the *Annual Energy Outlook 2000* (*AEO2000*). The assumptions provided by the Office of Fossil Energy, which were developed in consultation with representatives of the six trade groups, are summarized below:

- **New field discoveries are assumed to be smaller.** As specified by the Office of Fossil Energy, the size of new discoveries was reduced by one-third from the size assumed in the Reference Case, to represent smaller fields being brought into development in the future. Each newly discovered field adds not only proved reserves but also a much larger volume of inferred reserves. Proved reserves are reserves that can be certified using the original discovery wells; inferred reserves are those hydrocarbons that require additional drilling (developmental and other exploratory) before they are termed proved. The bulk of reserve additions in any year comes from inferred reserves. Because the new fields are assumed to be smaller in the Accelerated Depletion Case than in the Reference Case, fewer additions are made to inferred reserves. Overall future drilling in the Accelerated Depletion Case adds less to proved reserves, requiring more drilling to achieve a given level of production than in the Reference Case.

- **New reserves are assumed to be used more intensively.** As stated earlier, the underlying mechanism in the OGSM used to determine production is the P/R ratio. In the accelerated case, the P/R ratio for new proved reserve additions is assumed to be one-third higher than in the Reference Case, again as specified by the client. The Accelerated Depletion Case assumes that the smaller fields discovered with the reduced finding rate described above will be used more intensively than fields have been historically. The expected increased intensity of production is reflected in the higher P/R ratios.

- **Individual wells are assumed to reach a higher peak earlier in their development and to decline more quickly, changing expected well profitability.** In the Accelerated Depletion Case, the discounted cash flow algorithm and expected well profitability, which are used to determine future drilling levels, were adjusted by changing the expected production path of the representative well to match the assumptions made above. Initial flow rates were specified by the client to be one-third higher in the Accelerated Depletion Case than they are in the Reference Case, and production was assumed to decline more rapidly after the peak. Overall recovery from the representative well is roughly the same as in the Reference Case. The change in the production profiles captures the assumption that future wells will draw down reserves more intensively in earlier years than they have historically.

Results

In the Accelerated Depletion Case, the effects of depletion on future production and prices are stronger than in the Reference Case (Table 1). All other things being equal, production in the Accelerated Depletion Case is projected to be lower, because adding proved reserves is more difficult. As a result, total oil and gas production is projected to be lower. This means that the rate at which the total underlying resource is depleted is actually lower in the Accelerated Depletion Case than in the Reference Case. Thus, in this instance, the term "accelerated depletion" refers to the rate of reduction in future production caused by individual field depletion, rather than the overall rate of resource depletion.

Domestic production and prices in the Accelerated Depletion Case differ from those in Reference Case in several ways, as outlined below:

- **Prices for natural gas are higher in the Accelerated Depletion Case, while crude oil prices are roughly the same.**

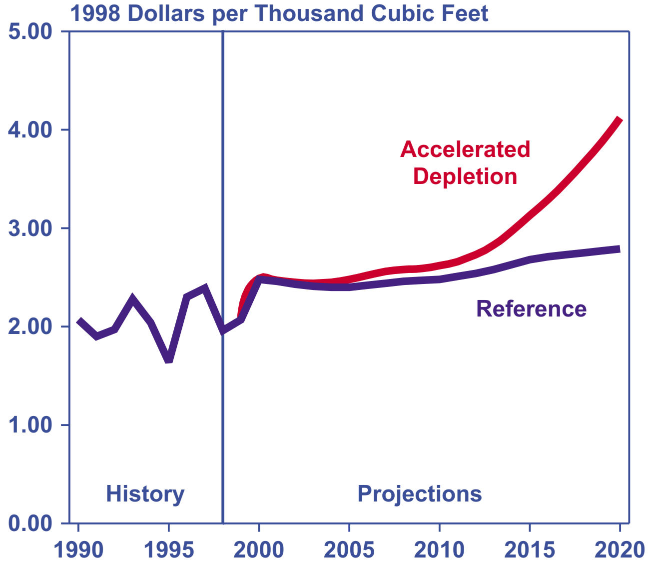
Figure 6 shows how the projected price of natural gas at the wellhead varies from the Reference Case in the Accelerated Depletion Case. The price difference between the two cases grows over time as the cumulative effect of smaller reserve additions reduces production levels in the Accelerated Depletion Case. In 2010, the lower 48 wellhead price of natural gas in the

Table 1. Projected Lower 48 Crude Oil and Natural Gas Production and Natural Gas Wellhead Prices in the Reference and Accelerated Depletion Cases, 2005-2020

Analysis Case	2005	2010	2015	2020
Lower 48 Natural Gas Production (Trillion Cubic Feet per Year)				
Reference	18.9	22.2	24.7	26.0
Accelerated Depletion	18.7	21.8	23.4	22.5
Lower 48 Crude Oil Production (Million Barrels per Day)				
Reference	4.3	4.5	4.8	5.0
Accelerated Depletion	4.3	4.2	4.5	4.7
Lower 48 Natural Gas Wellhead Price (1998 Dollars per Thousand Cubic Feet)				
Reference	2.40	2.48	2.68	2.79
Accelerated Depletion	2.48	2.62	3.13	4.12

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A and OGDEPL.D051200A.

Figure 6. Lower 48 Natural Gas Wellhead Prices in the Reference and Accelerated Depletion Cases, 1990-2020



Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A and OGDEPL.D051200A.

Accelerated Depletion Case is projected to be $2.62 per thousand cubic feet—14 cents higher than in the Reference Case (all prices in 1998 dollars). By 2020, the wellhead price in the Accelerated Depletion Case is projected to be $4.12 per thousand cubic feet—more than double the 1998 price and $1.33 higher than in the Reference Case. Because U.S. oil prices are determined primarily by the world oil price, which generally is unaffected by changes in domestic supply and demand, the projected prices for lower 48 oil at the wellhead are roughly the same in the two cases.

- **Higher natural gas prices lead to lower total energy consumption, lower gas use, and increased use of coal and petroleum.**

Total energy consumption is projected to be about 1 percent lower in the Accelerated Depletion Case than in the Reference Case, a difference of 1.2 quadrillion Btu. Expected total energy use is lower in the Accelerated Depletion Case because of the higher projected natural gas prices. Natural gas consumption in 2020 is roughly 3 quadrillion Btu lower in the Accelerated Depletion Case than in the Reference Case. At the same time, coal use and petroleum use are expected to be 0.7 and 1.0 quadrillion Btu higher, respectively, due to substitution of these fuels for natural gas by consumers faced with higher natural gas prices.[19] The increase in petroleum consumption is made possible by higher projected imports. In the Accelerated Depletion Case, net imports of crude oil and petroleum products increase to 16.9 million barrels per day in 2020, as compared with 15.8 million barrels per day in the Reference Case.

- **Oil and natural gas production is lower in the Accelerated Depletion Case than in the Reference Case, while imports are higher.**

Expected natural gas production in the Accelerated Depletion Case is lower than in the Reference Case (Figure 7), because gas consumption is expected to be lower. The difference is negligible over the first 5 years of the projection but increases over time. In 2015, natural gas production in the lower 48 States in the Accelerated Depletion Case is projected to be 23.4 trillion cubic feet, 1.3 trillion cubic feet lower than in the Reference Case. Gas production increases in the Reference Case between 2015 and 2020 but falls in the Accelerated Depletion Case, and by 2020 it is 3.5 trillion cubic feet, or 13 percent, lower than the Reference Case projection of 26.0 trillion cubic feet.

[19]The projected substitution of coal for natural gas between cases is not just a function of the price in a given year, but also reflects projected capital stocks and relative efficiencies, which are modeled in NEMS. Although coal prices per unit of energy (Btu) produced are projected to be lower than natural gas prices, lower capital and operating costs for natural gas burners make its use economical for electricity generation.

Lower domestic natural gas production in the Accelerated Depletion Case is partially offset by higher imports. While lower 48 production in 2020 is projected to be 3.5 trillion cubic feet lower in the Accelerated Depletion Case than in the Reference Case, natural gas imports are projected to be 640 billion cubic feet higher than in the Reference Case, at 5.5 trillion cubic feet per year. Most of the additional imports are projected to come from Canada; in addition, imports of liquefied natural gas (LNG) are projected to increase by 40 billion cubic feet. In both cases, the United States is projected to be a net exporter to Mexico, with exports exceeding imports from Mexico by 200 billion cubic feet. Increases in imports in response to higher domestic prices for natural gas are constrained in both the Reference and Accelerated Depletion Cases by LNG gasification capacity, expected production levels in Mexico, and limits on pipeline capacity between Canadian gas fields and U.S. markets.

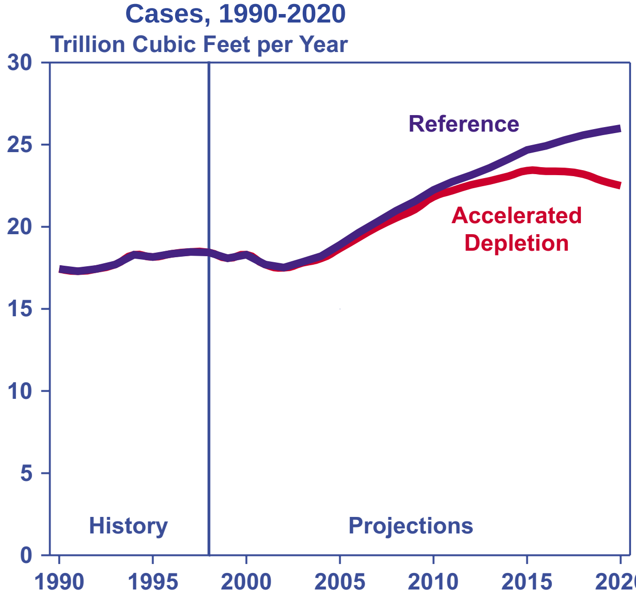
Projected crude oil production in the Accelerated Depletion Case is lower than in the Reference Case throughout most of the projection period. Although oil is more difficult to find in the Accelerated Depletion Case, its price is largely unaffected by the projected decrease in domestic supply. The projected shortfall in production is offset by an increase in imports, which are assumed to be available at the world oil price. Thus, crude oil production in the Accelerated Depletion Case, unlike natural gas production, is not projected to fall as a result of price-related reductions in demand. The assumed high production-to-reserve ratio for new crude oil reserve additions also helps to keep oil production, particularly onshore, from falling off as rapidly as natural gas production. In 2020, lower 48 oil production in the Accelerated Depletion Case is projected to be 4.7 million barrels per day, compared with 5.0 million barrels per day in the Reference Case (Figure 8). The difference is concentrated in offshore production in the Gulf of Mexico. In the Accelerated Depletion Case, smaller fields make some potential projects that were profitable in the Reference Case economically untenable.

- **End-of-year proved reserves drop sharply for natural gas but relatively slowly for crude oil.**

In the Reference Case, end-of-year proved reserves of lower 48 natural gas are projected to be 48 trillion cubic feet higher in 2020 than in 2000, as higher demand requires increased production and therefore more proved reserves. Over the period, reserve additions are projected to outpace production. In contrast, end-of-year natural gas reserves in the Accelerated Depletion Case are projected to increase until 2012 and then decline as the effects of increasingly smaller reserve additions per well accumulate. By 2020, end-of-year reserves in the Accelerated Depletion Case are projected to be 152 trillion cubic feet, 47 trillion cubic feet lower than in the Reference Case and only about 1 trillion cubic feet higher than at the end of 2000.

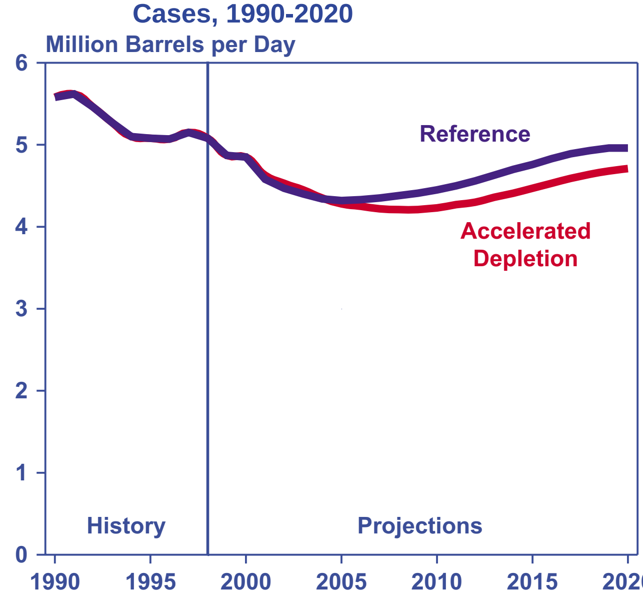
Both the Reference Case and the Accelerated Depletion Case project lower end-of-year crude oil reserves in 2020 than in 2000, as projected production outstrips projected total reserve additions. The Accelerated Depletion Case projects lower 48 reserves of 13.45 billion barrels at the end of 2020, about 0.4 billion barrels (4 percent) less than

Figure 7. Lower 48 Natural Gas Production in the Reference and Accelerated Depletion Cases, 1990-2020



Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A and OGDEPL.D051200A.

Figure 8. Lower 48 Crude Oil Production in the Reference and Accelerated Depletion Cases, 1990-2020



Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A and OGDEPL.D051200A.

in the Reference Case, as compared with a 24-percent difference in the projections for lower 48 natural gas reserves.The difference in lower 48 crude oil reserves occurs in offshore reserves, with less drilling expected in the Accelerated Depletion Case because there are fewer profitable fields to be found. Lower 48 onshore reserves are projected to be higher in the Accelerated Depletion Case than in the Reference Case, as projected oil drilling is higher.

- **Drilling activity is higher in the Accelerated Depletion Case than in the Reference Case.**

Improvements in well profitability as a result of improved production profiles are expected to lead to more drilling in the Accelerated Depletion Case than in the Reference Case. The total number of wells drilled per year roughly doubles between 2000 and 2020 in the Reference Case, and in the Accelerated Depletion Case the number of wells drilled in 2020 is 6 percent higher than in the Reference Case. Exploratory wells, which make up a relatively small portion of total wells drilled in both cases, are projected to be 16 percent more numerous in the Accelerated Depletion Case than in the Reference Case in 2020, whereas the number of developmental wells is projected to be only about 4 percent higher.

Sensitivity Analysis

The Accelerated Depletion Case describes how changing the assumptions about depletion alone may influence U.S. oil and natural gas prices and production. To determine the interaction of the accelerated depletion with other major variables in the model, the report specifically considers the effects of changes to the world price of oil, the rate of technological change, and the level of access to areas in the Rocky Mountains where development of natural gas is restricted. The analysis addresses these factors both independently and in combination. The results of these sensitivity cases are presented below.

Sensitivity of Accelerated Depletion to High Natural Gas Imports

The United States, currently a net importer of natural gas, is expected to continue to rely on imported gas in the future. Accelerated depletion of domestic natural gas resources will cause production to be more difficult in the United States, lowering the amount of natural gas that can be produced at any given price. Although depletion is not limited to the United States, domestic gas fields are considered to be more mature on average than those in Canada, Mexico, or other overseas producers who could supply LNG, suggesting that the effects of accelerated depletion will be felt more strongly by U.S. producers than by the potential suppliers of U.S. imports. Therefore, the higher natural gas prices that domestic consumers would face in the Accelerated Depletion Case could be avoided if additional natural gas imports were available from other countries where the effects of accelerated depletion were less pronounced.

The Accelerated Depletion with High Natural Gas Imports Case is designed to test the sensitivity of the Accelerated Depletion Case results to a change in assumptions that allow import capacity to increase beyond the reference case levels. In the Accelerated Depletion with High Natural Gas Imports Case, several assumptions were changed to show how more imports could influence the projections in the Accelerated Depletion Case.

Three changes were made to the Reference Case assumptions to show how higher projected prices in the Accelerated Depletion Case might increase imports of natural gas, and what effect the increase would have on the rest of the market:

- First, the total capacity for imports from Canada was increased. Increasing Canadian imports are projected in the Reference Case, based on past trends. Imports from Canada roughly doubled from 1990 to 1998, when they accounted for about 14 percent of total supply. Canadian natural gas imports are projected to increase from 1998 to 2020 in both the Reference Case and the Accelerated Depletion Case, but they are constrained by the projected capacity of natural gas pipelines between Canada and the United States. The Accelerated Depletion with High Natural Gas Imports Case relaxes the constraints on potential Canadian imports by increasing pipeline capacity. By 2020, the pipeline capacity to carry natural gas from Canada is projected to be 20 percent higher in the Accelerated Depletion with High Natural Gas Imports Case than in the Reference and Accelerated Depletion Cases. Higher pipeline capacity allows for an increase of 460 billion cubic feet per year in Canadian imports in 2020, 9 percent more than in the Accelerated Depletion Case.
- Second, it was assumed that Mexico would become a net exporter of gas to the United States, rather than a net importer as in the Reference and Accelerated Depletion Cases, with higher prices stimulating an increase in Mexico's production of natural gas for export to the United States. In the Reference and Accelerated Depletion Cases, the United States is projected to export 200 billion cubic feet of gas to the United States in 2020; however, in the Accelerated Depletion with High Natural Gas Imports Case, Mexico is projected to export 90 billion cubic feet per year to the United States in 2020.

- Third, U.S. imports of LNG in the Accelerated Depletion with High Natural Gas Imports Case are projected to increase to 450 billion cubic feet per year in 2020, compared with only 330 billion cubic feet in the Reference Case and 370 billion cubic feet in the Accelerated Depletion Case. Total U.S. imports of natural gas are projected to be 6.36 trillion cubic feet in 2020, compared with 5.52 trillion cubic feet in the Accelerated Depletion Case.

Higher imports lead to lower domestic prices for natural gas than are projected in the Accelerated Depletion Case, as more plentiful supplies allow consumers to buy more gas at lower prices. In the Accelerated Depletion with High Natural Gas Imports Case, the lower 48 wellhead price of natural gas in 2020 is projected to be $3.69 per million cubic feet—$0.90 higher than in the Reference Case but $0.43 lower than in the Accelerated Depletion Case (Table 2). As a result, lower 48 production of natural gas is projected to be lower, at 22.1 trillion cubic feet per year in 2020, than in the Accelerated Depletion Case (22.5 trillion cubic feet in 2020). Because the change in assumptions is limited to imports of natural gas, the projected level of domestic oil production in the High Natural Gas Imports Case is nearly the same as in the Accelerated Depletion Case.

The assumptions for the Accelerated Depletion with High Natural Gas Imports Case do not extend the projected effects of accelerated depletion to either Mexican or Canadian resources. Although those resources are also subject to depletion, development of a methodology to introduce similar accelerated depletion assumptions into the Mexican and Canadian markets is beyond the scope of this analysis.

Sensitivity of Accelerated Depletion to World Oil Prices

The world price of oil is determined by the international market. Although the U.S. consumes roughly one quarter of all oil consumed internationally, the changes in supply and demand considered in this analysis are small enough to ignore in the context of the world market, and the world price of oil is assumed to be independent of domestic petroleum market changes. World oil prices determine the level of domestic crude oil production, with the difference between domestic supply and demand being made up by imports. Higher oil prices lead to increased drilling for oil, increased domestic production, and lower demand and imports.

The impact of higher oil prices on natural gas prices is limited, because of the limited opportunities for further fuel switching from oil to natural gas. The Reference Case projects that roughly three quarters of all petroleum used in 2020 will be for transportation. The total amount of oil used in transportation is not very sensitive to price, and the NEMS projections show no substitution of natural gas for oil in the transportation sector. When the world oil price assumption is changed, substitution between the two fuels is projected for other sectors of the economy—notably commercial, industrial, and electric generation—but those opportunities are also limited. In total, changes in oil prices have only limited impact on natural gas demand, prices, and production.

This analysis uses the high and low oil price cases developed for *AEO2000* to assess the impact of the world price of oil on production and prices in the Accelerated Depletion Case. The oil price assumptions are designed to represent long-term trends and do not capture short-term

Table 2. Projected Lower 48 Crude Oil and Natural Gas Production and Natural Gas Wellhead Prices in the Reference, Accelerated Depletion, and Accelerated Depletion with High Natural Gas Imports Cases, 2005-2020

Analysis Case	2005	2010	2015	2020
Lower 48 Natural Gas Production (Trillion Cubic Feet per Year)				
Reference	18.9	22.2	24.7	26.0
Accelerated Depletion	18.7	21.8	23.4	22.5
Accelerated Depletion with High Natural Gas Imports	18.6	21.6	23.0	22.1
Lower 48 Crude Oil Production (Million Barrels per Day)				
Reference	4.3	4.5	4.8	5.0
Accelerated Depletion	4.3	4.2	4.5	4.7
Accelerated Depletion with High Natural Gas Imports	4.3	4.2	4.5	4.7
Lower 48 Natural Gas Wellhead Price (1998 Dollars per Thousand Cubic Feet)				
Reference	2.40	2.48	2.68	2.79
Accelerated Depletion	2.48	2.62	3.13	4.12
Accelerated Depletion with High Natural Gas Imports	2.45	2.56	2.98	3.69

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A, OGDEPL.D051200A, and DEPL2.D071700A.

fluctuations in prices. Through 2001 the forecast was calibrated to more recent projections from EIA's *Short-Term Energy Outlook*,[20] which became available after the completion of *AEO2000*. The world price in 2020 is projected to be $22.04 per barrel (in real 1998 dollars) in the Reference and Accelerated Depletion Cases in this report, $28.04 in the High World Oil Price Case, and $14.90 in the Low World Oil Price Case. In all the cases, the price changes smoothly with each year to reach its 2020 target.

The world oil market has been volatile in recent years. Prices increased sharply during 1999 and the first months of 2000, as the spot price for West Texas Intermediate crude climber from just over $12 a barrel in February 1999 to over $30 a barrel in March 2000. Such volatility is not expected to have much influence on average prices in the long term, as market forces are expected to return prices to a lower level over the next several years.[21]

In the Accelerated Depletion Case, the lower 48 wellhead price for crude oil closely follows the path set by the world price of crude. In 2020, the lower 48 wellhead price is $21.21 per barrel in the Accelerated Depletion Case, compared with $21.27 in the Reference Case. In the High and Low World Oil Price Cases, the lower 48 wellhead price in 2020 is projected to be $27.59 and $13.88 per barrel, respectively (Table 3).

The price difference between the Accelerated Depletion Case and the Accelerated Depletion with High and Low World Oil Price Cases are greater for oil than for natural gas. In the Accelerated Depletion Case, the wellhead price for natural gas is projected to be $4.12 per thousand cubic feet with reference world oil prices, $3.60 per thousand cubic feet with low world oil prices, and $4.40 per thousand cubic feet with high world oil prices (Figure 9). The greatest differences are projected for the later years of the forecast period. Lower 48 wellhead prices for natural gas are higher in the Accelerated Depletion with High World Oil Price Case than in the Accelerated Depletion Case because of higher demand for natural gas in the non-transportation sectors. With lower world oil prices the same sectors substitute oil for natural gas, and the projected gas prices are lower.

Higher wellhead prices lead to higher domestic production of both oil and natural gas (Figure 10). In the Accelerated Depletion with High World Oil Price Case, lower 48 oil production in 2020 is projected to be 5.3 million barrels per day, 13 percent higher than in the Accelerated Depletion Case. With high world oil prices, total U.S. crude oil production is projected to remain higher each year than in the Reference Case. For natural gas, the assumption of accelerated depletion keeps production levels below those in the reference case even when high world oil prices are also assumed (Figure 11). Lower 48 natural gas production in the Accelerated Depletion with High World Oil Price Case is projected to be 23.0 trillion cubic feet per year in 2020, compared with 22.5 trillion cubic feet in the Accelerated Depletion Case and 26.0 trillion cubic feet in the Reference Case.

Sensitivity of Accelerated Depletion to Rates of Technology Improvement

NEMS incorporates assumptions about the rate of technological change into its projections of future energy use. Technology enters the OGSM in three major ways:

- **Future costs are reduced.** Drilling, lease equipment, and operating costs incorporate the separate impacts

Table 3. Projected Lower 48 Crude Oil and Natural Gas Production and Natural Gas Wellhead Prices in the Accelerated Depletion and Accelerated Depletion with High and Low World Oil Price Cases, 2005-2020

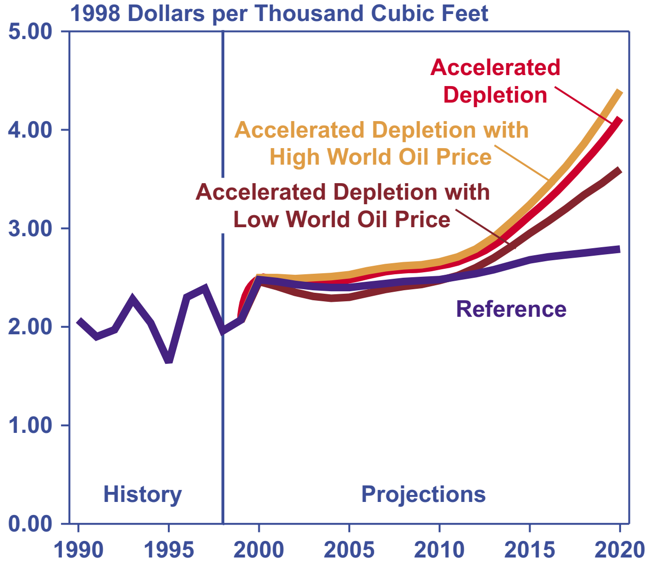
Analysis Case	2005	2010	2015	2020
Lower 48 Natural Gas Production (Trillion Cubic Feet per Year)				
Accelerated Depletion	18.7	21.8	23.4	22.5
Accelerated Depletion with High World Oil Price	18.9	22.2	23.8	23.0
Accelerated Depletion with Low World Oil Price	18.6	21.7	22.9	21.9
Lower 48 Crude Oil Production (Million Barrels per Day)				
Accelerated Depletion	4.3	4.2	4.5	4.7
Accelerated Depletion with High World Oil Price	4.5	4.5	4.9	5.3
Accelerated Depletion with Low World Oil Price	4.0	3.9	3.9	4.1
Lower 48 Natural Gas Wellhead Price (1998 Dollars per Thousand Cubic Feet)				
Accelerated Depletion	2.48	2.62	3.13	4.12
Accelerated Depletion with High World Oil Price	2.53	2.66	3.24	4.40
Accelerated Depletion with Low World Oil Price	2.30	2.47	2.95	3.60

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGDEPL.D051200A, OGHWOP.D051200A, and OGLWOP.D051200A.

[20]Energy Information Administration, *Short-Term Energy Outlook*, DOE/EIA-0202(00/2Q) (Washington, DC, April 2000), www.eia.doe.gov/pub/forecasting/steo/oldsteos/apr00.pdf.

[21]For a detailed discussion of the expected influence of recent high prices on long-term oil markets, see "Oil Market Volatility: The Long-Term Perspective," in Energy Information Administration, *International Energy Outlook 2000*, DOE/EIA-0484(2000) (Washington, DC, March 2000), p. xii.

Figure 9. Lower 48 Natural Gas Wellhead Prices in the Reference, Accelerated Depletion, and Accelerated Depletion with High and Low World Oil Price Cases, 1990-2020



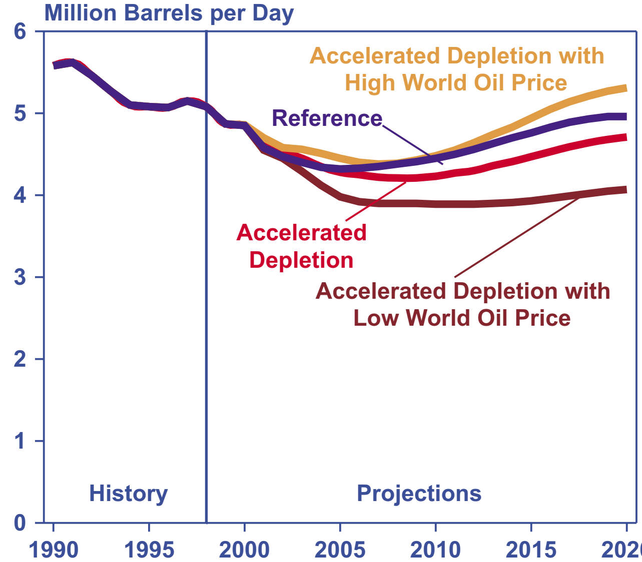
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A, OGDEPL.D051200A, OGHWOP.D051200A, and OGLWOP.D051200A.

of drilling to greater depths, the level of drilling activity, and technological progress. For drilling costs to decline, technological improvement must offset the upward pressure on costs due to drilling to deeper depths and increased drilling activity. In general, projected future drilling costs decline incrementally with each additional year, along with equipment costs and lease operating costs. This represents the oil and gas industry's continuing innovation in techniques that reduce production costs.

- **Drilling is more accurate.** The success rate for exploratory wells increases, as technology reduces the ratio of dry holes to total drilling activity.
- **Drilling becomes more effective.** The amount of reserve additions per well (or finding rate) captures the impact of technological improvement (as well as the effects of price variations and declining resources). In the absence of technology and price impacts the finding rate declines, reflecting the natural progression of the discovery process from larger, more profitable fields to smaller, less economical ones. Technological improvement helps to offset the natural decline in the finding rate.

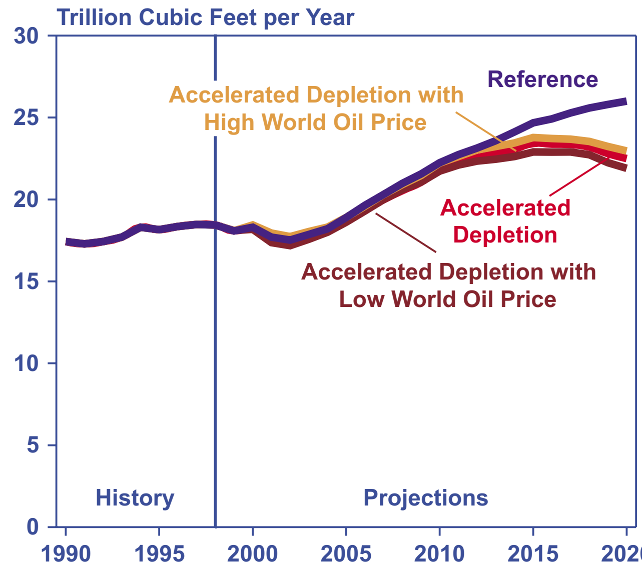
The effects of technology on production are modeled differently in each submodule of OGSM, but each module captures the effects of technology on production costs and drilling activity. In the conventional oil and gas module, technology enters as a parameter in the cost equations and finding rate equations. In the unconventional module, which is play-specific, technology

Figure 10. Lower 48 Crude Oil Production in the Reference, Accelerated Depletion, and Accelerated Depletion with High and Low World Oil Price Cases, 1990-2020



Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A, OGDEPL.D051200A, OGHWOP.D051200A, and OGLWOP.D051200A.

Figure 11. Lower 48 Natural Gas Production in the Reference, Accelerated Depletion, and Accelerated Depletion with High and Low World Oil Price Cases, 1990-2020



Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A, OGDEPL.D051200A, OGHWOP.D051200A, and OGLWOP.D051200A.

determines the years in which certain plays may be opened for development, how quickly the best producing locations in a given play can be identified, when certain techniques will become available, and at what rate costs will decline. (A play is defined as a set of oil or gas accumulations sharing similar geologic, geographic, and temporal properties.)

The focus of this part of the analysis is to consider how changes in assumptions about future technological development change the effects of accelerated depletion on U.S. oil and natural gas prices and production. For oil, the analysis considers only how technological change influences U.S. production. The world oil price is assumed to follow the same path in these sensitivity cases as in the Reference Case.

Rapid and Slow Technology Cases

As a first approach to assess the effect of varying the rate of technological development on prices and production in the Accelerated Depletion Case, the drilling success rates, finding rates, and changes in costs were adjusted in the conventional modules, with corresponding changes in the unconventional production modules. The assumptions for the Rapid and Slow Technology Cases are similar to those for the *AEO2000* rapid and slow technology cases, with only minor differences (see Appendix E for detailed assumptions). The Accelerated Depletion with Rapid and Slow Technology Growth Cases are designed to highlight the uncertainty around the effects of technological development, but they should not be considered a formal confidence interval.

Faster growth of technology in the Accelerated Depletion with Rapid Technology Growth Case is accompanied by higher projected natural gas production (Table 4 and Figure 12). Natural gas production in 2020 in the Accelerated Depletion with Rapid Technology Case is projected at 28.4 trillion cubic feet, as compared with 22.5 trillion cubic feet in the Accelerated Depletion Case, and is higher in every year of the forecast. Faster improvement in drilling technology is also projected to result in lower wellhead prices (Figure 13). In the Accelerated Depletion with Rapid Technology Case, the price of natural gas is projected to be $2.37 per thousand cubic feet in 2020 (more than 40 cents lower than in the Reference Case), compared with $4.12 per thousand cubic feet in the Accelerated Depletion Case.

Like natural gas production, projected crude oil production in the lower 48 States is higher when rapid technology growth is assumed. Production of more than 5 million barrels per day is projected for 2020 in the Accelerated Depletion with Rapid Technology Case, compared with 4.7 million barrels per day in the Accelerated Depletion Case. With rapid technology growth, oil production is uniformly higher throughout the forecast than it is in the Accelerated Depletion Case or the Reference Case (Figure 14). The wellhead price of crude oil in the lower 48 States changes only slightly, because the world oil price is independent of the technology assumption.

In the Accelerated Depletion with Slow Technology Case, the effects of accelerated depletion on prices and production are exacerbated. By 2020, the wellhead price of natural gas is projected to be an additional 44 cents per thousand cubic feet higher and lower 48 gas production an additional 2.2 thousand cubic feet less than in the Accelerated Depletion Case. Lower 48 oil production in 2020 is also lower by 700,000 barrels per day, or roughly 14 percent, than in the Accelerated Depletion Case.

Improved and Reduced Productivity Technology Cases

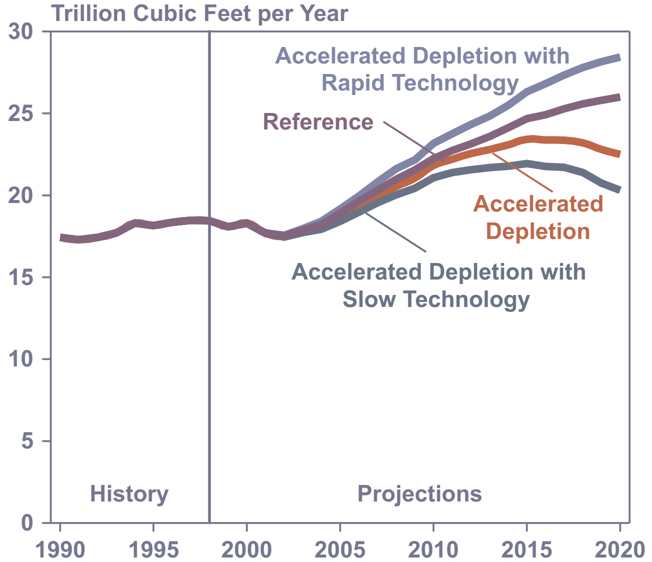
In addition to the Accelerated Depletion with Rapid and Slow Technology Cases, this analysis also considers Accelerated Depletion with Improved and Reduced Productivity Technology Cases, which are subsets of the technology sensitivity cases described above. In these more focused cases, the changes in the assumed rate of

Table 4. Projected Lower 48 Crude Oil and Natural Gas Production and Natural Gas Wellhead Prices in the Accelerated Depletion and Accelerated Depletion with Rapid and Slow Technology Cases, 2005-2020

Analysis Case	2005	2010	2015	2020
Lower 48 Natural Gas Production (Trillion Cubic Feet per Year)				
Accelerated Depletion	18.7	21.8	23.4	22.5
Accelerated Depletion with Rapid Technology Growth	19.2	23.2	26.8	28.4
Accelerated Depletion with Slow Technology Growth	18.4	21.1	21.9	20.3
Lower 48 Crude Oil Production (Million Barrels per Day)				
Accelerated Depletion	4.3	4.2	4.5	4.7
Accelerated Depletion with Rapid Technology Growth	4.4	4.6	5.0	5.3
Accelerated Depletion with Slow Technology Growth	4.1	4.0	4.0	4.0
Lower 48 Natural Gas Wellhead Price (1998 Dollars per Thousand Cubic Feet)				
Accelerated Depletion	2.48	2.62	3.13	4.12
Accelerated Depletion with Rapid Technology Growth	2.31	2.30	2.32	2.37
Accelerated Depletion with Slow Technology Growth	2.57	2.83	3.59	4.56

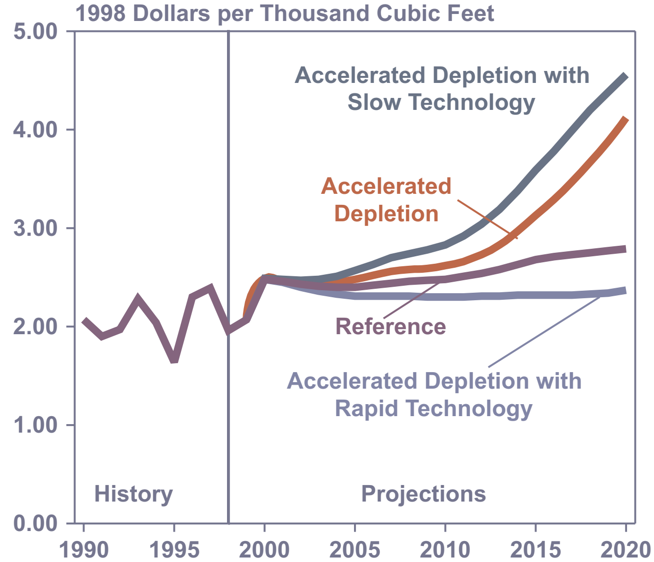
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGDEPL.D051200A, OGRTECH.D051200A, and OGSLOW.D051200A.

Figure 12. Lower 48 Natural Gas Production in the Reference, Accelerated Depletion, and Accelerated Depletion with Rapid and Slow Technology Cases, 1990-2020



Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A, OGDEPL.D051200A, OGRTECH.D051200A, and OGSLOW. D051200A.

Figure 13. Lower 48 Natural Gas Wellhead Prices in the Reference, Accelerated Depletion, and Accelerated Depletion with Rapid and Slow Technology Cases, 1990-2020



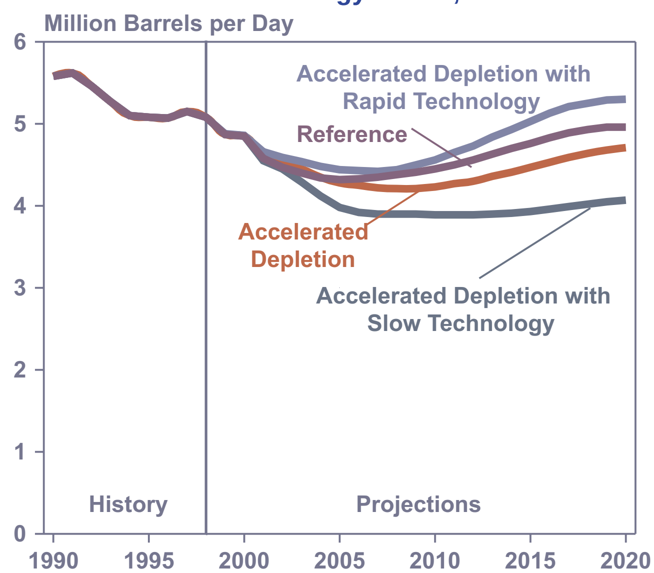
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A, OGDEPL.D051200A, OGRTECH.D051200A, and OGSLOW. D051200A.

technological progress from the Reference Case are limited to advances in production technology only. In the conventional model, only the finding rate, or the ultimate amount of proved reserves added with each well is adjusted. The other parameters, specifically the effects of technological development on costs and success rates for drilling, are not adjusted in this case, which was designed specifically to capture changes in production technology by itself. In the unconventional natural gas module, the adjustments for the Accelerated Depletion with Improved and Reduced Productivity Technology Cases are limited to performance technology assumptions, and not the assumptions about changes in costs or exploration technology (see Appendix E for specific assumptions).

Relative to the Reference Case, changes in prices and production in the Improved and Reduced Productivity Technology Cases are similar to those in the Accelerated Depletion Case but not as pronounced. Higher production in the Accelerated Depletion with Improved Productivity Technology Case leads to a projected natural gas wellhead price of $2.99 per thousand cubic feet in 2020, compared with $4.12 in the Accelerated Depletion Case (Table 5) and $2.37 in the Accelerated Depletion with Rapid Technology Growth Case (Table 4). Total gas production in 2020 in the Accelerated Depletion with Improved Productivity Technology Case is 3.3 trillion cubic feet higher than in the Accelerated Depletion Case.

Changing the finding rate by itself is enough to bring total natural gas production close to the levels projected in the Reference Case. Lower 48 natural gas production in the Accelerated Depletion with Improved Productivity Technology Case is slightly higher then in the Reference Case through most of the years of the forecast but slows to a level about 1 percent below the Reference

Figure 14. Lower 48 Crude Oil Production in the Reference, Accelerated Depletion, and Accelerated Depletion with Rapid and Slow Technology Cases, 1990-2020



Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A, OGDEPL.D051200A, OGRTECH.D051200A, and OGSLOW. D051200A.

Table 5. Projected Lower 48 Crude Oil and Natural Gas Production and Natural Gas Wellhead Prices in the Accelerated Depletion and Accelerated Depletion with Improved and Reduced Productivity Technology Cases, 2005-2020

Analysis Case	2005	2010	2015	2020
Lower 48 Natural Gas Production (Trillion Cubic Feet per Year)				
Accelerated Depletion	18.7	21.8	23.4	22.5
Accelerated Depletion with Improved Productivity Technology	19.0	22.8	25.2	25.8
Accelerated Depletion with Reduced Productivity Technology	18.6	21.6	22.8	21.9
Lower 48 Crude Oil Production (Million Barrels per Day)				
Accelerated Depletion	4.3	4.2	4.5	4.7
Accelerated Depletion with Improved Productivity Technology	4.4	4.6	5.0	5.3
Accelerated Depletion with Reduced Productivity Technology	4.1	4.0	4.0	4.1
Lower 48 Natural Gas Wellhead Price (1998 Dollars per Thousand Cubic Feet)				
Accelerated Depletion	2.48	2.62	3.13	4.12
Accelerated Depletion with Improved Productivity Technology	2.37	2.39	2.65	2.99
Accelerated Depletion with Reduced Productivity Technology	2.49	2.66	3.33	4.24

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGDEPL.D051200A, OGFRHTEC.D051200A, and OGFRLTEC.D051200A.

Case level in 2020. Lower 48 gas prices in the two cases differ by no more than 10 cents per thousand cubic feet until the last two years of the forecast. Oil production is uniformly higher in the Accelerated Depletion with Improved Productivity Technology Case than in the Reference Case, suggesting that the effects of accelerated depletion could be partially offset by improving production technology alone. The rate of technological growth assumed in the improved technology case is a composite of many individual expected improvements. Projecting the specific technologies introduced—and the level of investment that would be required to develop the technologies—is not within the scope of this analysis.

Sensitivity of Accelerated Depletion to Increased Access to Federal Lands in the Rocky Mountain Region

A large portion of the Nation's natural gas resource base is located on Federal lands (and in Federal waters) where development is restricted or prohibited. These restrictions reduce the accessible resource base and limit industry's ability to exploit known resources.

The Rocky Mountain region is an area of high future potential for natural gas production. Environmental and other constraints currently preclude industry's access to about 45 percent of the resource. The Rocky Mountain resource volumes and access restrictions are consistent with the findings of the recent National Petroleum Council study, which found that 40 percent of the natural gas resource located in the Rockies is either closed to exploration or faces severe restrictions on development.

Efficient development of the resource is further restricted by the complex nature of the reservoirs found in the Rocky Mountain basins. Much of the gas resource is locked in coalbed methane, gas shales, and low permeability/low porosity ("tight") sandstone formations—reservoirs that require special characterization, drilling, completion, and production techniques to become economically feasible to produce.

Accelerated Depletion in Rocky Mountain Basins

In the Accelerated Depletion Case, a "current technology" recoverable unconventional gas resource base was assumed to be approximately 235 trillion cubic feet in the Rocky Mountain region at the end of 1998. Of this, 108 trillion cubic feet is off limits because of development restrictions. Essentially 45 percent of the technically recoverable unconventional gas resource is deemed currently unavailable due to environmental and access constraints. Another 87 trillion cubic feet of resource is accessible but not economical to develop with today's technology and gas prices. Given these restrictions and economic realities, the current production level of 2.1 trillion cubic feet per year from unconventional sources is projected to increase to only 2.7 trillion cubic feet by 2020.

Under the conditions of the Accelerated Depletion Case, only limited improvements in technology are assumed to be made with respect to reservoir characterization and well performance, while exploration technology experiences no improvements at all. Optimization and cost reduction technologies are assumed to make some modest improvements, as in the Reference Case, and additional access is restricted under the Accelerated Depletion Case.[22]

[22]Small amounts of access were granted to those plays that had active development in 1999.

As shown in Table 6, the results of the Accelerated Depletion Case in the Rocky Mountain basins are as follows:

- Natural gas prices in the Rocky Mountain region are projected to reach $3.69 per thousand cubic feet in 2020, compared with $2.40 per thousand cubic feet in the Reference Case. Lower 48 average wellhead prices in 2020 are projected to reach $4.12 per thousand cubic feet in the Accelerated Depletion Case and $2.79 per thousand cubic feet in the Reference Case.
- 141 trillion cubic feet (38 percent) of the resource is projected to be either not accessible or economically infeasible in 2020.
- Production of natural gas is projected to remain modest, reaching 3.8 trillion cubic feet in 2020 compared with about 5 trillion cubic feet in the Reference Case.

Providing High Access to Rocky Mountain Basins

One potential approach to stimulating additional natural gas production (and countering the effects of accelerated depletion) is to provide increased access to resources in the Rocky Mountain natural gas basins. A list of the basins where access is expanded in the High Rocky Mountain Access Case is given in Appendix F. In this case, access to those basins is projected to increase steadily over the course of the next 20 years. (All other response levers are consistent with those in the Accelerated Depletion Case.)

As shown in Table 7, the results of the Accelerated Depletion with High Rocky Mountain Access Case are as follows:

- Total natural gas production from Rocky Mountain basins is projected to be 0.5 trillion cubic feet higher than in the Accelerated Depletion Case, at 4.3 trillion cubic feet per year in 2020.
- Natural gas wellhead prices in the Rocky Mountain region are projected to be 30 cents per thousand cubic feet lower, at $3.39 per thousand cubic feet in 2020.
- The great bulk of the Rocky Mountain unconventional natural gas resource is projected to become accessible, leaving only 18 trillion cubic feet without access in 2020.
- About one-third of the unconventional resource made physically accessible is projected to remain uneconomical due to high costs and inadequate exploration and production technology.

Table 6. Projected Unconventional Natural Gas Resource Base, Natural Gas Production, and Wellhead Natural Gas Prices in the Rocky Mountain Region, Accelerated Depletion Case, 2000 and 2020

Projection	2000	2020
Unconventional Resource Base (Trillion Cubic Feet)		
Accessible and Economical	39	110
Accessible But Not Economical	87	44
Not Accessible	108	97
Total Unconventional Resource	**235**	**251**
Total Regional Natural Gas Production (Trillion Cubic Feet per Year)	3.1	3.8
Regional Natural Gas Wellhead Price (1998 Dollars per Thousand Cubic Feet)	2.20	3.69

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System run OGDEPL.D051200A.

Table 7. Projected Unconventional Natural Gas Resource Base, Natural Gas Production, and Wellhead Natural Gas Prices in the Rocky Mountain Region, Accelerated Depletion and Accelerated Depletion with High Rocky Mountain Access Cases, 2000 and 2020

Projection	Accelerated Depletion		Accelerated Depletion with High Access, 2020
	2000	2020	
Unconventional Resource Base (Trillion Cubic Feet)			
Accessible and Economical	39	110	148
Accessible But Not Economical	87	44	84
Not Accessible	108	97	18
Total Unconventional Resource	**235**	**251**	**251**
Total Regional Natural Gas Production (Trillion Cubic Feet per Year)	3.1	3.8	4.3
Regional Natural Gas Wellhead Price (1998 Dollars per Thousand Cubic Feet)	2.20	3.69	3.39

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGDEPL.D051200A and OGACCESS.D051200A.

Providing Rapid Technological Progress to Rocky Mountain Basins

A second alternative for increasing production and arresting the effects of accelerated depletion would be to increase the rate at which technology is developed. More rapid technology development would expand the technically recoverable resource base by increasing the productive areas of economic plays, increasing efficiency, and reducing the costs associated with the exploration and production of natural gas resources.

Improved Productivity Technology

To evaluate gas production in the Rocky Mountains in the Accelerated Depletion with Improved Productivity Technology Case, the reservoir characterization and well performance technology levers were changed as requested by the Office of Fossil Energy, so that the rate of change in productivity technology was 50 percent higher than in the Reference Case. Other types of technology growth were kept at the reference level.

The effects of the improved productivity technology assumption on Rocky Mountain natural gas resources in the Accelerated Depletion Case (Table 8) are summarized below:

- Natural gas production from the Rocky Mountain basins in 2020 is projected to be 1.5 trillion cubic feet higher than in the Accelerated Depletion Case, at 5.3 trillion cubic feet of annual production.
- The Rocky Mountain natural gas wellhead price is projected to be $2.45 per thousand cubic feet in 2020, $1.24 per thousand cubic feet lower than in the Accelerated Depletion Case.
- The technically recoverable resource is projected to grow by 86 trillion cubic feet, yielding a total of 337 trillion cubic feet.
- Despite improvements in exploration and production technology and considerable growth in the resource, 37 percent of the resource base (126 trillion cubic feet) is projected to remain inaccessible in 2020, because of the limits imposed by environmental restrictions on exploration and production.

Rapid Technology Growth

To examine the impacts of the Accelerated Depletion with Rapid Technology Growth Case on Rocky Mountain gas production, all technology settings—including production technology—were set roughly 50 percent higher than the Reference Case settings. Access was still

Table 8. Projected Unconventional Natural Gas Resource Base, Natural Gas Production, and Wellhead Natural Gas Prices in the Rocky Mountain Region, Accelerated Depletion and Accelerated Depletion with Improved Productivity Technology Cases, 2000 and 2020

Projection	Accelerated Depletion 2000	Accelerated Depletion 2020	Accelerated Depletion with Improved Productivity Technology, 2020
Unconventional Resource Base (Trillion Cubic Feet)			
Accessible and Economical	39	110	158
Accessible But Not Economical	87	44	53
Not Accessible	108	97	126
Total Unconventional Resource	**235**	**251**	**337**
Total Regional Natural Gas Production (Trillion Cubic Feet per Year)	3.1	3.8	5.3
Regional Natural Gas Wellhead Price (1998 Dollars per Thousand Cubic Feet)	2.20	3.69	2.45

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGDEPL.D051200A and OGFRHTEC.D051200A.

Table 9. Projected Unconventional Natural Gas Resource Base, Natural Gas Production, and Wellhead Natural Gas Prices in the Rocky Mountain Region, Accelerated Depletion and Accelerated Depletion with Rapid Technology Cases, 2000 and 2020

Projection	Accelerated Depletion 2000	Accelerated Depletion 2020	Accelerated Depletion with Rapid Technology, 2020
Unconventional Resource Base (Trillion Cubic Feet)			
Accessible and Economical	39	110	210
Accessible But Not Economical	87	44	44
Not Accessible	108	97	140
Total Unconventional Resource	**235**	**251**	**394**
Total Regional Natural Gas Production (Trillion Cubic Feet per Year)	3.1	3.8	6.5
Regional Natural Gas Wellhead Price (1998 Dollars per Thousand Cubic Feet)	2.20	3.69	1.86

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGDEPL.D051200A and OGRTECH.D051200A.

assumed to be restricted, keeping this setting consistent with the Accelerated Depletion Case.

The effects of the rapid technology assumption on Rocky Mountain natural gas resources in the Accelerated Depletion Case (Table 9) are summarized below:

- Natural gas production in the Rocky Mountain region is projected to be 6.5 trillion cubic feet in 2020, exceeding the projected production in the Accelerated Depletion Case by 2.7 trillion cubic feet.
- Natural gas wellhead prices in the Rocky Mountain region in 2020 are projected to be $1.86 per thousand cubic feet, about half their level in the Accelerated Depletion Case.
- The technically recoverable resource is expected to be 143 trillion cubic feet higher than in the Accelerated Depletion Case; however, 140 trillion cubic feet of the resource base is projected to remain inaccessible in 2020, with an additional 44 trillion cubic feet being accessible but not economically viable.

Providing High Access and Accelerated Technological Progress to Rocky Mountain Basins

The Accelerated Depletion with High Rocky Mountain Access and Improved Productivity Technology Case and the Accelerated Depletion with High Rocky Mountain Access and Rapid Technology Case combine high resource access and more rapid technological progress assumptions. The effects on Rocky Mountain gas production and prices (Tables 10 and 11) are summarized below.

Accelerated Depletion with High Rocky Mountain Access and Improved Productivity Technology

- In this analysis case, natural gas production in the Rocky Mountains is projected to be 5.7 trillion cubic feet in 2020, 1.9 trillion cubic feet higher than the level projected in the Accelerated Depletion Case.
- Natural gas wellhead prices in the Rocky Mountain region are projected to be $2.25 per thousand cubic

Table 10. Projected Unconventional Natural Gas Resource Base, Natural Gas Production, and Wellhead Natural Gas Prices in the Rocky Mountain Region, Accelerated Depletion and Accelerated Depletion with High Rocky Mountain Access and Improved Productivity Technology Cases, 2000 and 2020

Projection	Accelerated Depletion		Accelerated Depletion with High Access and Improved Productivity Technology, 2020
	2000	2020	
Unconventional Resource Base (Trillion Cubic Feet)			
Accessible and Economical	39	110	215
Accessible But Not Economical	87	44	95
Not Accessible	108	97	23
Total Unconventional Resource	**235**	**251**	**333**
Total Regional Natural Gas Production (Trillion Cubic Feet per Year)	3.1	3.8	5.7
Regional Natural Gas Wellhead Price (1998 Dollars per Thousand Cubic Feet)	2.20	3.69	2.25

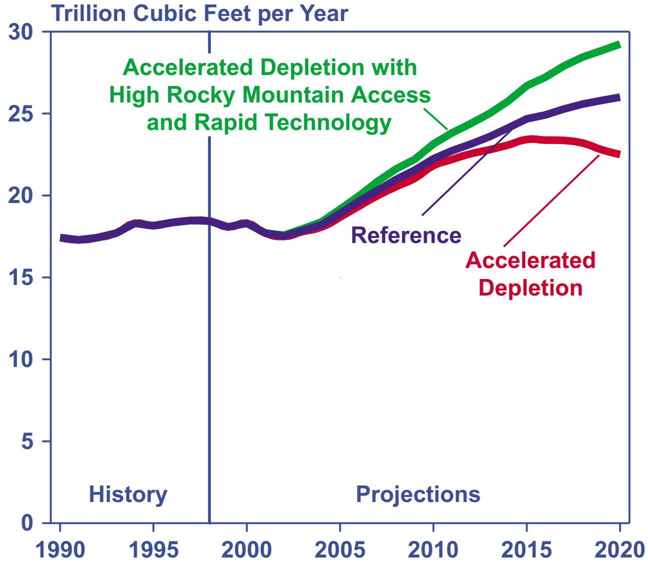
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGDEPL.D051200A and OGACCFR.D051200A.

Table 11. Projected Unconventional Natural Gas Resource Base, Natural Gas Production, and Wellhead Natural Gas Prices in the Rocky Mountain Region, Accelerated Depletion and Accelerated Depletion with High Rocky Mountain Access and Rapid Technology Cases, 2000 and 2020

Projection	Accelerated Depletion		Accelerated Depletion with High Access and Rapid Technology, 2020
	2000	2020	
Unconventional Resource Base (Trillion Cubic Feet)			
Accessible and Economical	39	110	286
Accessible But Not Economical	87	44	79
Not Accessible	108	97	27
Total Unconventional Resource	**235**	**251**	**393**
Total Regional Natural Gas Production (Trillion Cubic Feet per Year)	3.1	3.8	7.6
Regional Natural Gas Wellhead Price (1998 Dollars per Thousand Cubic Feet)	2.20	3.69	1.69

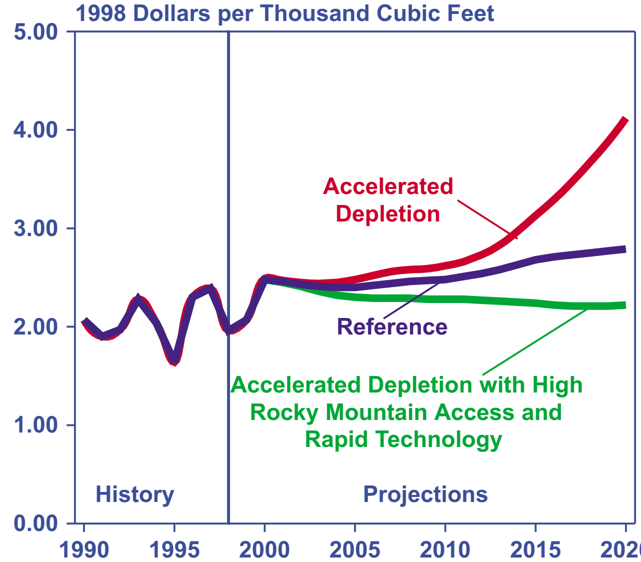
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGDEPL.D051200A and OGRAPID.D051200A.

Figure 15. Lower 48 Natural Gas Production in the Reference, Accelerated Depletion, and Accelerated Depletion with High Rocky Mountain Access and Rapid Technology Cases, 1990-2020



Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A, OGDEPL.D051200A, and OGRAPID. D051200A.

Figure 16. Lower 48 Natural Gas Wellhead Prices in the Reference, Accelerated Depletion, and Accelerated Depletion with High Rocky Mountain Access and Rapid Technology Cases, 1990-2020



Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A, OGDEPL.D051200A, and OGRAPID. D051200A.

feet in 2020, $1.44 per thousand cubic feet lower than in the Accelerated Depletion Case.

- In 2020, 64 percent of the technically recoverable resource is expected to be economical and accessible, leaving only 7 percent of the resource "off limits."

Accelerated Depletion with High Rocky Mountain Access and Rapid Technology

- In this case, natural gas production in the Rocky Mountain region is projected to be twice as large as it is in the Accelerated Depletion Case, reaching 7.6 trillion cubic feet of annual production in 2020, as more resources are open to development and more rapid introduction of technology lowers production costs. Lower 48 gas production is projected to total 29.2 trillion cubic feet in 2020, compared with only 22.5 trillion cubic feet in the Accelerated Depletion Case and 26.0 trillion cubic feet in the Reference Case (Figure 15).
- With higher production levels increasing supply, lower 48 natural gas prices are projected to be $2.22 per thousand cubic feet in 2020—$0.57 lower than in the Reference Case and $1.90 lower than in the Accelerated Depletion Case (Figure 16).
- The technically recoverable resource base in 2020 is projected to be 142 trillion cubic feet higher than in the Accelerated Depletion Case (Table 11), with only 7 percent remaining "off limits."

As expected, the combination of high access to Rocky Mountain resources and more rapid technological progress leads to the highest projections of gas production and the lowest projected wellhead costs for natural gas. Under these conditions the resource base is expected to grow significantly, and the large majority of it becomes accessible and economical. The results of the two cases assuming more rapid technological progress suggest that the effects of accelerated depletion could be offset to some degree by increased access to natural gas reserves in the Rocky Mountains in combination with improvements in exploration and production technology.

Conclusion

This study has shown that projections of future oil and gas prices and production are influenced by the assumptions that are made about the effects of depletion. The NEMS OGSM incorporates the effects of depletion in its projections. In the Accelerated Depletion Case, the change in assumptions about the effects of depletion causes the projected production of lower 48 natural gas in 2020 to be 3.5 trillion cubic feet , or 13 percent, lower than in the Reference Case, with wellhead gas prices projected to be $1.33 per thousand cubic feet, or 48 percent, higher.

Changes in assumptions about world oil prices, the availability of natural gas imports, and the rate of technological innovation modify the projected effects of accelerated depletion on prices and production. Higher projections of natural gas imports partially offset the higher prices projected in the Accelerated Depletion Case, but domestic gas production is also reduced. Assuming a higher path for world oil prices does not return natural gas production in the Accelerated Depletion Case to its level in the Reference Case but does cause projected oil production to be higher. Assuming a faster rate of technological innovation partially offsets the effects of accelerated depletion.

When increased access to Rocky Mountain natural gas resources is assumed, projected natural gas production is increased. Combining the increased access and improved technological progress assumptions raises the projected production levels for natural gas above those in the Reference Case. The projected real wellhead price of lower 48 natural gas in the Accelerated Depletion with High Rocky Mountain Access and Rapid Technology Case is less than half the projected price in the Accelerated Depletion Case. These results suggest that at least in the short to medium term, the potential negative effects of accelerated depletion could be offset to some degree by more research and by expanding the areas where exploration and production is allowed.

The assumptions used to create the Reference Case specifically extrapolate from historical trends, whereas the assumptions used in the Accelerated Depletion Case were chosen to illustrate a scenario in which the effects of depletion are more acute then they have been historically. Therefore, the Accelerated Depletion Cases, which illustrate how the effects of depletion may become increasingly important in the decades to come, should be seen as sensitivity cases rather than forecasts.

Appendix A

Request for Analysis

Department of Energy

Washington, DC 20585

March 3, 2000

The Honorable Jay E. Hakes
Administrator
Energy Information Administration
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Hakes:

On December 3, 1999, the Department sponsored a meeting that included representation from six oil and gas trade associations: the American Petroleum Institute, Domestic Petroleum Council, Independent Petroleum Association of America, U.S. Oil and Gas Association, National Ocean Industries Association, and Natural Gas Supply Association. The purpose of the meeting was to address concerns raised about depletion and related issues, and their potential affect on the Nation's future supplies and prices of oil and natural gas.

Depletion of oil and gas is a fundamental issue that can be associated with a number of ancillary issues such as capital availability, price volatility, deliverability, and the need for advances in technology. Some of these issues are addressed in recent work such as that of the National Petroleum Council's report "Meeting the Challenge of the Nation's Growing Natural Gas Demand." However, based on dialogue with the trade associations, we feel it would be valuable for the Nation to have the Energy Information Administration (EIA) perform a study on the specific issues of depletion effects, oil price sensitivity, technology impacts, and land access. This letter provides guidance for a Service Report that we would like you to generate to address these topics.

Depletion Effects. Depletion analysis in the Service Report should be conducted from both historical and outlook perspectives through the year 2020. The analysis should use EIA reserve and production data and analyze outlook scenarios based on the EIA *Annual Energy Outlook 2000 (AEO2000)*.

Examination of historical trends should document the rates of change in initial production and subsequent depletion by region, over the past twenty years or more, especially in maturing provinces such as the shallow Gulf of Mexico and Texas. The historical analysis provides an opportunity to increase the transparency of EIA's databases for industry concerning the issue of depletion.

To assess the effects of depletion on oil and gas supply, two cases should be examined. The first will be EIA's existing Reference Case (Table A15 in *AEO2000*) showing supply source detail. Although we believe that the Reference Case is properly capturing depletion, there is a perception that the fundamental nature of depletion may be undergoing change that may not be reflected in historical data. Specifically, the perception is that the remaining oil and gas fields in the United States are becoming smaller and more costly to find, while being produced at faster rates than in the past. To address this concern, we advise that an "Accelerated Depletion" Case be developed by adjusting key variables such as finding rates, production-to-reserves ratios, inferred reserves and production profiles as appropriate. The outputs of the analysis should consider the effects on prices and production as they relate to the combination of these key variables.

Oil Price Sensitivity. In view of the swings in oil prices of the recent past, we recommend that two sensitivity cases be developed using high and low world oil prices defined in *AEO2000* (Table C12), based on the Accelerated Depletion Case described above. The analysis should consider the effects on natural gas prices and oil and gas production.

Technology Impacts. Technology is closely connected with depletion. We thus seek to understand how changes in the trends of technology progress might affect the future, given that accelerated depletion may be occurring. This issue can be addressed by developing "Accelerated Depletion with Technology" Cases that address the impacts of slow and rapid technology progress (Table F13 in *AEO2000*) on the Accelerated Depletion Case described above. These cases should seek to examine the ability or inability of technology progress to arrest accelerated depletion effects and should consider key input variables such as drilling, operating and lease costs and success rates.

Land Access. Finally, a case should be developed that addresses a scenario of increased access to Federal lands, focusing on the Rocky Mountain region. The "Access" Case should use key input variables as defined in the Accelerated Depletion Case, while improving access to conventional and unconventional resources underlying Federal lands.

We would like the study to be concluded by July 2000. EIA's assessment of these important issues would enable policymakers and the public to better understand the supply and demand concerns related to the Nation's oil and gas industry. If you have any questions concerning these requirements, please contact Nancy Johnson or John Pyrdol in the Office of Natural Gas and Petroleum Technology.

Sincerely,

Robert S. Kripowicz
Principal Deputy Assistant Secretary
for Fossil Energy

Department of Energy
Washington, DC 20585

May 19, 2000

Ms. Mary Hutzler
Director, Integrated Analysis and Forecasting
Energy Information Administration
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Ms. Hutzler:

On March 3, 2000, we formally requested that the Energy Information Administration (EIA) undertake an analysis of depletion and related issues and their potential affect on the Nation's future supplies and prices of oil and natural gas. The purposes of this letter are to recommend the specific cases we would like you to consider and to fully define the assumptions to be used.

To capture the spectrum of depletion effects and the influence of price, technology (or lack thereof) and land access to countermand these effects, we have resolved the study into the following specific cases:

- Reference,
- Accelerated Depletion,
- Accelerated Depletion with High World Oil Price,
- Accelerated Depletion with Low World Oil Price,
- Accelerated Depletion with Slow Technology,
- Accelerated Depletion with Improved Productivity Technology,
- Accelerated Depletion with Rapid Technology,
- Accelerated Depletion with High Land Access,
- Accelerated Depletion with High Land Access and Improved Productivity Technology, and
- Accelerated Depletion with High Land Access and Rapid Technology.

The specific settings and assumptions for the National Energy Modeling System are provided in Exhibits 1 through 3, attached. The outlooks for these cases should be examined through the year 2020.

These cases will provide a foundation on which to thoroughly examine depletion issues, addressing public concerns and providing policy guidance. If you have questions concerning these cases and assumptions, please contact John Pyrdol or Nancy Johnson in the Office of Natural Gas and Petroleum Technology.

Sincerely,

Robert Kripowicz
Principal Deputy Assistant Secretary
for Fossil Energy

Enclosure

Exhibit 1. Reference, Accelerated Depletion, and Accelerated Depletion/World Oil Price Cases

Cases	Conventional Resources		Unconventional Resources	Use settings from:		
	Levers	Settings	Levers	Slow Tech Case	Reference Case	Rapid Tech Case
Reference	P/R ratio (new stock)	AEO Reference case	N/a			
	Production Profile	AEO Reference case	N/a			
	Success Rates	AEO Reference case	N/a			
	Costs	AEO Reference case	Optimization and Cost Reduction Tech.		3,7,8	
	Finding Rates	AEO Reference case	Reservoir Characterization and Well Performance Tech.		1,2,5,6	
	Rocky Mtn. Resources	Decrease by 8% from AEO Reference case	Access to Resources		11	
	N/a		Exploration/ Breakthrough Tech.		4,9,10	
Accelerated Depletion (AD)	P/R ratio (new stock)	Increase by 33%	N/a			
	Production Profile	Faster decline by 33%	N/a			
	Success Rates	Reference case	N/a			
	Costs	Reference case	Optimization and Cost Reduction Tech.		3,7,8	
	Finding Rates	Decrease by 33%	Reservoir Characterization and Well Performance Tech.	1,2,5,6		
	Rocky Mtn. Resources	Reference case	Access to Resources	11		
	N/a		Exploration/ Breakthrough Tech.	4,9,10		
Accelerated Depletion	AD levers	AD settings	AD levers	AD settings		
with High World Oil Price	Oil prices	High AEO price track	Oil prices	High AEO price track		
Accelerated Depletion	AD levers	AD settings	AD levers	AD settings		
with Low World Oil Price	Oil prices	Low AEO price track	Oil prices	Low AEO price track		

Exhibit 2. Accelerated Depletion with Technology and Access Cases

Cases	Conventional Resources		Unconventional Resources	Use settings from:		
				Slow		Rapid
	Levers	Technology or Resource Settings	Levers	Tech Case	Reference Case	Tech Case
Accelerated Depletion w/ Slow Technology	AD settings with:					
	Success Rates	Decrease by 50%	N/a			
	Costs	Decrease by 50%	Optimization and Cost Reduction Tech.	3,7,8		
	Finding Rates	Decrease by 50%	Reservoir Characterization and Well Performance Tech.	1,2,5,6		
	Rocky Mtn. Resources	Reference case	Access to Resources	11		
	N/a		Exploration/ Breakthrough Tech.	4,9,10		
Accelerated Depletion w/ Improved Productivity Technology	AD settings with:					
	Success Rates	Reference case	N/a			
	Costs	Reference case	Optimization and Cost Reduction Tech.		3,7,8	
	Finding Rates	Increase by 50%	Reservoir Characterization and Well Performance Tech.			1,2,5,6
	Rocky Mtn. Resources	Reference case	Access to Resources	11		
	N/a		Exploration/ Breakthrough Tech.		4,9,10	
Accelerated Depletion w/ Rapid Technology	AD settings with:					
	Success Rates	Increase by 50%	N/a			
	Costs	Increase by 50%	Optimization and Cost Reduction Tech.			3,7,8
	Finding Rates	Increase by 50%	Reservoir Characterization and Well Performance Tech.			1,2,5,6
	Rocky Mtn. Resources	Reference case	Access to Resources	11		
	N/a		Exploration/ Breakthrough Tech.			4,9,10
Accelerated Depletion w/ High Access	AD settings with:					
			Optimization and Cost Reduction Tech.		3,7,8	
			Reservoir Characterization and Well Performance Tech.	1,2,5,6		
	Rocky Mtn. Resources	Increase by 8%	Access to Resources			11
			Exploration/ Breakthrough Tech.	4,9,10		
Accelerated Depletion w/ High Access and Improved Productivity Technology	AD settings with:					
	Success Rates	Reference case	N/a			
	Costs	Reference case	Optimization and Cost Reduction Tech.		3,7,8	
	Finding Rates	Increase by 50%	Reservoir Characterization and Well Performance Tech.			1,2,5,6
	Rocky Mtn. Resources	Increase by 8%	Access to Resources			11
	N/a		Exploration/ Breakthrough Tech.		4,9,10	
Accelerated Depletion w/ High Access and Rapid Technology	AD settings with:					
	Success Rates	Increase by 50%	N/a			
	Costs	Increase by 50%	Optimization and Cost Reduction Tech.			3,7,8
	Finding Rates	Increase by 50%	Reservoir Characterization and Well Performance Tech.			1,2,5,6
	Rocky Mtn. Resources	Increase by 8%	Access to Resources			11
	N/a		Exploration/ Breakthrough Tech.			4,9,10

Exhibit 3. Unconventional Resources--Technology and Access Settings

Unconventional Resources			Settings for:		
Levers	Resource Type		Slow Tech Case	Reference Case	Rapid Tech Case
1 Basin Assesment/Hypothetial Plays	All unconventional resource types	Date available	No improvement	Yr. 2016	Yr. 2011
2 Extended resource characterization/	Tight gas sands	Development pace	-0.5yr/yr	-1.25yr/yr	-2yr/yr
Emerging Basins	Coalbed methane	Development pace	-0.5yr/yr	-1.00yr/yr	-1.5yr/yr
	Gas shales	Development pace	-0.5yr/yr	-1.00yr/yr	-1.5yr/yr
3 Well performance diagnostics and remediation/	Tight gas sands	Reserve growth	1%/yr (decline to 0%)	2%/yr (decline to 0%)	3%/yr (decline to 0%)
Proved reserves	Coalbed methane	Reserve growth	1.5%/yr (decline to 0%)	3.0%/yr (decline to 0%)	4.5%/yr (decline to 0%)
	Gas shales	Reserve growth	1.5%/yr (decline to 0%)	3.0%/yr (decline to 0%)	4.5%/yr (decline to 0%)
4 Natural fracture detection R&D	All unconventional resource types	a. E/D success rate	No improvement	+ 0.25%/yr from yr 2000	+ 0.50%/yr from yr 2000
	All unconventional resource types	b. Exploration efficiency	No improvement	ID "best" 30% by 2017	ID "best" 30% by 2007
5 Geol./tech. modeling & matching	All unconventional resource types	EUR/well	No improvement	5%	10%
6 Improved drilling & stimulation	All unconventional resource types	EUR/well	5%	10%	15%
7 Lower cost drilling & stimulation	All unconventional resource types	Cost/well	-5%	-10%	-15%
8 Water & gas treating R&D	All unconventional resource types	Cost/Mcf	-10%	-20%	-30%
9 Horizontal wells	Tight gas sands	Recovery efficiency	No improvement	10% yr 2011	15% yr 2011
Advanced cavitation	Coalbed methane	EUR/well	No improvement	20% yr 2011	30% yr 2006
Multilateral completions	Gas shales	Recovery efficiency	No improvement	No improvement	15% yr 2011
10 Other tight gas technology	Tight gas sands	EUR/well	No improvement	+10% yr 2021	+10% yr 2016
a. Enhanced CBM recovery efficiency	Coalbed methane	Recovery efficiency	No improvement	+30% yr 2015	+45% yr 2010
b. Enhanced CBM O&M	Coalbed methane	Cost/Mcf	N/a	$1.00/Mcf, incremental	$0.75/Mcf, incremental
Other technology	Gas shales		N/a	N/a	N/a
11 Access restrictions	All unconventional resource types	Acreage available	No improvement	Removed in 50 yrs (1%/yr)	Removed in 25 yrs (2%/yr)

Appendix B

Model Results

Table B1. Total Energy Supply and Disposition Summary, High Natural Gas Import Comparisons
(Quadrillion Btu per Year, Unless Otherwise Noted)

Supply, Disposition, and Prices	1998	2005			2010		
		Reference	Accelerated Depletion	Accelerated Depletion with High Natural Gas Imports	Reference	Accelerated Depletion	Accelerated Depletion with High Natural Gas Imports
Production							
Crude Oil & Lease Condensate	13.23	11.20	11.10	11.09	11.15	10.68	10.66
Natural Gas Plant Liquids	2.49	2.53	2.50	2.49	2.93	2.88	2.85
Dry Natural Gas	19.41	19.90	19.67	19.59	23.37	22.93	22.65
Coal	23.89	25.97	26.02	26.01	26.51	26.54	26.65
Nuclear Power	7.19	7.20	7.20	7.20	6.70	6.70	6.70
Renewable Energy[1]	6.67	7.09	7.10	7.09	7.43	7.43	7.43
Other[2]	0.57	0.58	0.59	0.59	0.59	0.59	0.60
Total	**73.46**	**74.46**	**74.18**	**74.06**	**78.69**	**77.75**	**77.54**
Imports							
Crude Oil[3]	18.90	23.31	23.44	23.47	24.70	25.16	25.18
Petroleum Products[4]	3.99	5.79	5.81	5.82	6.79	6.79	6.83
Natural Gas	3.37	4.57	4.66	4.67	4.65	4.82	4.91
Other Imports[5]	0.59	0.99	0.99	0.99	0.89	0.89	0.89
Total	**26.85**	**34.67**	**34.90**	**34.94**	**37.02**	**37.67**	**37.81**
Exports							
Petroleum[6]	1.94	1.94	1.93	1.93	2.03	2.00	2.00
Natural Gas	0.17	0.24	0.24	0.14	0.29	0.29	0.14
Coal	2.05	1.65	1.65	1.65	1.73	1.77	1.77
Total	**4.16**	**3.83**	**3.82**	**3.73**	**4.06**	**4.06**	**3.91**
Discrepancy[7]	**1.28**	**0.14**	**0.15**	**0.19**	**0.11**	**0.10**	**0.15**
Consumption							
Petroleum Products[8]	37.21	41.26	41.30	41.27	43.98	43.96	43.92
Natural Gas	21.99	24.26	24.14	24.15	27.70	27.45	27.41
Coal	21.50	24.83	24.87	24.86	25.35	25.35	25.45
Nuclear Power	7.19	7.20	7.20	7.20	6.70	6.70	6.70
Renewable Energy[1]	6.67	7.09	7.10	7.09	7.44	7.44	7.44
Other[9]	0.32	0.50	0.50	0.50	0.36	0.36	0.36
Total	**94.88**	**105.15**	**105.11**	**105.08**	**111.54**	**111.26**	**111.29**
Net Imports - Petroleum	**20.95**	**27.16**	**27.32**	**27.35**	**29.45**	**29.96**	**30.01**
Prices (1998 dollars per unit)							
World Oil Price (dollars per bbl)[10]	12.10	20.49	20.49	20.49	21.00	21.00	21.00
Gas Wellhead Price (dollars per Mcf)[11]	1.96	2.40	2.48	2.45	2.48	2.62	2.56
Coal Minemouth Price (dollars per ton)	17.51	14.80	14.82	14.85	13.89	14.08	13.95
Average Electric Price (cents per Kwh)	6.71	6.20	6.22	6.21	5.94	6.02	5.97

[1]Includes grid-connected electricity from conventional hydroelectric; wood and wood waste; landfill gas; municipal solid waste; other biomass; wind; photovoltaic and solar thermal sources; non-electric energy from renewable sources, such as active and passive solar systems, and wood; and both the ethanol and gasoline components of E85, but not the ethanol components of blends less than 85 percent. Excludes electricity imports using renewable sources and nonmarketed renewable energy.
[2]Includes liquid hydrogen, methanol, supplemental natural gas, and some domestic inputs to refineries.
[3]Includes imports of crude oil for the Strategic Petroleum Reserve.
[4]Includes imports of finished petroleum products, imports of unfinished oils, alcohols, ethers, and blending components.
[5]Includes coal, coal coke (net), and electricity (net).
[6]Includes crude oil and petroleum products.
[7]Balancing item. Includes unaccounted for supply, losses, gains, and net storage withdrawals.
[8]Includes natural gas plant liquids, crude oil consumed as a fuel, and nonpetroleum based liquids for blending, such as ethanol.
[9]Includes net electricity imports, methanol, and liquid hydrogen.
[10]Average refiner acquisition cost for imported crude oil.
[11]Represents lower 48 onshore and offshore supplies.
Btu = British thermal unit.
Mcf = Thousand cubic feet.
Kwh = Kilowatthour.
Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A, OGDEPL.D051200A, and DEPL2.D071700A.

Table B1. Total Energy Supply and Disposition Summary, High Natural Gas Import Comparisons (Continued)

(Quadrillion Btu per Year, Unless Otherwise Noted)

Supply, Disposition, and Prices	2015			2020		
	Reference	Accelerated Depletion	Accelerated Depletion with High Natural Gas Imports	Reference	Accelerated Depletion	Accelerated Depletion with High Natural Gas Imports
Production						
Crude Oil & Lease Condensate	11.41	10.79	10.76	11.57	10.97	10.84
Natural Gas Plant Liquids	3.23	3.07	3.02	3.38	2.94	2.89
Dry Natural Gas	25.90	24.61	24.21	27.29	23.68	23.32
Coal	26.97	27.40	27.39	27.53	28.21	28.11
Nuclear Power	5.45	5.45	5.45	4.56	4.56	4.56
Renewable Energy[1]	7.71	7.72	7.72	7.99	8.06	8.02
Other[2]	0.61	0.59	0.60	0.66	0.63	0.64
Total	**81.28**	**79.64**	**79.16**	**82.98**	**79.04**	**78.38**
Imports						
Crude Oil[3]	24.56	25.20	25.22	24.82	25.45	25.58
Petroleum Products[4]	9.08	9.36	9.36	10.83	12.12	11.89
Natural Gas	5.00	5.33	5.70	5.35	6.01	6.63
Other Imports[5]	0.89	0.89	0.89	0.97	0.97	0.97
Total	**39.53**	**40.78**	**41.17**	**41.97**	**44.55**	**45.08**
Exports						
Petroleum[6]	2.06	2.02	2.04	1.99	1.85	1.91
Natural Gas	0.35	0.35	0.14	0.36	0.36	0.14
Coal	1.63	1.74	1.76	1.50	1.49	1.49
Total	**4.04**	**4.11**	**3.94**	**3.85**	**3.70**	**3.53**
Discrepancy[7]	**0.09**	**0.08**	**0.14**	**0.10**	**0.09**	**0.15**
Consumption						
Petroleum Products[8]	46.64	46.82	46.70	49.06	50.04	49.67
Natural Gas	30.54	29.58	29.77	32.28	29.34	29.82
Coal	25.99	26.31	26.26	26.74	27.43	27.33
Nuclear Power	5.45	5.45	5.45	4.56	4.56	4.56
Renewable Energy[1]	7.73	7.74	7.74	8.01	8.07	8.03
Other[9]	0.32	0.32	0.33	0.36	0.36	0.36
Total	**116.68**	**116.23**	**116.24**	**121.00**	**119.80**	**119.78**
Net Imports - Petroleum	**31.58**	**32.53**	**32.53**	**33.66**	**35.72**	**35.57**
Prices (1998 dollars per unit)						
World Oil Price (dollars per bbl)[10]	21.53	21.53	21.53	22.04	22.04	22.04
Gas Wellhead Price (dollars per Mcf)[11]	2.68	3.13	2.98	2.79	4.12	3.69
Coal Minemouth Price (dollars per ton)	13.41	13.63	13.57	12.57	12.71	12.74
Average Electric Price (cents per Kwh)	5.87	6.06	5.98	5.83	6.33	6.23

Table B2. Natural Gas Supply and Disposition, High Natural Gas Import Comparisons
(Trillion Cubic Feet per Year, Unless Otherwise Noted)

Supply, Disposition, and Prices	1998	2005			2010		
		Reference	Accelerated Depletion	Accelerated Depletion with High Natural Gas Imports	Reference	Accelerated Depletion	Accelerated Depletion with High Natural Gas Imports
Lower 48 Average Wellhead Price[1]							
(1998 dollars per thousand cubic feet)	**1.96**	**2.40**	**2.48**	**2.45**	**2.48**	**2.62**	**2.56**
Dry Gas Production[2]							
U.S. Total	**18.88**	**19.35**	**19.14**	**19.05**	**22.73**	**22.31**	**22.04**
Lower 48 Onshore	12.91	13.09	12.93	12.86	16.33	16.04	15.76
Associated-Dissolved[3]	1.72	1.26	1.26	1.26	1.25	1.23	1.23
Non-Associated	11.19	11.84	11.67	11.60	15.08	14.80	14.53
Conventional	6.69	6.54	6.68	6.64	9.24	9.37	9.30
Unconventional	4.50	5.29	4.99	4.96	5.84	5.44	5.23
Lower 48 Offshore	5.54	5.80	5.75	5.74	5.91	5.78	5.79
Associated-Dissolved[3]	0.89	0.89	0.89	0.89	0.90	0.86	0.86
Non-Associated	4.65	4.91	4.85	4.84	5.01	4.92	4.93
Alaska	0.44	0.46	0.46	0.46	0.49	0.49	0.49
Supplemental Natural Gas[4]	**0.12**	**0.11**	**0.11**	**0.11**	**0.06**	**0.06**	**0.06**
Net Imports	**3.13**	**4.24**	**4.33**	**4.43**	**4.26**	**4.43**	**4.66**
Total Supply	**22.13**	**23.71**	**23.58**	**23.59**	**27.05**	**26.80**	**26.76**
Consumption by Sector							
Residential	4.48	5.07	5.05	5.06	5.32	5.29	5.30
Commercial	3.03	3.32	3.31	3.31	3.50	3.47	3.48
Industrial[5]	8.23	8.75	8.73	8.74	9.24	9.18	9.20
Electric Generators[6]	3.67	4.36	4.31	4.31	6.42	6.33	6.27
Lease and Plant Fuel[7]	1.24	1.23	1.22	1.21	1.41	1.40	1.38
Pipeline Fuel	0.73	0.73	0.72	0.72	0.85	0.83	0.83
Transportation[8]	0.02	0.15	0.15	0.15	0.22	0.22	0.22
Total	**21.40**	**23.61**	**23.49**	**23.50**	**26.97**	**26.72**	**26.68**
Discrepancy[9]	**0.74**	**0.10**	**0.09**	**0.09**	**0.08**	**0.08**	**0.08**
Lower 48 End of Year Reserves	**156.00**	**164.17**	**157.10**	**157.01**	**180.14**	**166.49**	**165.40**

[1]Represents lower 48 onshore and offshore supplies.
[2]Marketed production (wet) minus extraction losses.
[3]Gas which occurs in crude oil reserves either as free gas (associated) or as gas in solution with crude oil (dissolved).
[4]Synthetic natural gas, propane air, coke oven gas, refinery gas, biomass gas, air injected for Btu stabilization, and manufactured gas commingled and distributed with natural gas.
[5]Includes consumption by cogenerators.
[6]Includes all electric power generators except cogenerators, which produce electricity and other useful thermal energy. Includes small power producers and exempt wholesale generators.
[7]Represents natural gas used in the field gathering and processing plant machinery.
[8]Compressed natural gas used as vehicle fuel.
[9]Balancing item. Natural gas lost as a result of converting flow data measured at varying temperatures and pressures to a standard temperature and pressure and the merger of different data reporting systems which vary in scope, format, definition, and respondent type.
Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A, OGDEPL.D051200A, and DEPL2.D071700A.

Table B2. Natural Gas Supply and Disposition, High Natural Gas Import Comparisons (Continued)
(Trillion Cubic Feet per Year, Unless Otherwise Noted)

Supply, Disposition, and Prices	2015			2020		
	Reference	Accelerated Depletion	Accelerated Depletion with High Natural Gas Imports	Reference	Accelerated Depletion	Accelerated Depletion with High Natural Gas Imports
Lower 48 Average Wellhead Price[1]						
(1998 dollars per thousand cubic feet)	**2.68**	**3.13**	**2.98**	**2.79**	**4.12**	**3.69**
Dry Gas Production[2]						
U.S. Total	**25.19**	**23.94**	**23.55**	**26.54**	**23.03**	**22.68**
Lower 48 Onshore	17.97	17.42	17.16	19.36	17.58	17.29
Associated-Dissolved[3]	1.30	1.29	1.28	1.32	1.31	1.30
Non-Associated	16.67	16.13	15.88	18.03	16.26	15.99
Conventional	10.19	10.26	10.19	10.65	10.26	10.25
Unconventional	6.48	5.87	5.69	7.38	6.00	5.74
Lower 48 Offshore	6.71	6.01	5.88	6.65	4.92	4.86
Associated-Dissolved[3]	0.93	0.87	0.87	0.94	0.88	0.88
Non-Associated	5.78	5.14	5.01	5.71	4.04	3.98
Alaska	0.51	0.51	0.51	0.54	0.54	0.54
Supplemental Natural Gas[4]	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**
Net Imports	**4.55**	**4.87**	**5.44**	**4.88**	**5.52**	**6.36**
Total Supply	**29.80**	**28.87**	**29.05**	**31.48**	**28.62**	**29.09**
Consumption by Sector						
Residential	5.49	5.40	5.43	5.71	5.45	5.51
Commercial	3.61	3.53	3.56	3.65	3.45	3.50
Industrial[5]	9.65	9.48	9.53	10.00	9.54	9.64
Electric Generators[6]	8.22	7.72	7.83	9.14	7.47	7.76
Lease and Plant Fuel[7]	1.56	1.50	1.48	1.66	1.49	1.48
Pipeline Fuel	0.92	0.88	0.88	0.96	0.84	0.84
Transportation[8]	0.28	0.28	0.28	0.32	0.31	0.31
Total	**29.74**	**28.80**	**28.99**	**31.43**	**28.56**	**29.03**
Discrepancy[9]	**0.06**	**0.07**	**0.06**	**0.05**	**0.05**	**0.06**
Lower 48 End of Year Reserves	**193.46**	**166.04**	**165.02**	**199.54**	**152.26**	**151.26**

Table B3. Crude Oil Supply and Disposition, High Natural Gas Import Comparisons
(Million Barrels per Day, Unless Otherwise Noted)

Supply, Disposition, and Prices	1998	2005			2010		
		Reference	Accelerated Depletion	Accelerated Depletion with High Natural Gas Imports	Reference	Accelerated Depletion	Accelerated Depletion with High Natural Gas Imports
Lower 48 Average Wellhead Price[1]							
(1998 dollars per barrel)	**11.60**	**20.12**	**20.11**	**20.11**	**20.65**	**20.65**	**20.64**
Production[2]							
U.S. Total	**6.25**	**5.29**	**5.25**	**5.24**	**5.27**	**5.04**	**5.03**
Lower 48 Onshore	3.60	2.93	2.94	2.93	3.01	2.95	2.94
Conventional	2.87	2.33	2.34	2.33	2.39	2.34	2.32
Enhanced Oil Recovery	0.73	0.60	0.60	0.60	0.62	0.62	0.62
Lower 48 Offshore	1.47	1.39	1.34	1.34	1.44	1.27	1.28
Alaska	1.18	0.96	0.96	0.96	0.82	0.82	0.81
Net Crude Imports	**8.60**	**10.71**	**10.77**	**10.78**	**11.35**	**11.57**	**11.58**
Total Crude Supply	**14.89**	**15.99**	**16.01**	**16.02**	**16.61**	**16.61**	**16.61**
Natural Gas Plant Liquids	**1.76**	**1.78**	**1.76**	**1.76**	**2.07**	**2.03**	**2.01**
Other Inputs[3]	**0.25**	**0.27**	**0.27**	**0.28**	**0.29**	**0.29**	**0.30**
Refinery Processing Gain[4]	**0.89**	**1.02**	**1.02**	**1.00**	**1.11**	**1.10**	**1.09**
Net Product Imports[5]	**1.17**	**1.98**	**1.99**	**1.99**	**2.38**	**2.41**	**2.43**
Total Primary Supply[6]	**18.95**	**21.05**	**21.07**	**21.05**	**22.47**	**22.46**	**22.44**
Refined Petroleum Products Supplied							
Residential and Commercial	1.06	1.05	1.05	1.05	1.03	1.03	1.03
Industrial[7]	4.80	5.29	5.29	5.27	5.54	5.54	5.52
Transportation	12.54	14.43	14.43	14.43	15.74	15.71	15.72
Electric Generators[8]	0.54	0.33	0.34	0.34	0.20	0.22	0.22
Total	**18.94**	**21.09**	**21.11**	**21.10**	**22.51**	**22.50**	**22.48**
Discrepancy[9]	**0.01**	**-0.05**	**-0.05**	**-0.05**	**-0.04**	**-0.04**	**-0.04**
L48 End Year Reserves (billion barrels)[2]	**18.16**	**14.46**	**14.12**	**14.11**	**13.98**	**13.39**	**13.35**

[1]Represents lower 48 onshore and offshore supplies.
[2]Includes lease condensate.
[3]Includes alcohols, ethers, petroleum product stock withdrawals, domestic sources of blending components, and other hydrocarbons.
[4]Represents volumetric gain in refinery distillation and cracking processes.
[5]Includes net imports of finished petroleum products, unfinished oils, other hydrocarbons, alcohols, ethers, and blending components.
[6]Total crude supply plus natural gas plant liquids, other inputs, refinery processing gain, and net petroleum imports.
[7]Includes consumption by cogenerators.
[8]Includes all electric power generators except cogenerators, which produce electricity and other useful thermal energy. Includes small power producers and exempt wholesale generators.
[9]Balancing item. Includes unaccounted for supply, losses and gains.
Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A, OGDEPL.D051200A, and DEPL2.D071700A.

Table B3. Crude Oil Supply and Disposition, High Natural Gas Import Comparisons (Continued)
(Million Barrels per Day, Unless Otherwise Noted)

Supply, Disposition, and Prices	2015			2020		
	Reference	Accelerated Depletion	Accelerated Depletion with High Natural Gas Imports	Reference	Accelerated Depletion	Accelerated Depletion with High Natural Gas Imports
Lower 48 Average Wellhead Price[1]						
(1998 dollars per barrel)	**20.96**	**21.06**	**21.07**	**21.27**	**21.21**	**21.30**
Production[2]						
U.S. Total	**5.39**	**5.10**	**5.08**	**5.47**	**5.18**	**5.12**
Lower 48 Onshore	3.22	3.17	3.14	3.36	3.39	3.31
Conventional	2.54	2.49	2.46	2.65	2.67	2.59
Enhanced Oil Recovery	0.69	0.68	0.69	0.71	0.72	0.72
Lower 48 Offshore	1.54	1.30	1.31	1.60	1.33	1.34
Alaska	0.63	0.63	0.63	0.51	0.47	0.47
Net Crude Imports	**11.28**	**11.59**	**11.59**	**11.39**	**11.70**	**11.76**
Total Crude Supply	**16.67**	**16.68**	**16.68**	**16.86**	**16.88**	**16.88**
Natural Gas Plant Liquids	**2.28**	**2.17**	**2.13**	**2.38**	**2.07**	**2.04**
Other Inputs[3]	**0.30**	**0.29**	**0.29**	**0.32**	**0.31**	**0.31**
Refinery Processing Gain[4]	**1.11**	**1.10**	**1.09**	**1.12**	**1.11**	**1.09**
Net Product Imports[5]	**3.50**	**3.68**	**3.67**	**4.42**	**5.16**	**5.02**
Total Primary Supply[6]	**23.85**	**23.91**	**23.86**	**25.10**	**25.52**	**25.35**
Refined Petroleum Products Supplied						
Residential and Commercial	0.99	1.00	0.99	0.96	0.96	0.96
Industrial[7]	5.81	5.83	5.80	6.03	6.12	6.06
Transportation	16.89	16.85	16.86	17.94	17.90	17.86
Electric Generators[8]	0.18	0.27	0.24	0.17	0.56	0.48
Total	**23.87**	**23.95**	**23.89**	**25.10**	**25.54**	**25.37**
Discrepancy[9]	**-0.03**	**-0.03**	**-0.03**	**0.00**	**-0.02**	**-0.02**
L48 End Year Reserves (billion barrels)[2]	**14.05**	**13.41**	**13.34**	**13.86**	**13.45**	**13.26**

Table B4. Total Energy Supply and Disposition Summary, World Oil Price Comparisons
(Quadrillion Btu per Year, Unless Otherwise Noted)

Supply, Disposition, and Prices	1998	2005 Reference	2005 Accelerated Depletion	2005 Accelerated Depletion Low World Oil Price	2005 Accelerated Depletion High World Oil Price	2010 Reference	2010 Accelerated Depletion	2010 Accelerated Depletion Low World Oil Price	2010 Accelerated Depletion High World Oil Price
Production									
Crude Oil & Lease Condensate	13.23	11.20	11.10	10.44	11.47	11.15	10.68	9.91	11.23
Natural Gas Plant Liquids	2.49	2.53	2.50	2.49	2.53	2.93	2.88	2.87	2.93
Dry Natural Gas	19.41	19.90	19.67	19.60	19.91	23.37	22.93	22.84	23.34
Coal	23.89	25.97	26.02	25.93	25.98	26.51	26.54	26.39	26.34
Nuclear Power	7.19	7.20	7.20	7.20	7.20	6.70	6.70	6.70	6.70
Renewable Energy[1]	6.67	7.09	7.10	7.06	7.08	7.43	7.43	7.38	7.47
Other[2]	0.57	0.58	0.59	0.50	0.67	0.59	0.59	0.49	0.73
Total	**73.46**	**74.46**	**74.18**	**73.23**	**74.84**	**78.69**	**77.75**	**76.58**	**78.75**
Imports									
Crude Oil[3]	18.90	23.31	23.44	24.17	23.20	24.70	25.16	26.51	24.61
Petroleum Products[4]	3.99	5.79	5.81	7.08	4.97	6.79	6.79	8.12	5.68
Natural Gas	3.37	4.57	4.66	4.43	4.72	4.65	4.82	4.63	4.81
Other Imports[5]	0.59	0.99	0.99	0.99	0.99	0.89	0.89	0.89	0.90
Total	**26.85**	**34.67**	**34.90**	**36.66**	**33.88**	**37.02**	**37.67**	**40.15**	**36.00**
Exports									
Petroleum[6]	1.94	1.94	1.93	1.85	2.05	2.03	2.00	1.84	2.09
Natural Gas	0.17	0.24	0.24	0.24	0.24	0.29	0.29	0.29	0.29
Coal	2.05	1.65	1.65	1.65	1.65	1.73	1.77	1.73	1.73
Total	**4.16**	**3.83**	**3.82**	**3.74**	**3.94**	**4.06**	**4.06**	**3.86**	**4.11**
Discrepancy[7]	**1.28**	**0.14**	**0.15**	**0.27**	**0.09**	**0.11**	**0.10**	**0.23**	**-0.04**
Consumption									
Petroleum Products[8]	37.21	41.26	41.30	42.50	40.64	43.98	43.96	45.78	43.08
Natural Gas	21.99	24.26	24.14	23.83	24.43	27.70	27.45	27.16	27.84
Coal	21.50	24.83	24.87	24.79	24.83	25.35	25.35	25.23	25.21
Nuclear Power	7.19	7.20	7.20	7.20	7.20	6.70	6.70	6.70	6.70
Renewable Energy[1]	6.67	7.09	7.10	7.07	7.08	7.44	7.44	7.39	7.48
Other[9]	0.32	0.50	0.50	0.50	0.50	0.36	0.36	0.37	0.35
Total	**94.88**	**105.15**	**105.11**	**105.89**	**104.69**	**111.54**	**111.26**	**112.63**	**110.67**
Net Imports - Petroleum	**20.95**	**27.16**	**27.32**	**29.40**	**26.12**	**29.45**	**29.96**	**32.79**	**28.21**
Prices (1998 dollars per unit)									
World Oil Price (dollars per bbl)[10]	12.10	20.49	20.49	14.90	24.16	21.00	21.00	14.90	26.31
Gas Wellhead Price (dollars per Mcf)[11]	1.96	2.40	2.48	2.30	2.53	2.48	2.62	2.47	2.66
Coal Minemouth Price (dollars per ton)	17.51	14.80	14.82	14.81	14.84	13.89	14.08	13.95	14.04
Average Electric Price (cents per Kwh)	6.71	6.20	6.22	6.10	6.25	5.94	6.02	5.95	6.05

[1]Includes grid-connected electricity from conventional hydroelectric; wood and wood waste; landfill gas; municipal solid waste; other biomass; wind; photovoltaic and solar thermal sources; non-electric energy from renewable sources, such as active and passive solar systems, and wood; and both the ethanol and gasoline components of E85, but not the ethanol components of blends less than 85 percent. Excludes electricity imports using renewable sources and nonmarketed renewable energy.
[2]Includes liquid hydrogen, methanol, supplemental natural gas, and some domestic inputs to refineries.
[3]Includes imports of crude oil for the Strategic Petroleum Reserve.
[4]Includes imports of finished petroleum products, imports of unfinished oils, alcohols, ethers, and blending components.
[5]Includes coal, coal coke (net), and electricity (net).
[6]Includes crude oil and petroleum products.
[7]Balancing item. Includes unaccounted for supply, losses, gains, and net storage withdrawals.
[8]Includes natural gas plant liquids, crude oil consumed as a fuel, and nonpetroleum based liquids for blending, such as ethanol.
[9]Includes net electricity imports, methanol, and liquid hydrogen.
[10]Average refiner acquisition cost for imported crude oil.
[11]Represents lower 48 onshore and offshore supplies.
Btu = British thermal unit.
Mcf = Thousand cubic feet.
Kwh = Kilowatthour.
Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A, OGDEPL.D051200A, OGLWOP.D051200A, and OGHWOP.D051200A.

Table B4. Total Energy Supply and Disposition Summary, World Oil Price Comparisons (Continued)
(Quadrillion Btu per Year, Unless Otherwise Noted)

Supply, Disposition, and Prices	2015				2020			
			Accelerated Depletion				Accelerated Depletion	
	Reference	Accelerated Depletion	Low World Oil Price	High World Oil Price	Reference	Accelerated Depletion	Low World Oil Price	High World Oil Price
Production								
Crude Oil & Lease Condensate	11.41	10.79	9.59	11.83	11.57	10.97	9.55	12.27
Natural Gas Plant Liquids	3.23	3.07	3.00	3.11	3.38	2.94	2.86	3.00
Dry Natural Gas	25.90	24.61	24.06	24.97	27.29	23.68	23.06	24.15
Coal	26.97	27.40	27.03	27.27	27.53	28.21	27.51	28.26
Nuclear Power	5.45	5.45	5.41	5.45	4.56	4.56	4.51	4.55
Renewable Energy[1]	7.71	7.72	7.70	7.77	7.99	8.06	7.96	8.15
Other[2]	0.61	0.59	0.55	0.74	0.66	0.63	0.52	0.66
Total	**81.28**	**79.64**	**77.36**	**81.16**	**82.98**	**79.04**	**75.98**	**81.05**
Imports								
Crude Oil[3]	24.56	25.20	27.20	24.30	24.82	25.45	27.42	24.16
Petroleum Products[4]	9.08	9.36	11.00	7.67	10.83	12.12	15.22	10.40
Natural Gas	5.00	5.33	5.24	5.40	5.35	6.01	5.77	6.10
Other Imports[5]	0.89	0.89	0.89	0.90	0.97	0.97	0.97	0.98
Total	**39.53**	**40.78**	**44.32**	**38.27**	**41.97**	**44.55**	**49.38**	**41.63**
Exports								
Petroleum[6]	2.06	2.02	1.70	2.18	1.99	1.85	1.80	2.33
Natural Gas	0.35	0.35	0.35	0.35	0.36	0.36	0.36	0.36
Coal	1.63	1.74	1.69	1.64	1.50	1.49	1.49	1.49
Total	**4.04**	**4.11**	**3.75**	**4.18**	**3.85**	**3.70**	**3.65**	**4.18**
Discrepancy[7]	**0.09**	**0.08**	**0.18**	**-0.10**	**0.10**	**0.09**	**0.16**	**-0.04**
Consumption								
Petroleum Products[8]	46.64	46.82	49.36	45.52	49.06	50.04	53.49	48.10
Natural Gas	30.54	29.58	28.94	30.02	32.28	29.34	28.46	29.90
Coal	25.99	26.31	25.98	26.27	26.74	27.43	26.73	27.49
Nuclear Power	5.45	5.45	5.41	5.45	4.56	4.56	4.51	4.55
Renewable Energy[1]	7.73	7.74	7.72	7.78	8.01	8.07	7.98	8.16
Other[9]	0.32	0.32	0.33	0.31	0.36	0.36	0.37	0.34
Total	**116.68**	**116.23**	**117.75**	**115.35**	**121.00**	**119.80**	**121.55**	**118.54**
Net Imports - Petroleum	**31.58**	**32.53**	**36.50**	**29.79**	**33.66**	**35.72**	**40.85**	**32.23**
Prices (1998 dollars per unit)								
World Oil Price (dollars per bbl)[10]	21.53	21.53	14.90	27.86	22.04	22.04	14.90	28.04
Gas Wellhead Price (dollars per Mcf)[11]	2.68	3.13	2.95	3.24	2.79	4.12	3.60	4.40
Coal Minemouth Price (dollars per ton)	13.41	13.63	13.40	13.68	12.57	12.71	12.21	12.81
Average Electric Price (cents per Kwh)	5.87	6.06	6.00	6.11	5.83	6.33	6.20	6.45

Table B5. Natural Gas Supply and Disposition, World Oil Price Comparisons
(Trillion Cubic Feet per Year, Unless Otherwise Noted)

Supply, Disposition, and Prices	1998	2005 Reference	2005 Accelerated Depletion	2005 Accelerated Depletion Low World Oil Price	2005 Accelerated Depletion High World Oil Price	2010 Reference	2010 Accelerated Depletion	2010 Accelerated Depletion Low World Oil Price	2010 Accelerated Depletion High World Oil Price
Lower 48 Average Wellhead Price[1] (1998 dollars per thousand cubic feet)	**1.96**	**2.40**	**2.48**	**2.30**	**2.53**	**2.48**	**2.62**	**2.47**	**2.66**
Dry Gas Production[2]									
U.S. Total	**18.88**	**19.35**	**19.14**	**19.07**	**19.37**	**22.73**	**22.31**	**22.22**	**22.71**
Lower 48 Onshore	12.91	13.09	12.93	12.92	13.19	16.33	16.04	15.93	16.45
Associated-Dissolved[3]	1.72	1.26	1.26	1.19	1.30	1.25	1.23	1.20	1.26
Non-Associated	11.19	11.84	11.67	11.73	11.89	15.08	14.80	14.73	15.19
Conventional	6.69	6.54	6.68	6.85	6.68	9.24	9.37	9.78	9.55
Unconventional	4.50	5.29	4.99	4.88	5.21	5.84	5.44	4.96	5.64
Lower 48 Offshore	5.54	5.80	5.75	5.69	5.72	5.91	5.78	5.80	5.77
Associated-Dissolved[3]	0.89	0.89	0.89	0.89	0.89	0.90	0.86	0.85	0.85
Non-Associated	4.65	4.91	4.85	4.80	4.83	5.01	4.92	4.95	4.92
Alaska	0.44	0.46	0.46	0.46	0.46	0.49	0.49	0.49	0.49
Supplemental Natural Gas[4]	**0.12**	**0.11**	**0.11**	**0.11**	**0.11**	**0.06**	**0.06**	**0.06**	**0.06**
Net Imports	**3.13**	**4.24**	**4.33**	**4.10**	**4.38**	**4.26**	**4.43**	**4.24**	**4.42**
Total Supply	**22.13**	**23.71**	**23.58**	**23.28**	**23.87**	**27.05**	**26.80**	**26.51**	**27.18**
Consumption by Sector									
Residential	4.48	5.07	5.05	5.07	5.05	5.32	5.29	5.30	5.29
Commercial	3.03	3.32	3.31	3.32	3.30	3.50	3.47	3.47	3.47
Industrial[5]	8.23	8.75	8.73	8.71	8.78	9.24	9.18	9.20	9.27
Electric Generators[6]	3.67	4.36	4.31	4.00	4.54	6.42	6.33	6.02	6.60
Lease and Plant Fuel[7]	1.24	1.23	1.22	1.21	1.23	1.41	1.40	1.39	1.42
Pipeline Fuel	0.73	0.73	0.72	0.72	0.73	0.85	0.83	0.82	0.85
Transportation[8]	0.02	0.15	0.15	0.15	0.15	0.22	0.22	0.23	0.22
Total	**21.40**	**23.61**	**23.49**	**23.19**	**23.78**	**26.97**	**26.72**	**26.43**	**27.11**
Discrepancy[9]	**0.74**	**0.10**	**0.09**	**0.09**	**0.09**	**0.08**	**0.08**	**0.08**	**0.08**
Lower 48 End of Year Reserves	**156.00**	**164.17**	**157.10**	**158.02**	**160.95**	**180.14**	**166.49**	**163.37**	**169.50**

[1]Represents lower 48 onshore and offshore supplies.
[2]Marketed production (wet) minus extraction losses.
[3]Gas which occurs in crude oil reserves either as free gas (associated) or as gas in solution with crude oil (dissolved).
[4]Synthetic natural gas, propane air, coke oven gas, refinery gas, biomass gas, air injected for Btu stabilization, and manufactured gas commingled and distributed with natural gas.
[5]Includes consumption by cogenerators.
[6]Includes all electric power generators except cogenerators, which produce electricity and other useful thermal energy. Includes small power producers and exempt wholesale generators.
[7]Represents natural gas used in the field gathering and processing plant machinery.
[8]Compressed natural gas used as vehicle fuel.
[9]Balancing item. Natural gas lost as a result of converting flow data measured at varying temperatures and pressures to a standard temperature and pressure and the merger of different data reporting systems which vary in scope, format, definition, and respondent type.
Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A, OGDEPL.D051200A, OGLWOP.D051200A, and OGHWOP.D051200A.

Table B5. Natural Gas Supply and Disposition, World Oil Price Comparisons (Continued)
(Trillion Cubic Feet per Year, Unless Otherwise Noted)

Supply, Disposition, and Prices	2015				2020			
			Accelerated Depletion				Accelerated Depletion	
	Reference	Accelerated Depletion	Low World Oil Price	High World Oil Price	Reference	Accelerated Depletion	Low World Oil Price	High World Oil Price
Lower 48 Average Wellhead Price[1]								
(1998 dollars per thousand cubic feet)	**2.68**	**3.13**	**2.95**	**3.24**	**2.79**	**4.12**	**3.60**	**4.40**
Dry Gas Production[2]								
U.S. Total	**25.19**	**23.94**	**23.41**	**24.29**	**26.54**	**23.03**	**22.43**	**23.50**
Lower 48 Onshore	17.97	17.42	17.19	17.76	19.36	17.58	17.29	17.95
Associated-Dissolved[3]	1.30	1.29	1.25	1.34	1.32	1.31	1.30	1.35
Non-Associated	16.67	16.13	15.94	16.42	18.03	16.26	15.99	16.60
Conventional	10.19	10.26	10.50	10.44	10.65	10.26	10.23	10.49
Unconventional	6.48	5.87	5.45	5.98	7.38	6.00	5.75	6.11
Lower 48 Offshore	6.71	6.01	5.71	6.02	6.65	4.92	4.61	5.01
Associated-Dissolved[3]	0.93	0.87	0.85	0.86	0.94	0.88	0.85	0.89
Non-Associated	5.78	5.14	4.86	5.16	5.71	4.04	3.76	4.12
Alaska	0.51	0.51	0.51	0.51	0.54	0.54	0.54	0.54
Supplemental Natural Gas[4]	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**
Net Imports	**4.55**	**4.87**	**4.78**	**4.94**	**4.88**	**5.52**	**5.29**	**5.61**
Total Supply	**29.80**	**28.87**	**28.24**	**29.29**	**31.48**	**28.62**	**27.78**	**29.17**
Consumption by Sector								
Residential	5.49	5.40	5.41	5.40	5.71	5.45	5.51	5.42
Commercial	3.61	3.53	3.52	3.52	3.65	3.45	3.47	3.42
Industrial[5]	9.65	9.48	9.41	9.59	10.00	9.54	9.46	9.64
Electric Generators[6]	8.22	7.72	7.22	8.03	9.14	7.47	6.68	7.94
Lease and Plant Fuel[7]	1.56	1.50	1.48	1.52	1.66	1.49	1.47	1.52
Pipeline Fuel	0.92	0.88	0.85	0.89	0.96	0.84	0.81	0.86
Transportation[8]	0.28	0.28	0.28	0.28	0.32	0.31	0.31	0.31
Total	**29.74**	**28.80**	**28.18**	**29.23**	**31.43**	**28.56**	**27.71**	**29.11**
Discrepancy[9]	**0.06**	**0.07**	**0.07**	**0.06**	**0.05**	**0.05**	**0.08**	**0.05**
Lower 48 End of Year Reserves	**193.46**	**166.04**	**164.83**	**168.03**	**199.54**	**152.26**	**152.91**	**152.87**

Table B6. Crude Oil Supply and Disposition, World Oil Price Comparisons
(Million Barrels per Day, Unless Otherwise Noted)

Supply, Disposition, and Prices	1998	2005				2010			
				Accelerated Depletion				Accelerated Depletion	
		Reference	Accelerated Depletion	Low World Oil Price	High World Oil Price	Reference	Accelerated Depletion	Low World Oil Price	High World Oil Price
Lower 48 Average Wellhead Price[1] (1998 dollars per barrel)	**11.60**	**20.12**	**20.11**	**14.43**	**23.73**	**20.65**	**20.65**	**14.39**	**25.89**
Production[2]									
U.S. Total	**6.25**	**5.29**	**5.25**	**4.93**	**5.42**	**5.27**	**5.04**	**4.68**	**5.30**
Lower 48 Onshore	3.60	2.93	2.94	2.65	3.12	3.01	2.95	2.66	3.25
Conventional	2.87	2.33	2.34	2.13	2.43	2.39	2.34	2.24	2.43
Enhanced Oil Recovery	0.73	0.60	0.60	0.52	0.68	0.62	0.62	0.42	0.82
Lower 48 Offshore	1.47	1.39	1.34	1.33	1.33	1.44	1.27	1.22	1.23
Alaska	1.18	0.96	0.96	0.95	0.97	0.82	0.82	0.79	0.82
Net Crude Imports	**8.60**	**10.71**	**10.77**	**11.12**	**10.65**	**11.35**	**11.57**	**12.20**	**11.31**
Total Crude Supply	**14.89**	**15.99**	**16.01**	**16.05**	**16.07**	**16.61**	**16.61**	**16.88**	**16.61**
Natural Gas Plant Liquids	**1.76**	**1.78**	**1.76**	**1.76**	**1.79**	**2.07**	**2.03**	**2.03**	**2.07**
Other Inputs[3]	**0.25**	**0.27**	**0.27**	**0.24**	**0.31**	**0.29**	**0.29**	**0.25**	**0.37**
Refinery Processing Gain[4]	**0.89**	**1.02**	**1.02**	**0.92**	**1.09**	**1.11**	**1.10**	**0.97**	**1.19**
Net Product Imports[5]	**1.17**	**1.98**	**1.99**	**2.68**	**1.51**	**2.38**	**2.41**	**3.20**	**1.81**
Total Primary Supply[6]	**18.95**	**21.05**	**21.07**	**21.64**	**20.77**	**22.47**	**22.46**	**23.33**	**22.04**
Refined Petroleum Products Supplied									
Residential and Commercial	1.06	1.05	1.05	1.11	1.02	1.03	1.03	1.11	0.98
Industrial[7]	4.80	5.29	5.29	5.28	5.27	5.54	5.54	5.56	5.48
Transportation	12.54	14.43	14.43	14.59	14.35	15.74	15.71	15.95	15.54
Electric Generators[8]	0.54	0.33	0.34	0.69	0.17	0.20	0.22	0.74	0.07
Total	**18.94**	**21.09**	**21.11**	**21.68**	**20.80**	**22.51**	**22.50**	**23.36**	**22.07**
Discrepancy[9]	**0.01**	**-0.05**	**-0.05**	**-0.04**	**-0.04**	**-0.04**	**-0.04**	**-0.03**	**-0.03**
L48 End Year Reserves (billion barrels)[2]	**18.16**	**14.46**	**14.12**	**13.31**	**14.55**	**13.98**	**13.39**	**12.19**	**14.39**

[1]Represents lower 48 onshore and offshore supplies.
[2]Includes lease condensate.
[3]Includes alcohols, ethers, petroleum product stock withdrawals, domestic sources of blending components, and other hydrocarbons.
[4]Represents volumetric gain in refinery distillation and cracking processes.
[5]Includes net imports of finished petroleum products, unfinished oils, other hydrocarbons, alcohols, ethers, and blending components.
[6]Total crude supply plus natural gas plant liquids, other inputs, refinery processing gain, and net petroleum imports.
[7]Includes consumption by cogenerators.
[8]Includes all electric power generators except cogenerators, which produce electricity and other useful thermal energy. Includes small power producers and exempt wholesale generators.
[9]Balancing item. Includes unaccounted for supply, losses and gains.
Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A, OGDEPL.D051200A, OGLWOP.D051200A, and OGHWOP.D051200A.

Table B6. Crude Oil Supply and Disposition, World Oil Price Comparisons (Continued)
(Million Barrels per Day, Unless Otherwise Noted)

Supply, Disposition, and Prices	2015 Reference	2015 Accelerated Depletion	2015 Accelerated Depletion: Low World Oil Price	2015 Accelerated Depletion: High World Oil Price	2020 Reference	2020 Accelerated Depletion	2020 Accelerated Depletion: Low World Oil Price	2020 Accelerated Depletion: High World Oil Price
Lower 48 Average Wellhead Price[1] (1998 dollars per barrel)	**20.96**	**21.06**	**14.26**	**27.39**	**21.27**	**21.21**	**13.88**	**27.59**
Production[2]								
U.S. Total	**5.39**	**5.10**	**4.53**	**5.59**	**5.47**	**5.18**	**4.51**	**5.80**
Lower 48 Onshore	3.22	3.17	2.72	3.63	3.36	3.39	2.85	3.91
Conventional	2.54	2.49	2.36	2.63	2.65	2.67	2.53	2.80
Enhanced Oil Recovery	0.69	0.68	0.36	1.00	0.71	0.72	0.31	1.11
Lower 48 Offshore	1.54	1.30	1.22	1.31	1.60	1.33	1.23	1.40
Alaska	0.63	0.63	0.60	0.65	0.51	0.47	0.44	0.49
Net Crude Imports	**11.28**	**11.59**	**12.52**	**11.15**	**11.39**	**11.70**	**12.62**	**11.07**
Total Crude Supply	**16.67**	**16.68**	**17.05**	**16.74**	**16.86**	**16.88**	**17.13**	**16.87**
Natural Gas Plant Liquids	**2.28**	**2.17**	**2.12**	**2.20**	**2.38**	**2.07**	**2.02**	**2.11**
Other Inputs[3]	**0.30**	**0.29**	**0.26**	**0.37**	**0.32**	**0.31**	**0.25**	**0.33**
Refinery Processing Gain[4]	**1.11**	**1.10**	**1.01**	**1.22**	**1.12**	**1.11**	**0.98**	**1.16**
Net Product Imports[5]	**3.50**	**3.68**	**4.67**	**2.75**	**4.42**	**5.16**	**6.78**	**4.10**
Total Primary Supply[6]	**23.85**	**23.91**	**25.12**	**23.27**	**25.10**	**25.52**	**27.16**	**24.57**
Refined Petroleum Products Supplied								
Residential and Commercial	0.99	1.00	1.10	0.93	0.96	0.96	1.09	0.90
Industrial[7]	5.81	5.83	5.87	5.76	6.03	6.12	6.14	6.02
Transportation	16.89	16.85	17.12	16.54	17.94	17.90	18.16	17.49
Electric Generators[8]	0.18	0.27	1.05	0.07	0.17	0.56	1.78	0.18
Total	**23.87**	**23.95**	**25.14**	**23.30**	**25.10**	**25.54**	**27.17**	**24.60**
Discrepancy[9]	**-0.03**	**-0.03**	**-0.02**	**-0.03**	**0.00**	**-0.02**	**-0.01**	**-0.02**
L48 End Year Reserves (billion barrels)[2]	**14.05**	**13.41**	**11.56**	**15.26**	**13.86**	**13.45**	**11.22**	**15.73**

Table B7. Total Energy Supply and Disposition Summary, Rapid and Slow Technology Comparisons
(Quadrillion Btu per Year, Unless Otherwise Noted)

Supply, Disposition, and Prices	1998	2005				2010			
				Accelerated Depletion				Accelerated Depletion	
		Reference	Accelerated Depletion	Slow Tech-nology	Rapid Tech-nology	Reference	Accelerated Depletion	Slow Tech-nology	Rapid Tech-
Production									
Crude Oil & Lease Condensate	13.23	11.20	11.10	10.70	11.55	11.15	10.68	9.89	11.59
Natural Gas Plant Liquids	2.49	2.53	2.50	2.47	2.56	2.93	2.88	2.79	3.05
Dry Natural Gas	19.41	19.90	19.67	19.40	20.18	23.37	22.93	22.16	24.32
Coal	23.89	25.97	26.02	26.03	25.87	26.51	26.54	26.69	26.06
Nuclear Power	7.19	7.20	7.20	7.20	7.20	6.70	6.70	6.70	6.70
Renewable Energy[1]	6.67	7.09	7.10	7.10	7.09	7.43	7.43	7.43	7.42
Other[2]	0.57	0.58	0.59	0.58	0.59	0.59	0.59	0.60	0.61
Total	**73.46**	**74.46**	**74.18**	**73.47**	**75.04**	**78.69**	**77.75**	**76.25**	**79.75**
Imports									
Crude Oil[3]	18.90	23.31	23.44	23.77	23.12	24.70	25.16	25.89	24.26
Petroleum Products[4]	3.99	5.79	5.81	5.94	5.59	6.79	6.79	7.01	6.55
Natural Gas	3.37	4.57	4.66	4.74	4.46	4.65	4.82	4.99	4.36
Other Imports[5]	0.59	0.99	0.99	0.99	0.99	0.89	0.89	0.89	0.89
Total	**26.85**	**34.67**	**34.90**	**35.44**	**34.17**	**37.02**	**37.67**	**38.78**	**36.07**
Exports									
Petroleum[6]	1.94	1.94	1.93	1.90	1.96	2.03	2.00	1.93	2.03
Natural Gas	0.17	0.24	0.24	0.24	0.24	0.29	0.29	0.29	0.29
Coal	2.05	1.65	1.65	1.65	1.58	1.73	1.77	1.71	1.63
Total	**4.16**	**3.83**	**3.82**	**3.79**	**3.79**	**4.06**	**4.06**	**3.94**	**3.96**
Discrepancy[7]	**1.28**	**0.14**	**0.15**	**0.14**	**0.19**	**0.11**	**0.10**	**0.14**	**0.13**
Consumption									
Petroleum Products[8]	37.21	41.26	41.30	41.34	41.20	43.98	43.96	44.05	43.87
Natural Gas	21.99	24.26	24.14	23.94	24.43	27.70	27.45	26.84	28.37
Coal	21.50	24.83	24.87	24.88	24.79	25.35	25.35	25.55	25.00
Nuclear Power	7.19	7.20	7.20	7.20	7.20	6.70	6.70	6.70	6.70
Renewable Energy[1]	6.67	7.09	7.10	7.11	7.10	7.44	7.44	7.45	7.43
Other[9]	0.32	0.50	0.50	0.50	0.50	0.36	0.36	0.36	0.36
Total	**94.88**	**105.15**	**105.11**	**104.98**	**105.23**	**111.54**	**111.26**	**110.95**	**111.73**
Net Imports - Petroleum	**20.95**	**27.16**	**27.32**	**27.81**	**26.75**	**29.45**	**29.96**	**30.96**	**28.78**
Prices (1998 dollars per unit)									
World Oil Price (dollars per bbl)[10]	12.10	20.49	20.49	20.49	20.49	21.00	21.00	21.00	21.00
Gas Wellhead Price (dollars per Mcf)[11]	1.96	2.40	2.48	2.57	2.31	2.48	2.62	2.83	2.30
Coal Minemouth Price (dollars per ton)	17.51	14.80	14.82	14.85	14.69	13.89	14.08	14.11	13.68
Average Electric Price (cents per Kwh)	6.71	6.20	6.22	6.24	6.18	5.94	6.02	6.10	5.89

[1]Includes grid-connected electricity from conventional hydroelectric; wood and wood waste; landfill gas; municipal solid waste; other biomass; wind; photovoltaic and solar thermal sources; non-electric energy from renewable sources, such as active and passive solar systems, and wood; and both the ethanol and gasoline components of E85, but not the ethanol components of blends less than 85 percent. Excludes electricity imports using renewable sources and nonmarketed renewable energy.
[2]Includes liquid hydrogen, methanol, supplemental natural gas, and some domestic inputs to refineries.
[3]Includes imports of crude oil for the Strategic Petroleum Reserve.
[4]Includes imports of finished petroleum products, imports of unfinished oils, alcohols, ethers, and blending components.
[5]Includes coal, coal coke (net), and electricity (net).
[6]Includes crude oil and petroleum products.
[7]Balancing item. Includes unaccounted for supply, losses, gains, and net storage withdrawals.
[8]Includes natural gas plant liquids, crude oil consumed as a fuel, and nonpetroleum based liquids for blending, such as ethanol.
[9]Includes net electricity imports, methanol, and liquid hydrogen.
[10]Average refiner acquisition cost for imported crude oil.
[11]Represents lower 48 onshore and offshore supplies.
Btu = British thermal unit.
Mcf = Thousand cubic feet.
Kwh = Kilowatthour.
Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A, OGDEPL.D051200A, OGSLOW.D051200A, and OGRTECH.D051200A.

Table B7. Total Energy Supply and Disposition Summary, Rapid and Slow Technology Comparisons (Continued)

(Quadrillion Btu per Year, Unless Otherwise Noted)

Supply, Disposition, and Prices	2015				2020			
			Accelerated Depletion				Accelerated Depletion	
	Reference	Accelerated Depletion	Slow Tech-nology	Rapid Tech-nology	Reference	Accelerated Depletion	Slow Tech-nology	Rapid Tech-
Production								
Crude Oil & Lease Condensate	11.41	10.79	9.51	12.38	11.57	10.97	9.26	12.61
Natural Gas Plant Liquids	3.23	3.07	2.88	3.43	3.38	2.94	2.66	3.68
Dry Natural Gas	25.90	24.61	23.09	27.59	27.29	23.68	21.43	29.80
Coal	26.97	27.40	27.65	26.29	27.53	28.21	28.87	26.86
Nuclear Power	5.45	5.45	5.45	5.45	4.56	4.56	4.62	4.57
Renewable Energy[1]	7.71	7.72	7.74	7.75	7.99	8.06	8.06	8.03
Other[2]	0.61	0.59	0.59	0.63	0.66	0.63	0.62	0.66
Total	**81.28**	**79.64**	**76.90**	**83.52**	**82.98**	**79.04**	**75.53**	**86.20**
Imports								
Crude Oil[3]	24.56	25.20	26.47	23.68	24.82	25.45	27.18	23.81
Petroleum Products[4]	9.08	9.36	9.84	8.57	10.83	12.12	13.33	10.41
Natural Gas	5.00	5.33	5.60	4.47	5.35	6.01	5.97	4.36
Other Imports[5]	0.89	0.89	0.89	0.89	0.97	0.97	0.98	0.97
Total	**39.53**	**40.78**	**42.80**	**37.62**	**41.97**	**44.55**	**47.46**	**39.55**
Exports								
Petroleum[6]	2.06	2.02	1.93	2.07	1.99	1.85	1.82	2.07
Natural Gas	0.35	0.35	0.35	0.35	0.36	0.36	0.36	0.36
Coal	1.63	1.74	1.65	1.44	1.50	1.49	1.49	1.46
Total	**4.04**	**4.11**	**3.93**	**3.87**	**3.85**	**3.70**	**3.66**	**3.90**
Discrepancy[7]	**0.09**	**0.08**	**0.13**	**0.04**	**0.10**	**0.09**	**0.16**	**0.03**
Consumption								
Petroleum Products[8]	46.64	46.82	47.13	46.46	49.06	50.04	50.96	48.96
Natural Gas	30.54	29.58	28.33	31.69	32.28	29.34	27.04	33.79
Coal	25.99	26.31	26.65	25.53	26.74	27.43	28.11	26.11
Nuclear Power	5.45	5.45	5.45	5.45	4.56	4.56	4.62	4.57
Renewable Energy[1]	7.73	7.74	7.76	7.76	8.01	8.07	8.08	8.05
Other[9]	0.32	0.32	0.33	0.33	0.36	0.36	0.36	0.36
Total	**116.68**	**116.23**	**115.65**	**117.23**	**121.00**	**119.80**	**119.16**	**121.82**
Net Imports - Petroleum	**31.58**	**32.53**	**34.39**	**30.18**	**33.66**	**35.72**	**38.70**	**32.15**
Prices (1998 dollars per unit)								
World Oil Price (dollars per bbl)[10]	21.53	21.53	21.53	21.53	22.04	22.04	22.04	22.04
Gas Wellhead Price (dollars per Mcf)[11]	2.68	3.13	3.59	2.32	2.79	4.12	4.56	2.37
Coal Minemouth Price (dollars per ton)	13.41	13.63	13.56	13.08	12.57	12.71	12.57	12.34
Average Electric Price (cents per Kwh)	5.87	6.06	6.22	5.73	5.83	6.33	6.44	5.63

Table B8. Natural Gas Supply and Disposition, Rapid and Slow Technology Comparisons
(Trillion Cubic Feet per Year, Unless Otherwise Noted)

Supply, Disposition, and Prices	1998	2005				2010			
		Reference	Accelerated Depletion	Accelerated Depletion		Reference	Accelerated Depletion	Accelerated Depletion	
				Slow Tech-nology	Rapid Tech-nology			Slow Tech-nology	Rapid Tech-
Lower 48 Average Wellhead Price[1]									
(1998 dollars per thousand cubic feet)	**1.96**	**2.40**	**2.48**	**2.57**	**2.31**	**2.48**	**2.62**	**2.83**	**2.30**
Dry Gas Production[2]									
U.S. Total	**18.88**	**19.35**	**19.14**	**18.87**	**19.63**	**22.73**	**22.31**	**21.55**	**23.66**
Lower 48 Onshore	12.91	13.09	12.93	12.82	13.35	16.33	16.04	15.70	16.81
Associated-Dissolved[3]	1.72	1.26	1.26	1.25	1.27	1.25	1.23	1.21	1.26
Non-Associated	11.19	11.84	11.67	11.58	12.07	15.08	14.80	14.49	15.56
Conventional	6.69	6.54	6.68	6.75	6.52	9.24	9.37	9.18	8.88
Unconventional	4.50	5.29	4.99	4.83	5.55	5.84	5.44	5.31	6.68
Lower 48 Offshore	5.54	5.80	5.75	5.59	5.82	5.91	5.78	5.36	6.36
Associated-Dissolved[3]	0.89	0.89	0.89	0.88	0.91	0.90	0.86	0.83	0.90
Non-Associated	4.65	4.91	4.85	4.71	4.91	5.01	4.92	4.54	5.46
Alaska	0.44	0.46	0.46	0.46	0.46	0.49	0.49	0.49	0.49
Supplemental Natural Gas[4]	**0.12**	**0.11**	**0.11**	**0.11**	**0.11**	**0.06**	**0.06**	**0.06**	**0.06**
Net Imports	**3.13**	**4.24**	**4.33**	**4.40**	**4.14**	**4.26**	**4.43**	**4.60**	**3.98**
Total Supply	**22.13**	**23.71**	**23.58**	**23.38**	**23.88**	**27.05**	**26.80**	**26.21**	**27.70**
Consumption by Sector									
Residential	4.48	5.07	5.05	5.03	5.08	5.32	5.29	5.24	5.36
Commercial	3.03	3.32	3.31	3.29	3.33	3.50	3.47	3.43	3.53
Industrial[5]	8.23	8.75	8.73	8.70	8.79	9.24	9.18	9.09	9.32
Electric Generators[6]	3.67	4.36	4.31	4.21	4.44	6.42	6.33	5.98	6.85
Lease and Plant Fuel[7]	1.24	1.23	1.22	1.20	1.24	1.41	1.40	1.36	1.46
Pipeline Fuel	0.73	0.73	0.72	0.72	0.74	0.85	0.83	0.81	0.88
Transportation[8]	0.02	0.15	0.15	0.15	0.15	0.22	0.22	0.22	0.22
Total	**21.40**	**23.61**	**23.49**	**23.30**	**23.78**	**26.97**	**26.72**	**26.13**	**27.62**
Discrepancy[9]	**0.74**	**0.10**	**0.09**	**0.09**	**0.10**	**0.08**	**0.08**	**0.08**	**0.08**
Lower 48 End of Year Reserves	**156.00**	**164.17**	**157.10**	**150.87**	**171.25**	**180.14**	**166.49**	**156.56**	**196.52**

[1]Represents lower 48 onshore and offshore supplies.
[2]Marketed production (wet) minus extraction losses.
[3]Gas which occurs in crude oil reserves either as free gas (associated) or as gas in solution with crude oil (dissolved).
[4]Synthetic natural gas, propane air, coke oven gas, refinery gas, biomass gas, air injected for Btu stabilization, and manufactured gas commingled and distributed with natural gas.
[5]Includes consumption by cogenerators.
[6]Includes all electric power generators except cogenerators, which produce electricity and other useful thermal energy. Includes small power producers and exempt wholesale generators.
[7]Represents natural gas used in the field gathering and processing plant machinery.
[8]Compressed natural gas used as vehicle fuel.
[9]Balancing item. Natural gas lost as a result of converting flow data measured at varying temperatures and pressures to a standard temperature and pressure and the merger of different data reporting systems which vary in scope, format, definition, and respondent type.
Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A, OGDEPL.D051200A, OGSLOW.D051200A, and OGRTECH.D051200A.

Table B8. Natural Gas Supply and Disposition, Rapid and Slow Technology Comparisons (Continued)
(Trillion Cubic Feet per Year, Unless Otherwise Noted)

Supply, Disposition, and Prices	2015				2020			
			Accelerated Depletion				Accelerated Depletion	
	Reference	Accelerated Depletion	Slow Tech-nology	Rapid Tech-nology	Reference	Accelerated Depletion	Slow Tech-nology	Rapid Tech-
Lower 48 Average Wellhead Price[1]								
(1998 dollars per thousand cubic feet)	**2.68**	**3.13**	**3.59**	**2.32**	**2.79**	**4.12**	**4.56**	**2.37**
Dry Gas Production[2]								
U.S. Total	**25.19**	**23.94**	**22.46**	**26.84**	**26.54**	**23.03**	**20.84**	**28.98**
Lower 48 Onshore	17.97	17.42	16.68	19.88	19.36	17.58	15.85	23.04
Associated-Dissolved[3]	1.30	1.29	1.22	1.35	1.32	1.31	1.23	1.37
Non-Associated	16.67	16.13	15.45	18.53	18.03	16.26	14.62	21.66
Conventional	10.19	10.26	9.58	10.00	10.65	10.26	8.85	10.78
Unconventional	6.48	5.87	5.88	8.53	7.38	6.00	5.76	10.88
Lower 48 Offshore	6.71	6.01	5.27	6.44	6.65	4.92	4.46	5.41
Associated-Dissolved[3]	0.93	0.87	0.83	0.92	0.94	0.88	0.83	0.93
Non-Associated	5.78	5.14	4.43	5.53	5.71	4.04	3.63	4.47
Alaska	0.51	0.51	0.51	0.51	0.54	0.54	0.54	0.54
Supplemental Natural Gas[4]	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**
Net Imports	**4.55**	**4.87**	**5.13**	**4.03**	**4.88**	**5.52**	**5.49**	**3.91**
Total Supply	**29.80**	**28.87**	**27.64**	**30.92**	**31.48**	**28.62**	**26.39**	**32.95**
Consumption by Sector								
Residential	5.49	5.40	5.31	5.58	5.71	5.45	5.35	5.82
Commercial	3.61	3.53	3.46	3.67	3.65	3.45	3.37	3.73
Industrial[5]	9.65	9.48	9.29	9.79	10.00	9.54	9.32	10.16
Electric Generators[6]	8.22	7.72	6.98	8.93	9.14	7.47	5.80	10.07
Lease and Plant Fuel[7]	1.56	1.50	1.43	1.63	1.66	1.49	1.38	1.77
Pipeline Fuel	0.92	0.88	0.83	0.98	0.96	0.84	0.78	1.03
Transportation[8]	0.28	0.28	0.28	0.28	0.32	0.31	0.31	0.32
Total	**29.74**	**28.80**	**27.58**	**30.86**	**31.43**	**28.56**	**26.32**	**32.91**
Discrepancy[9]	**0.06**	**0.07**	**0.07**	**0.06**	**0.05**	**0.05**	**0.08**	**0.04**
Lower 48 End of Year Reserves	**193.46**	**166.04**	**155.18**	**226.00**	**199.54**	**152.26**	**142.20**	**232.16**

Table B9. Crude Oil Supply and Disposition, Rapid and Slow Technology Comparisons
(Million Barrels per Day, Unless Otherwise Noted)

		2005				2010			
				Accelerated Depletion				Accelerated Depletion	
Supply, Disposition, and Prices	1998	Reference	Accelerated Depletion	Slow Tech-nology	Rapid Tech-nology	Reference	Accelerated Depletion	Slow Tech-nology	Rapid Tech-
Lower 48 Average Wellhead Price[1]									
(1998 dollars per barrel)	**11.60**	**20.12**	**20.11**	**20.16**	**20.00**	**20.65**	**20.65**	**20.73**	**20.50**
Production[2]									
U.S. Total	**6.25**	**5.29**	**5.25**	**5.05**	**5.45**	**5.27**	**5.04**	**4.67**	**5.47**
Lower 48 Onshore	3.60	2.93	2.94	2.87	3.01	3.01	2.95	2.81	3.13
Conventional	2.87	2.33	2.34	2.29	2.38	2.39	2.34	2.23	2.44
Enhanced Oil Recovery	0.73	0.60	0.60	0.59	0.63	0.62	0.62	0.58	0.69
Lower 48 Offshore	1.47	1.39	1.34	1.27	1.43	1.44	1.27	1.15	1.43
Alaska	1.18	0.96	0.96	0.91	1.02	0.82	0.82	0.71	0.91
Net Crude Imports	**8.60**	**10.71**	**10.77**	**10.93**	**10.61**	**11.35**	**11.57**	**11.91**	**11.13**
Total Crude Supply	**14.89**	**15.99**	**16.01**	**15.98**	**16.07**	**16.61**	**16.61**	**16.59**	**16.61**
Natural Gas Plant Liquids	**1.76**	**1.78**	**1.76**	**1.74**	**1.81**	**2.07**	**2.03**	**1.97**	**2.15**
Other Inputs[3]	**0.25**	**0.27**	**0.27**	**0.27**	**0.28**	**0.29**	**0.29**	**0.30**	**0.30**
Refinery Processing Gain[4]	**0.89**	**1.02**	**1.02**	**1.00**	**1.01**	**1.11**	**1.10**	**1.09**	**1.09**
Net Product Imports[5]	**1.17**	**1.98**	**1.99**	**2.09**	**1.86**	**2.38**	**2.41**	**2.55**	**2.27**
Total Primary Supply[6]	**18.95**	**21.05**	**21.07**	**21.08**	**21.02**	**22.47**	**22.46**	**22.49**	**22.42**
Refined Petroleum Products Supplied									
Residential and Commercial	1.06	1.05	1.05	1.05	1.05	1.03	1.03	1.03	1.03
Industrial[7]	4.80	5.29	5.29	5.29	5.27	5.54	5.54	5.54	5.52
Transportation	12.54	14.43	14.43	14.43	14.44	15.74	15.71	15.70	15.76
Electric Generators[8]	0.54	0.33	0.34	0.37	0.31	0.20	0.22	0.28	0.16
Total	**18.94**	**21.09**	**21.11**	**21.13**	**21.07**	**22.51**	**22.50**	**22.53**	**22.46**
Discrepancy[9]	**0.01**	**-0.05**	**-0.05**	**-0.05**	**-0.04**	**-0.04**	**-0.04**	**-0.04**	**-0.04**
L48 End Year Reserves (billion barrels)[2]	**18.16**	**14.46**	**14.12**	**13.69**	**14.61**	**13.98**	**13.39**	**12.60**	**14.39**

[1]Represents lower 48 onshore and offshore supplies.
[2]Includes lease condensate.
[3]Includes alcohols, ethers, petroleum product stock withdrawals, domestic sources of blending components, and other hydrocarbons.
[4]Represents volumetric gain in refinery distillation and cracking processes.
[5]Includes net imports of finished petroleum products, unfinished oils, other hydrocarbons, alcohols, ethers, and blending components.
[6]Total crude supply plus natural gas plant liquids, other inputs, refinery processing gain, and net petroleum imports.
[7]Includes consumption by cogenerators.
[8]Includes all electric power generators except cogenerators, which produce electricity and other useful thermal energy. Includes small power producers and exempt wholesale generators.
9Balancing item. Includes unaccounted for supply, losses and gains.
Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A, OGDEPL.D051200A, OGSLOW.D051200A, and OGRTECH.D051200A.

Table B9. Crude Oil Supply and Disposition, Rapid and Slow Technology Comparisons (Continued)
(Million Barrels per Day, Unless Otherwise Noted)

Supply, Disposition, and Prices	2015				2020			
			Accelerated Depletion				Accelerated Depletion	
	Reference	Accelerated Depletion	Slow Tech-nology	Rapid Tech-nology	Reference	Accelerated Depletion	Slow Tech-nology	Rapid Tech-
Lower 48 Average Wellhead Price[1]								
(1998 dollars per barrel)	**20.96**	**21.06**	**21.15**	**20.71**	**21.27**	**21.21**	**21.30**	**21.08**
Production[2]								
U.S. Total	**5.39**	**5.10**	**4.49**	**5.85**	**5.47**	**5.18**	**4.37**	**5.96**
Lower 48 Onshore	3.22	3.17	2.85	3.52	3.36	3.39	2.87	3.73
Conventional	2.54	2.49	2.25	2.73	2.65	2.67	2.28	2.94
Enhanced Oil Recovery	0.69	0.68	0.60	0.79	0.71	0.72	0.59	0.79
Lower 48 Offshore	1.54	1.30	1.16	1.51	1.60	1.33	1.17	1.57
Alaska	0.63	0.63	0.48	0.82	0.51	0.47	0.34	0.66
Net Crude Imports	**11.28**	**11.59**	**12.18**	**10.85**	**11.39**	**11.70**	**12.51**	**10.91**
Total Crude Supply	**16.67**	**16.68**	**16.68**	**16.70**	**16.86**	**16.88**	**16.88**	**16.86**
Natural Gas Plant Liquids	**2.28**	**2.17**	**2.03**	**2.42**	**2.38**	**2.07**	**1.87**	**2.59**
Other Inputs[3]	**0.30**	**0.29**	**0.29**	**0.31**	**0.32**	**0.31**	**0.30**	**0.32**
Refinery Processing Gain[4]	**1.11**	**1.10**	**1.10**	**1.09**	**1.12**	**1.11**	**1.10**	**1.10**
Net Product Imports[5]	**3.50**	**3.68**	**3.96**	**3.27**	**4.42**	**5.16**	**5.79**	**4.19**
Total Primary Supply[6]	**23.85**	**23.91**	**24.05**	**23.78**	**25.10**	**25.52**	**25.95**	**25.07**
Refined Petroleum Products Supplied								
Residential and Commercial	0.99	1.00	1.00	1.00	0.96	0.96	0.97	0.97
Industrial[7]	5.81	5.83	5.84	5.77	6.03	6.12	6.13	6.00
Transportation	16.89	16.85	16.83	16.92	17.94	17.90	17.89	18.00
Electric Generators[8]	0.18	0.27	0.41	0.12	0.17	0.56	0.98	0.10
Total	**23.87**	**23.95**	**24.08**	**23.80**	**25.10**	**25.54**	**25.97**	**25.07**
Discrepancy[9]	**-0.03**	**-0.03**	**-0.03**	**-0.02**	**0.00**	**-0.02**	**-0.02**	**0.00**
L48 End Year Reserves (billion barrels)[2]	**14.05**	**13.41**	**12.08**	**14.95**	**13.86**	**13.45**	**11.54**	**14.93**

Table B10. Total Energy Supply and Disposition Summary, Reduced and Improved Productivity Technology Comparisons

(Quadrillion Btu per Year, Unless Otherwise Noted)

Supply, Disposition, and Prices	1998	2005				2010			
				Accelerated Depletion				Accelerated Depletion	
		Reference	Accelerated Depletion	Reduced Productivity Technology	Improved Productivity Technology	Reference	Accelerated Depletion	Reduced Productivity Technology	Improved Productivity Technology
Production									
Crude Oil & Lease Condensate	13.23	11.20	11.10	10.70	11.55	11.15	10.68	9.90	11.59
Natural Gas Plant Liquids	2.49	2.53	2.50	2.49	2.54	2.93	2.88	2.86	3.00
Dry Natural Gas	19.41	19.90	19.67	19.62	19.98	23.37	22.93	22.72	23.90
Coal	23.89	25.97	26.02	26.00	25.97	26.51	26.54	26.54	26.28
Nuclear Power	7.19	7.20	7.20	7.20	7.20	6.70	6.70	6.70	6.70
Renewable Energy[1]	6.67	7.09	7.10	7.09	7.09	7.43	7.43	7.43	7.42
Other[2]	0.57	0.58	0.59	0.58	0.58	0.59	0.59	0.60	0.61
Total	**73.46**	**74.46**	**74.18**	**73.68**	**74.91**	**78.69**	**77.75**	**76.74**	**79.51**
Imports									
Crude Oil[3]	18.90	23.31	23.44	23.78	22.96	24.70	25.16	25.88	24.25
Petroleum Products[4]	3.99	5.79	5.81	5.87	5.79	6.79	6.79	6.84	6.60
Natural Gas	3.37	4.57	4.66	4.68	4.53	4.65	4.82	4.87	4.52
Other Imports[5]	0.59	0.99	0.99	0.99	0.99	0.89	0.89	0.89	0.89
Total	**26.85**	**34.67**	**34.90**	**35.32**	**34.27**	**37.02**	**37.67**	**38.49**	**36.26**
Exports									
Petroleum[6]	1.94	1.94	1.93	1.91	1.98	2.03	2.00	1.93	2.02
Natural Gas	0.17	0.24	0.24	0.24	0.24	0.29	0.29	0.29	0.29
Coal	2.05	1.65	1.65	1.65	1.65	1.73	1.77	1.74	1.75
Total	**4.16**	**3.83**	**3.82**	**3.80**	**3.87**	**4.06**	**4.06**	**3.96**	**4.06**
Discrepancy[7]	**1.28**	**0.14**	**0.15**	**0.16**	**0.14**	**0.11**	**0.10**	**0.16**	**0.09**
Consumption									
Petroleum Products[8]	37.21	41.26	41.30	41.29	41.24	43.98	43.96	43.96	43.90
Natural Gas	21.99	24.26	24.14	24.10	24.31	27.70	27.45	27.28	28.11
Coal	21.50	24.83	24.87	24.85	24.83	25.35	25.35	25.37	25.11
Nuclear Power	7.19	7.20	7.20	7.20	7.20	6.70	6.70	6.70	6.70
Renewable Energy[1]	6.67	7.09	7.10	7.10	7.09	7.44	7.44	7.44	7.43
Other[9]	0.32	0.50	0.50	0.50	0.50	0.36	0.36	0.36	0.36
Total	**94.88**	**105.15**	**105.11**	**105.03**	**105.17**	**111.54**	**111.26**	**111.11**	**111.62**
Net Imports - Petroleum	**20.95**	**27.16**	**27.32**	**27.74**	**26.77**	**29.45**	**29.96**	**30.80**	**28.83**
Prices (1998 dollars per unit)									
World Oil Price (dollars per bbl)[10]	12.10	20.49	20.49	20.49	20.49	21.00	21.00	21.00	21.00
Gas Wellhead Price (dollars per Mcf)[11]	1.96	2.40	2.48	2.49	2.37	2.48	2.62	2.66	2.39
Coal Minemouth Price (dollars per ton)	17.51	14.80	14.82	14.83	14.80	13.89	14.08	14.05	13.93
Average Electric Price (cents per Kwh)	6.71	6.20	6.22	6.22	6.19	5.94	6.02	6.03	5.93

[1]Includes grid-connected electricity from conventional hydroelectric; wood and wood waste; landfill gas; municipal solid waste; other biomass; wind; photovoltaic and solar thermal sources; non-electric energy from renewable sources, such as active and passive solar systems, and wood; and both the ethanol and gasoline components of E85, but not the ethanol components of blends less than 85 percent. Excludes electricity imports using renewable sources and nonmarketed renewable energy.
[2]Includes liquid hydrogen, methanol, supplemental natural gas, and some domestic inputs to refineries.
[3]Includes imports of crude oil for the Strategic Petroleum Reserve.
[4]Includes imports of finished petroleum products, imports of unfinished oils, alcohols, ethers, and blending components.
[5]Includes coal, coal coke (net), and electricity (net).
[6]Includes crude oil and petroleum products.
[7]Balancing item. Includes unaccounted for supply, losses, gains, and net storage withdrawals.
[8]Includes natural gas plant liquids, crude oil consumed as a fuel, and nonpetroleum based liquids for blending, such as ethanol.
[9]Includes net electricity imports, methanol, and liquid hydrogen.
[10]Average refiner acquisition cost for imported crude oil.
[11]Represents lower 48 onshore and offshore supplies.
Btu = British thermal unit.
Mcf = Thousand cubic feet.
Kwh = Kilowatthour.
Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A, OGDEPL.D051200A, OGFRLTEC.D051200A, and OGFRHTEC.D051200A.

Table B10. Total Energy Supply and Disposition Summary, Reduced and Improved Productivity Technology Comparisons (Continued)

(Quadrillion Btu per Year, Unless Otherwise Noted)

Supply, Disposition, and Prices	2015				2020			
			Accelerated Depletion				Accelerated Depletion	
	Reference	Accelerated Depletion	Reduced Productivity Technology	Improved Productivity Technology	Reference	Accelerated Depletion	Reduced Productivity Technology	Improved Productivity Technology
Production								
Crude Oil & Lease Condensate	11.41	10.79	9.50	12.36	11.57	10.97	9.29	12.64
Natural Gas Plant Liquids	3.23	3.07	2.99	3.29	3.38	2.94	2.85	3.34
Dry Natural Gas	25.90	24.61	23.98	26.41	27.29	23.68	23.06	27.06
Coal	26.97	27.40	27.45	26.85	27.53	28.21	28.40	27.59
Nuclear Power	5.45	5.45	5.45	5.45	4.56	4.56	4.55	4.56
Renewable Energy[1]	7.71	7.72	7.75	7.73	7.99	8.06	8.05	8.00
Other[2]	0.61	0.59	0.59	0.61	0.66	0.63	0.63	0.66
Total	**81.28**	**79.64**	**77.71**	**82.70**	**82.98**	**79.04**	**76.83**	**83.85**
Imports								
Crude Oil[3]	24.56	25.20	26.45	23.71	24.82	25.45	27.14	23.80
Petroleum Products[4]	9.08	9.36	9.59	8.92	10.83	12.12	12.34	10.88
Natural Gas	5.00	5.33	5.44	4.86	5.35	6.01	6.00	5.40
Other Imports[5]	0.89	0.89	0.89	0.89	0.97	0.97	0.97	0.97
Total	**39.53**	**40.78**	**42.37**	**38.38**	**41.97**	**44.55**	**46.46**	**41.05**
Exports								
Petroleum[6]	2.06	2.02	1.95	2.12	1.99	1.85	1.81	2.02
Natural Gas	0.35	0.35	0.35	0.35	0.36	0.36	0.36	0.36
Coal	1.63	1.74	1.65	1.63	1.50	1.49	1.49	1.50
Total	**4.04**	**4.11**	**3.95**	**4.10**	**3.85**	**3.70**	**3.65**	**3.87**
Discrepancy[7]	**0.09**	**0.08**	**0.15**	**0.08**	**0.10**	**0.09**	**0.18**	**0.08**
Consumption								
Petroleum Products[8]	46.64	46.82	46.94	46.62	49.06	50.04	50.14	49.12
Natural Gas	30.54	29.58	29.06	30.91	32.28	29.34	28.72	32.09
Coal	25.99	26.31	26.44	25.85	26.74	27.43	27.63	26.80
Nuclear Power	5.45	5.45	5.45	5.45	4.56	4.56	4.55	4.56
Renewable Energy[1]	7.73	7.74	7.76	7.74	8.01	8.07	8.06	8.02
Other[9]	0.32	0.32	0.33	0.32	0.36	0.36	0.36	0.36
Total	**116.68**	**116.23**	**115.98**	**116.90**	**121.00**	**119.80**	**119.46**	**120.95**
Net Imports - Petroleum	**31.58**	**32.53**	**34.09**	**30.51**	**33.66**	**35.72**	**37.67**	**32.66**
Prices (1998 dollars per unit)								
World Oil Price (dollars per bbl)[10]	21.53	21.53	21.53	21.53	22.04	22.04	22.04	22.04
Gas Wellhead Price (dollars per Mcf)[11]	2.68	3.13	3.33	2.65	2.79	4.12	4.24	2.99
Coal Minemouth Price (dollars per ton)	13.41	13.63	13.55	13.46	12.57	12.71	12.61	12.65
Average Electric Price (cents per Kwh)	5.87	6.06	6.13	5.86	5.83	6.33	6.36	5.91

Table B11. Natural Gas Supply and Disposition, Reduced and Improved Productivity Technology Comparisons
(Trillion Cubic Feet per Year, Unless Otherwise Noted)

Supply, Disposition, and Prices	1998	2005				2010			
				Accelerated Depletion				Accelerated Depletion	
		Reference	Accelerated Depletion	Reduced Productivity Technology	Improved Productivity Technology	Reference	Accelerated Depletion	Reduced Productivity Technology	Improved Productivity Technology
Lower 48 Average Wellhead Price[1]									
(1998 dollars per thousand cubic feet)	**1.96**	**2.40**	**2.48**	**2.49**	**2.37**	**2.48**	**2.62**	**2.66**	**2.39**
Dry Gas Production[2]									
U.S. Total	**18.88**	**19.35**	**19.14**	**19.08**	**19.44**	**22.73**	**22.31**	**22.10**	**23.25**
Lower 48 Onshore	12.91	13.09	12.93	13.07	13.16	16.33	16.04	16.19	16.49
Associated-Dissolved[3]	1.72	1.26	1.26	1.24	1.28	1.25	1.23	1.21	1.26
Non-Associated	11.19	11.84	11.67	11.83	11.88	15.08	14.80	14.99	15.24
Conventional	6.69	6.54	6.68	6.64	6.51	9.24	9.37	9.30	9.16
Unconventional	4.50	5.29	4.99	5.19	5.37	5.84	5.44	5.69	6.07
Lower 48 Offshore	5.54	5.80	5.75	5.55	5.83	5.91	5.78	5.42	6.27
Associated-Dissolved[3]	0.89	0.89	0.89	0.88	0.91	0.90	0.86	0.83	0.90
Non-Associated	4.65	4.91	4.85	4.67	4.92	5.01	4.92	4.59	5.38
Alaska	0.44	0.46	0.46	0.46	0.46	0.49	0.49	0.49	0.49
Supplemental Natural Gas[4]	**0.12**	**0.11**	**0.11**	**0.11**	**0.11**	**0.06**	**0.06**	**0.06**	**0.06**
Net Imports	**3.13**	**4.24**	**4.33**	**4.34**	**4.20**	**4.26**	**4.43**	**4.47**	**4.13**
Total Supply	**22.13**	**23.71**	**23.58**	**23.54**	**23.76**	**27.05**	**26.80**	**26.63**	**27.45**
Consumption by Sector									
Residential	4.48	5.07	5.05	5.05	5.07	5.32	5.29	5.28	5.34
Commercial	3.03	3.32	3.31	3.30	3.32	3.50	3.47	3.46	3.51
Industrial[5]	8.23	8.75	8.73	8.72	8.77	9.24	9.18	9.15	9.29
Electric Generators[6]	3.67	4.36	4.31	4.29	4.38	6.42	6.33	6.23	6.69
Lease and Plant Fuel[7]	1.24	1.23	1.22	1.21	1.23	1.41	1.40	1.39	1.44
Pipeline Fuel	0.73	0.73	0.72	0.72	0.73	0.85	0.83	0.83	0.86
Transportation[8]	0.02	0.15	0.15	0.15	0.15	0.22	0.22	0.22	0.22
Total	**21.40**	**23.61**	**23.49**	**23.45**	**23.66**	**26.97**	**26.72**	**26.55**	**27.37**
Discrepancy[9]	**0.74**	**0.10**	**0.09**	**0.09**	**0.10**	**0.08**	**0.08**	**0.08**	**0.08**
Lower 48 End of Year Reserves	**156.00**	**164.17**	**157.10**	**157.12**	**167.55**	**180.14**	**166.49**	**163.24**	**183.40**

[1]Represents lower 48 onshore and offshore supplies.
[2]Marketed production (wet) minus extraction losses.
[3]Gas which occurs in crude oil reserves either as free gas (associated) or as gas in solution with crude oil (dissolved).
[4]Synthetic natural gas, propane air, coke oven gas, refinery gas, biomass gas, air injected for Btu stabilization, and manufactured gas commingled and distributed with natural gas.
[5]Includes consumption by cogenerators.
[6]Includes all electric power generators except cogenerators, which produce electricity and other useful thermal energy. Includes small power producers and exempt wholesale generators.
[7]Represents natural gas used in the field gathering and processing plant machinery.
[8]Compressed natural gas used as vehicle fuel.
[9]Balancing item. Natural gas lost as a result of converting flow data measured at varying temperatures and pressures to a standard temperature and pressure and the merger of different data reporting systems which vary in scope, format, definition, and respondent type.
Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A, OGDEPL.D051200A, OGFRLTEC.D051200A, and OGFRHTEC.D051200A.

Table B11. Natural Gas Supply and Disposition, Reduced and Improved Productivity Technology Comparisons (Continued)

(Trillion Cubic Feet per Year, Unless Otherwise Noted)

Supply, Disposition, and Prices	2015				2020			
			Accelerated Depletion				Accelerated Depletion	
	Reference	Accelerated Depletion	Reduced Productivity Technology	Improved Productivity Technology	Reference	Accelerated Depletion	Reduced Productivity Technology	Improved Productivity Technology
Lower 48 Average Wellhead Price[1]								
(1998 dollars per thousand cubic feet)	**2.68**	**3.13**	**3.33**	**2.65**	**2.79**	**4.12**	**4.24**	**2.99**
Dry Gas Production[2]								
U.S. Total	**25.19**	**23.94**	**23.33**	**25.69**	**26.54**	**23.03**	**22.43**	**26.32**
Lower 48 Onshore	17.97	17.42	17.31	18.63	19.36	17.58	17.35	20.48
Associated-Dissolved[3]	1.30	1.29	1.22	1.35	1.32	1.31	1.23	1.38
Non-Associated	16.67	16.13	16.09	17.28	18.03	16.26	16.12	19.10
Conventional	10.19	10.26	9.92	10.30	10.65	10.26	9.56	10.86
Unconventional	6.48	5.87	6.18	6.98	7.38	6.00	6.56	8.24
Lower 48 Offshore	6.71	6.01	5.50	6.55	6.65	4.92	4.55	5.30
Associated-Dissolved[3]	0.93	0.87	0.83	0.92	0.94	0.88	0.83	0.93
Non-Associated	5.78	5.14	4.67	5.63	5.71	4.04	3.71	4.37
Alaska	0.51	0.51	0.51	0.51	0.54	0.54	0.54	0.54
Supplemental Natural Gas[4]	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**
Net Imports	**4.55**	**4.87**	**4.98**	**4.41**	**4.88**	**5.52**	**5.52**	**4.93**
Total Supply	**29.80**	**28.87**	**28.36**	**30.16**	**31.48**	**28.62**	**28.01**	**31.31**
Consumption by Sector								
Residential	5.49	5.40	5.37	5.51	5.71	5.45	5.42	5.68
Commercial	3.61	3.53	3.50	3.62	3.65	3.45	3.42	3.63
Industrial[5]	9.65	9.48	9.39	9.69	10.00	9.54	9.45	9.95
Electric Generators[6]	8.22	7.72	7.43	8.48	9.14	7.47	7.06	9.08
Lease and Plant Fuel[7]	1.56	1.50	1.47	1.58	1.66	1.49	1.46	1.65
Pipeline Fuel	0.92	0.88	0.86	0.93	0.96	0.84	0.83	0.95
Transportation[8]	0.28	0.28	0.28	0.28	0.32	0.31	0.31	0.32
Total	**29.74**	**28.80**	**28.30**	**30.09**	**31.43**	**28.56**	**27.96**	**31.25**
Discrepancy[9]	**0.06**	**0.07**	**0.06**	**0.06**	**0.05**	**0.05**	**0.05**	**0.05**
Lower 48 End of Year Reserves	**193.46**	**166.04**	**163.36**	**196.31**	**199.54**	**152.26**	**152.10**	**196.80**

Table B12. Crude Oil Supply and Disposition, Reduced and Improved Productivity Technology Comparisons

(Million Barrels per Day, Unless Otherwise Noted)

Supply, Disposition, and Prices	1998	2005 Reference	2005 Accelerated Depletion	2005 Accelerated Depletion: Reduced Productivity Technology	2005 Accelerated Depletion: Improved Productivity Technology	2010 Reference	2010 Accelerated Depletion	2010 Accelerated Depletion: Reduced Productivity Technology	2010 Accelerated Depletion: Improved Productivity Technology
Lower 48 Average Wellhead Price[1]									
(1998 dollars per barrel)	**11.60**	**20.12**	**20.11**	**20.16**	**20.06**	**20.65**	**20.65**	**20.71**	**20.52**
Production[2]									
U.S. Total	**6.25**	**5.29**	**5.25**	**5.05**	**5.46**	**5.27**	**5.04**	**4.68**	**5.47**
Lower 48 Onshore	3.60	2.93	2.94	2.87	3.01	3.01	2.95	2.81	3.13
Conventional	2.87	2.33	2.34	2.28	2.38	2.39	2.34	2.23	2.44
Enhanced Oil Recovery	0.73	0.60	0.60	0.59	0.63	0.62	0.62	0.59	0.69
Lower 48 Offshore	1.47	1.39	1.34	1.27	1.43	1.44	1.27	1.15	1.43
Alaska	1.18	0.96	0.96	0.91	1.02	0.82	0.82	0.71	0.91
Net Crude Imports	**8.60**	**10.71**	**10.77**	**10.93**	**10.54**	**11.35**	**11.57**	**11.91**	**11.13**
Total Crude Supply	**14.89**	**15.99**	**16.01**	**15.99**	**15.99**	**16.61**	**16.61**	**16.59**	**16.60**
Natural Gas Plant Liquids	**1.76**	**1.78**	**1.76**	**1.76**	**1.79**	**2.07**	**2.03**	**2.01**	**2.12**
Other Inputs[3]	**0.25**	**0.27**	**0.27**	**0.27**	**0.27**	**0.29**	**0.29**	**0.30**	**0.30**
Refinery Processing Gain[4]	**0.89**	**1.02**	**1.02**	**1.00**	**1.01**	**1.11**	**1.10**	**1.08**	**1.11**
Net Product Imports[5]	**1.17**	**1.98**	**1.99**	**2.04**	**1.97**	**2.38**	**2.41**	**2.48**	**2.30**
Total Primary Supply[6]	**18.95**	**21.05**	**21.07**	**21.06**	**21.04**	**22.47**	**22.46**	**22.46**	**22.44**
Refined Petroleum Products Supplied									
Residential and Commercial	1.06	1.05	1.05	1.05	1.05	1.03	1.03	1.03	1.03
Industrial[7]	4.80	5.29	5.29	5.28	5.29	5.54	5.54	5.52	5.53
Transportation	12.54	14.43	14.43	14.43	14.43	15.74	15.71	15.71	15.75
Electric Generators[8]	0.54	0.33	0.34	0.35	0.32	0.20	0.22	0.24	0.17
Total	**18.94**	**21.09**	**21.11**	**21.11**	**21.08**	**22.51**	**22.50**	**22.50**	**22.47**
Discrepancy[9]	**0.01**	**-0.05**	**-0.05**	**-0.05**	**-0.05**	**-0.04**	**-0.04**	**-0.04**	**-0.04**
L48 End Year Reserves (billion barrels)[2]	**18.16**	**14.46**	**14.12**	**13.69**	**14.60**	**13.98**	**13.39**	**12.60**	**14.40**

[1]Represents lower 48 onshore and offshore supplies.
[2]Includes lease condensate.
[3]Includes alcohols, ethers, petroleum product stock withdrawals, domestic sources of blending components, and other hydrocarbons.
[4]Represents volumetric gain in refinery distillation and cracking processes.
[5]Includes net imports of finished petroleum products, unfinished oils, other hydrocarbons, alcohols, ethers, and blending components.
[6]Total crude supply plus natural gas plant liquids, other inputs, refinery processing gain, and net petroleum imports.
[7]Includes consumption by cogenerators.
[8]Includes all electric power generators except cogenerators, which produce electricity and other useful thermal energy. Includes small power producers and exempt wholesale generators.
9Balancing item. Includes unaccounted for supply, losses and gains.
Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A, OGDEPL.D051200A, OGFRLTEC.D051200A, and OGFRHTEC.D051200A.

Table B12. Crude Oil Supply and Disposition, Reduced and Improved Productivity Technology Comparisons (Continued)
(Million Barrels per Day, Unless Otherwise Noted)

Supply, Disposition, and Prices	2015				2020			
			Accelerated Depletion				Accelerated Depletion	
	Reference	Accelerated Depletion	Reduced Productivity Technology	Improved Productivity Technology	Reference	Accelerated Depletion	Reduced Productivity Technology	Improved Productivity Technology
Lower 48 Average Wellhead Price[1]								
(1998 dollars per barrel)	**20.96**	**21.06**	**21.17**	**20.72**	**21.27**	**21.21**	**21.36**	**21.12**
Production[2]								
U.S. Total	**5.39**	**5.10**	**4.49**	**5.84**	**5.47**	**5.18**	**4.39**	**5.97**
Lower 48 Onshore	3.22	3.17	2.85	3.52	3.36	3.39	2.89	3.77
Conventional	2.54	2.49	2.25	2.73	2.65	2.67	2.30	2.98
Enhanced Oil Recovery	0.69	0.68	0.60	0.79	0.71	0.72	0.59	0.80
Lower 48 Offshore	1.54	1.30	1.15	1.50	1.60	1.33	1.16	1.54
Alaska	0.63	0.63	0.48	0.82	0.51	0.47	0.34	0.66
Net Crude Imports	**11.28**	**11.59**	**12.17**	**10.86**	**11.39**	**11.70**	**12.49**	**10.90**
Total Crude Supply	**16.67**	**16.68**	**16.66**	**16.70**	**16.86**	**16.88**	**16.88**	**16.87**
Natural Gas Plant Liquids	**2.28**	**2.17**	**2.11**	**2.32**	**2.38**	**2.07**	**2.01**	**2.36**
Other Inputs[3]	**0.30**	**0.29**	**0.29**	**0.30**	**0.32**	**0.31**	**0.31**	**0.32**
Refinery Processing Gain[4]	**1.11**	**1.10**	**1.09**	**1.11**	**1.12**	**1.11**	**1.10**	**1.12**
Net Product Imports[5]	**3.50**	**3.68**	**3.82**	**3.41**	**4.42**	**5.16**	**5.28**	**4.45**
Total Primary Supply[6]	**23.85**	**23.91**	**23.97**	**23.85**	**25.10**	**25.52**	**25.57**	**25.13**
Refined Petroleum Products Supplied								
Residential and Commercial	0.99	1.00	1.00	0.99	0.96	0.96	0.97	0.96
Industrial[7]	5.81	5.83	5.82	5.80	6.03	6.12	6.11	6.03
Transportation	16.89	16.85	16.85	16.90	17.94	17.90	17.88	17.92
Electric Generators[8]	0.18	0.27	0.33	0.17	0.17	0.56	0.63	0.21
Total	**23.87**	**23.95**	**24.00**	**23.87**	**25.10**	**25.54**	**25.58**	**25.12**
Discrepancy[9]	**-0.03**	**-0.03**	**-0.03**	**-0.02**	**0.00**	**-0.02**	**-0.02**	**0.00**
L48 End Year Reserves (billion barrels)[2]	**14.05**	**13.41**	**12.08**	**14.93**	**13.86**	**13.45**	**11.59**	**14.99**

Table B13. Total Energy Supply and Disposition Summary, High Rocky Mountain Access Comparisons
(Quadrillion Btu per Year, Unless Otherwise Noted)

Supply, Disposition, and Prices	1998	2005 Reference	2005 Accelerated Depletion	2005 Accelerated Depletion: High Access	2005 Accelerated Depletion: High Access: Improved Productivity Technology	2005 Accelerated Depletion: High Access: Rapid Technology	2010 Reference	2010 Accelerated Depletion	2010 Accelerated Depletion: High Access	2010 Accelerated Depletion: High Access: Improved Productivity Technology	2010 Accelerated Depletion: High Access: Rapid Technology
Production											
Crude Oil & Lease Condensate	**13.23**	**11.20**	**11.10**	**11.10**	**11.55**	**11.55**	**11.15**	**10.68**	**10.67**	**11.59**	**11.61**
Natural Gas Plant Liquids	2.49	2.53	2.50	2.50	2.54	2.56	2.93	2.88	2.90	3.01	3.05
Dry Natural Gas	19.41	19.90	19.67	19.72	20.03	20.17	23.37	22.93	23.07	24.03	24.30
Coal	23.89	25.97	26.02	26.00	25.97	25.94	26.51	26.54	26.45	26.27	26.18
Nuclear Power	7.19	7.20	7.20	7.20	7.20	7.20	6.70	6.70	6.70	6.70	6.70
Renewable Energy[1]	6.67	7.09	7.10	7.09	7.08	7.08	7.43	7.43	7.42	7.44	7.42
Other[2]	0.57	0.58	0.59	0.59	0.58	0.58	0.59	0.59	0.60	0.61	0.62
Total	**73.46**	**74.46**	**74.18**	**74.19**	**74.96**	**75.09**	**78.69**	**77.75**	**77.80**	**79.64**	**79.88**
Imports											
Crude Oil[3]	18.90	23.31	23.44	23.45	22.95	22.89	24.70	25.16	25.16	24.24	24.24
Petroleum Products[4]	3.99	5.79	5.81	5.80	5.77	5.76	6.79	6.79	6.77	6.60	6.52
Natural Gas	3.37	4.57	4.66	4.64	4.53	4.50	4.65	4.82	4.78	4.48	4.36
Other Imports[5]	0.59	0.99	0.99	0.99	0.99	0.99	0.89	0.89	0.89	0.89	0.89
Total	**26.85**	**34.67**	**34.90**	**34.89**	**34.24**	**34.14**	**37.02**	**37.67**	**37.61**	**36.21**	**36.01**
Exports											
Petroleum[6]	1.94	1.94	1.93	1.93	1.98	1.97	2.03	2.00	2.00	2.02	2.02
Natural Gas	0.17	0.24	0.24	0.24	0.24	0.24	0.29	0.29	0.29	0.29	0.29
Coal	2.05	1.65	1.65	1.65	1.65	1.65	1.73	1.77	1.73	1.75	1.73
Total	**4.16**	**3.83**	**3.82**	**3.82**	**3.87**	**3.86**	**4.06**	**4.06**	**4.02**	**4.06**	**4.04**
Discrepancy[7]	**1.28**	**0.14**	**0.15**	**0.15**	**0.15**	**0.15**	**0.11**	**0.10**	**0.11**	**0.10**	**0.06**
Consumption											
Petroleum Products[8]	37.21	41.26	41.30	41.30	41.22	41.18	43.98	43.96	43.94	43.90	43.89
Natural Gas	21.99	24.26	24.14	24.16	24.35	24.46	27.70	27.45	27.54	28.19	28.35
Coal	21.50	24.83	24.87	24.86	24.82	24.79	25.35	25.35	25.30	25.09	25.08
Nuclear Power	7.19	7.20	7.20	7.20	7.20	7.20	6.70	6.70	6.70	6.70	6.70
Renewable Energy[1]	6.67	7.09	7.10	7.09	7.09	7.09	7.44	7.44	7.43	7.45	7.43
Other[9]	0.32	0.50	0.50	0.50	0.50	0.50	0.36	0.36	0.36	0.36	0.36
Total	**94.88**	**105.15**	**105.11**	**105.11**	**105.18**	**105.22**	**111.54**	**111.26**	**111.28**	**111.70**	**111.80**
Net Imports - Petroleum	**20.95**	**27.16**	**27.32**	**27.32**	**26.75**	**26.69**	**29.45**	**29.96**	**29.94**	**28.82**	**28.74**
Prices (1998 dollars per unit)											
World Oil Price (dollars per bbl)[10]	12.10	20.49	20.49	20.49	20.49	20.49	21.00	21.00	21.00	21.00	21.00
Gas Wellhead Price (dollars per Mcf)[11]	1.96	2.40	2.48	2.46	2.35	2.30	2.48	2.62	2.57	2.37	2.28
Coal Minemouth Price (dollars per ton)	17.51	14.80	14.82	14.85	14.79	14.77	13.89	14.08	14.03	13.93	13.82
Average Electric Price (cents per Kwh)	6.71	6.20	6.22	6.22	6.19	6.18	5.94	6.02	6.00	5.92	5.89

[1]Includes grid-connected electricity from conventional hydroelectric; wood and wood waste; landfill gas; municipal solid waste; other biomass; wind; photovoltaic and solar thermal sources; non-electric energy from renewable sources, such as active and passive solar systems, and wood; and both the ethanol and gasoline components of E85, but not the ethanol components of blends less than 85 percent. Excludes electricity imports using renewable sources and nonmarketed renewable energy.
[2]Includes liquid hydrogen, methanol, supplemental natural gas, and some domestic inputs to refineries.
[3]Includes imports of crude oil for the Strategic Petroleum Reserve.
[4]Includes imports of finished petroleum products, imports of unfinished oils, alcohols, ethers, and blending components.
[5]Includes coal, coal coke (net), and electricity (net).
[6]Includes crude oil and petroleum products.
[7]Balancing item. Includes unaccounted for supply, losses, gains, and net storage withdrawals.
[8]Includes natural gas plant liquids, crude oil consumed as a fuel, and nonpetroleum based liquids for blending, such as ethanol.
[9]Includes net electricity imports, methanol, and liquid hydrogen.
[10]Average refiner acquisition cost for imported crude oil.
[11]Represents lower 48 onshore and offshore supplies.
Btu = British thermal unit.
Mcf = Thousand cubic feet.
Kwh = Kilowatthour.
Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A, OGDEPL.D051200A, OGACCESS.D051200A, OGFRACC.D051200A, and OGRAPID.D051200A.

Table B13. Total Energy Supply and Disposition Summary, High Rocky Mountain Access Comparisons (Continued)
(Quadrillion Btu per Year, Unless Otherwise Noted)

Supply, Disposition, and Prices	2015					2020				
			Accelerated Depletion					Accelerated Depletion		
				High Access					High Access	
	Reference	Accelerated Depletion	High Access	Improved Productivity Technology	Rapid Technology	Reference	Accelerated Depletion	High Access	Improved Productivity Technology	Rapid Technology
Production										
Crude Oil & Lease Condensate	11.41	10.79	10.81	12.36	12.40	11.57	10.97	10.97	12.61	12.58
Natural Gas Plant Liquids	3.23	3.07	3.12	3.32	3.48	3.38	2.94	3.02	3.42	3.77
Dry Natural Gas	25.90	24.61	25.00	26.70	27.98	27.29	23.68	24.35	27.68	30.61
Coal	26.97	27.40	27.22	26.79	26.46	27.53	28.21	28.10	27.45	26.65
Nuclear Power	5.45	5.45	5.45	5.45	5.45	4.56	4.56	4.56	4.56	4.57
Renewable Energy[1]	7.71	7.72	7.74	7.73	7.76	7.99	8.06	8.03	8.01	8.03
Other[2]	0.61	0.59	0.59	0.61	0.62	0.66	0.63	0.64	0.66	0.66
Total	**81.28**	**79.64**	**79.93**	**82.96**	**84.15**	**82.98**	**79.04**	**79.67**	**84.39**	**86.87**
Imports										
Crude Oil[3]	24.56	25.20	25.17	23.71	23.66	24.82	25.45	25.45	23.82	23.86
Petroleum Products[4]	9.08	9.36	9.27	8.82	8.47	10.83	12.12	11.80	10.80	10.27
Natural Gas	5.00	5.33	5.26	4.74	4.34	5.35	6.01	5.92	5.16	4.01
Other Imports[5]	0.89	0.89	0.89	0.89	0.89	0.97	0.97	0.97	0.97	0.97
Total	**39.53**	**40.78**	**40.59**	**38.17**	**37.36**	**41.97**	**44.55**	**44.13**	**40.74**	**39.11**
Exports										
Petroleum[6]	2.06	2.02	2.03	2.11	2.07	1.99	1.85	1.88	2.03	2.04
Natural Gas	0.35	0.35	0.35	0.35	0.35	0.36	0.36	0.36	0.36	0.36
Coal	1.63	1.74	1.65	1.63	1.65	1.50	1.49	1.49	1.50	1.50
Total	**4.04**	**4.11**	**4.03**	**4.09**	**4.07**	**3.85**	**3.70**	**3.73**	**3.90**	**3.91**
Discrepancy[7]	**0.09**	**0.08**	**0.09**	**0.09**	**0.09**	**0.10**	**0.09**	**0.11**	**0.07**	**0.03**
Consumption										
Petroleum Products[8]	46.64	46.82	46.75	46.57	46.47	49.06	50.04	49.76	49.10	48.98
Natural Gas	30.54	29.58	29.90	31.08	31.95	32.28	29.34	29.91	32.48	34.25
Coal	25.99	26.31	26.22	25.79	25.38	26.74	27.43	27.33	26.66	25.83
Nuclear Power	5.45	5.45	5.45	5.45	5.45	4.56	4.56	4.56	4.56	4.57
Renewable Energy[1]	7.73	7.74	7.75	7.74	7.77	8.01	8.07	8.05	8.02	8.05
Other[9]	0.32	0.32	0.32	0.32	0.32	0.36	0.36	0.36	0.36	0.36
Total	**116.68**	**116.23**	**116.40**	**116.95**	**117.35**	**121.00**	**119.80**	**119.97**	**121.17**	**122.04**
Net Imports - Petroleum	**31.58**	**32.53**	**32.42**	**30.43**	**30.06**	**33.66**	**35.72**	**35.36**	**32.59**	**32.09**
Prices (1998 dollars per unit)										
World Oil Price (dollars per bbl)[10]	21.53	21.53	21.53	21.53	21.53	22.04	22.04	22.04	22.04	22.04
Gas Wellhead Price (dollars per Mcf)[11]	2.68	3.13	3.01	2.57	2.24	2.79	4.12	3.90	2.81	2.22
Coal Minemouth Price (dollars per ton)	13.41	13.63	13.54	13.38	13.29	12.57	12.71	12.71	12.60	12.57
Average Electric Price (cents per Kwh)	5.87	6.06	6.02	5.82	5.69	5.83	6.33	6.26	5.83	5.56

Table B14. Natural Gas Supply and Disposition, High Rocky Mountain Access Comparisons
(Trillion Cubic Feet per Year, Unless Otherwise Noted)

Supply, Disposition, and Prices	1998	2005 Reference	2005 Accelerated Depletion	2005 Accelerated Depletion: High Access	2005 Accelerated Depletion, High Access: Improved Productivity Technology	2005 Accelerated Depletion, High Access: Rapid Technology	2010 Reference	2010 Accelerated Depletion	2010 Accelerated Depletion: High Access	2010 Accelerated Depletion, High Access: Improved Productivity Technology	2010 Accelerated Depletion, High Access: Rapid Technology
Lower 48 Average. Wellhead Price[1]											
(1998 dollars per thousand cubic feet)	**1.96**	**2.40**	**2.48**	**2.46**	**2.35**	**2.30**	**2.48**	**2.62**	**2.57**	**2.37**	**2.28**
Dry Gas Production[2]											
U.S. Total	**18.88**	**19.35**	**19.14**	**19.18**	**19.48**	**19.62**	**22.73**	**22.31**	**22.44**	**23.37**	**23.64**
Lower 48 Onshore	12.91	13.09	12.93	12.98	13.21	13.35	16.33	16.04	16.19	16.59	16.87
Associated-Dissolved[3]	1.72	1.26	1.26	1.26	1.28	1.28	1.25	1.23	1.23	1.26	1.26
Non-Associated	11.19	11.84	11.67	11.72	11.93	12.08	15.08	14.80	14.95	15.33	15.62
Conventional	6.69	6.54	6.68	6.67	6.50	6.49	9.24	9.37	9.32	8.91	8.62
Unconventional	4.50	5.29	4.99	5.05	5.43	5.58	5.84	5.44	5.63	6.42	7.00
Lower 48 Offshore	5.54	5.80	5.75	5.74	5.82	5.81	5.91	5.78	5.77	6.30	6.28
Associated-Dissolved[3]	0.89	0.89	0.89	0.89	0.91	0.91	0.90	0.86	0.86	0.90	0.90
Non-Associated	4.65	4.91	4.85	4.84	4.91	4.90	5.01	4.92	4.91	5.40	5.38
Alaska	0.44	0.46	0.46	0.46	0.46	0.46	0.49	0.49	0.49	0.49	0.49
Supplemental Natural Gas[4]	**0.12**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**
Net Imports	**3.13**	**4.24**	**4.33**	**4.31**	**4.20**	**4.17**	**4.26**	**4.43**	**4.39**	**4.09**	**3.98**
Total Supply	**22.13**	**23.71**	**23.58**	**23.60**	**23.79**	**23.90**	**27.05**	**26.80**	**26.89**	**27.52**	**27.67**
Consumption by Sector											
Residential	4.48	5.07	5.05	5.05	5.08	5.09	5.32	5.29	5.30	5.35	5.37
Commercial	3.03	3.32	3.31	3.31	3.32	3.33	3.50	3.47	3.48	3.52	3.53
Industrial[5]	8.23	8.75	8.73	8.73	8.78	8.79	9.24	9.18	9.20	9.30	9.33
Electric Generators[6]	3.67	4.36	4.31	4.32	4.40	4.46	6.42	6.33	6.38	6.74	6.80
Lease and Plant Fuel[7]	1.24	1.23	1.22	1.22	1.23	1.24	1.41	1.40	1.40	1.44	1.45
Pipeline Fuel	0.73	0.73	0.72	0.73	0.73	0.74	0.85	0.83	0.84	0.87	0.89
Transportation[8]	0.02	0.15	0.15	0.15	0.15	0.15	0.22	0.22	0.22	0.22	0.22
Total	**21.40**	**23.61**	**23.49**	**23.51**	**23.69**	**23.80**	**26.97**	**26.72**	**26.81**	**27.45**	**27.60**
Discrepancy[9]	**0.74**	**0.10**	**0.09**	**0.09**	**0.10**	**0.10**	**0.08**	**0.08**	**0.08**	**0.08**	**0.08**
Lower 48 End of Year Reserves	**156.00**	**164.17**	**157.10**	**158.27**	**169.19**	**172.80**	**180.14**	**166.49**	**169.89**	**188.88**	**202.78**

[1]Represents lower 48 onshore and offshore supplies.
[2]Marketed production (wet) minus extraction losses.
[3]Gas which occurs in crude oil reserves either as free gas (associated) or as gas in solution with crude oil (dissolved).
[4]Synthetic natural gas, propane air, coke oven gas, refinery gas, biomass gas, air injected for Btu stabilization, and manufactured gas commingled and distributed with natural gas.
[5]Includes consumption by cogenerators.
[6]Includes all electric power generators except cogenerators, which produce electricity and other useful thermal energy. Includes small power producers and exempt wholesale generators.
[7]Represents natural gas used in the field gathering and processing plant machinery.
[8]Compressed natural gas used as vehicle fuel.
[9]Balancing item. Natural gas lost as a result of converting flow data measured at varying temperatures and pressures to a standard temperature and pressure and the merger of different data reporting systems which vary in scope, format, definition, and respondent type.

Note: Totals may not equal sum of components due to independent rounding.

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A, OGDEPL.D051200A, OGACCESS.D051200A, OGFRACC.D051200A, and OGRAPID.D051200A.

Table B14. Natural Gas Supply and Disposition, High Rocky Mountain Access Comparisons (Continued)
(Trillion Cubic Feet per Year, Unless Otherwise Noted)

Supply, Disposition, and Prices	2015					2020				
			Accelerated Depletion					Accelerated Depletion		
				High Access					High Access	
	Reference	Accelerated Depletion	High Access	Improved Productivity Technology	Rapid Technology	Reference	Accelerated Depletion	High Access	Improved Productivity Technology	Rapid Technology
Lower 48 Average. Wellhead Price[1]										
(1998 dollars per thousand cubic feet)	**2.68**	**3.13**	**3.01**	**2.57**	**2.24**	**2.79**	**4.12**	**3.90**	**2.81**	**2.22**
Dry Gas Production[2]										
U.S. Total	**25.19**	**23.94**	**24.32**	**25.97**	**27.22**	**26.54**	**23.03**	**23.69**	**26.93**	**29.78**
Lower 48 Onshore	17.97	17.42	17.84	18.97	20.24	19.36	17.58	18.31	21.09	23.86
Associated-Dissolved[3]	1.30	1.29	1.28	1.35	1.35	1.32	1.31	1.31	1.38	1.37
Non-Associated	16.67	16.13	16.56	17.62	18.89	18.03	16.26	17.00	19.71	22.49
Conventional	10.19	10.26	10.25	10.09	9.69	10.65	10.26	10.38	10.86	10.52
Unconventional	6.48	5.87	6.31	7.53	9.20	7.38	6.00	6.63	8.85	11.97
Lower 48 Offshore	6.71	6.01	5.96	6.49	6.46	6.65	4.92	4.84	5.30	5.38
Associated-Dissolved[3]	0.93	0.87	0.87	0.92	0.92	0.94	0.88	0.88	0.93	0.93
Non-Associated	5.78	5.14	5.09	5.57	5.54	5.71	4.04	3.96	4.37	4.45
Alaska	0.51	0.51	0.51	0.51	0.51	0.54	0.54	0.54	0.54	0.54
Supplemental Natural Gas[4]	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**
Net Imports	**4.55**	**4.87**	**4.80**	**4.30**	**3.90**	**4.88**	**5.52**	**5.44**	**4.69**	**3.57**
Total Supply	**29.80**	**28.87**	**29.17**	**30.33**	**31.17**	**31.48**	**28.62**	**29.18**	**31.68**	**33.41**
Consumption by Sector										
Residential	5.49	5.40	5.43	5.53	5.60	5.71	5.45	5.50	5.72	5.85
Commercial	3.61	3.53	3.55	3.63	3.68	3.65	3.45	3.48	3.66	3.75
Industrial[5]	9.65	9.48	9.53	9.71	9.81	10.00	9.54	9.61	10.01	10.21
Electric Generators[6]	8.22	7.72	7.91	8.57	9.09	9.14	7.47	7.83	9.28	10.35
Lease and Plant Fuel[7]	1.56	1.50	1.52	1.59	1.65	1.66	1.49	1.53	1.68	1.81
Pipeline Fuel	0.92	0.88	0.90	0.94	0.99	0.96	0.84	0.87	0.96	1.07
Transportation[8]	0.28	0.28	0.28	0.28	0.28	0.32	0.31	0.31	0.32	0.33
Total	**29.74**	**28.80**	**29.11**	**30.26**	**31.11**	**31.43**	**28.56**	**29.13**	**31.63**	**33.36**
Discrepancy[9]	**0.06**	**0.07**	**0.06**	**0.06**	**0.06**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
Lower 48 End of Year Reserves	**193.46**	**166.04**	**171.50**	**204.91**	**238.27**	**199.54**	**152.26**	**159.29**	**207.81**	**250.38**

Table B15. Crude Oil Supply and Disposition, High Rocky Mountain Access Comparisons
(Million Barrels per Day, Unless Otherwise Noted)

Supply, Disposition, and Prices	1998	2005					2010				
				Accelerated Depletion					Accelerated Depletion		
					High Access					High Access	
		Reference	Accelerated Depletion	High Access	Improved Productivity Technology	Rapid Technology	Reference	Accelerated Depletion	High Access	Improved Productivity Technology	Rapid Technology
Lower 48 Average Wellhead Price[1]											
(1998 dollars per barrel)	**11.60**	**20.12**	**20.11**	**20.11**	**20.06**	**20.05**	**20.65**	**20.65**	**20.65**	**20.52**	**20.52**
Production[2]											
U.S. Total	**6.25**	**5.29**	**5.25**	**5.24**	**5.46**	**5.46**	**5.27**	**5.04**	**5.04**	**5.47**	**5.49**
Lower 48 Onshore	3.60	2.93	2.94	2.94	3.01	3.01	3.01	2.95	2.95	3.13	3.14
Conventional	2.87	2.33	2.34	2.33	2.38	2.38	2.39	2.34	2.33	2.43	2.44
Enhanced Oil Recovery	0.73	0.60	0.60	0.60	0.63	0.63	0.62	0.62	0.62	0.69	0.70
Lower 48 Offshore	1.47	1.39	1.34	1.34	1.43	1.43	1.44	1.27	1.27	1.43	1.43
Alaska	1.18	0.96	0.96	0.96	1.02	1.02	0.82	0.82	0.82	0.91	0.91
Net Crude Imports	**8.60**	**10.71**	**10.77**	**10.77**	**10.53**	**10.51**	**11.35**	**11.57**	**11.57**	**11.13**	**11.13**
Total Crude Supply	**14.89**	**15.99**	**16.01**	**16.02**	**15.99**	**15.96**	**16.61**	**16.61**	**16.61**	**16.60**	**16.61**
Natural Gas Plant Liquids	**1.76**	**1.78**	**1.76**	**1.77**	**1.79**	**1.81**	**2.07**	**2.03**	**2.04**	**2.13**	**2.15**
Other Inputs[3]	**0.25**	**0.27**	**0.27**	**0.28**	**0.27**	**0.27**	**0.29**	**0.29**	**0.30**	**0.30**	**0.31**
Refinery Processing Gain[4]	**0.89**	**1.02**	**1.02**	**1.02**	**1.01**	**1.01**	**1.11**	**1.10**	**1.10**	**1.11**	**1.11**
Net Product Imports[5]	**1.17**	**1.98**	**1.99**	**1.99**	**1.96**	**1.96**	**2.38**	**2.41**	**2.40**	**2.30**	**2.26**
Total Primary Supply[6]	**18.95**	**21.05**	**21.07**	**21.06**	**21.03**	**21.01**	**22.47**	**22.46**	**22.45**	**22.44**	**22.44**
Refined Petroleum Products Supplied											
Residential and Commercial	1.06	1.05	1.05	1.05	1.05	1.05	1.03	1.03	1.03	1.03	1.03
Industrial[7]	4.80	5.29	5.29	5.29	5.28	5.28	5.54	5.54	5.53	5.53	5.53
Transportation	12.54	14.43	14.43	14.43	14.43	14.43	15.74	15.71	15.71	15.75	15.76
Electric Generators[8]	0.54	0.33	0.34	0.34	0.31	0.30	0.20	0.22	0.22	0.17	0.16
Total	**18.94**	**21.09**	**21.11**	**21.11**	**21.08**	**21.06**	**22.51**	**22.50**	**22.49**	**22.48**	**22.47**
Discrepancy[9]	**0.01**	**-0.05**	**-0.05**	**-0.05**	**-0.05**	**-0.05**	**-0.04**	**-0.04**	**-0.04**	**-0.04**	**-0.03**
L48 End Year Reserves (billion barrels)[2]	**18.16**	**14.46**	**14.12**	**14.12**	**14.60**	**14.61**	**13.98**	**13.39**	**13.38**	**14.40**	**14.42**

[1]Represents lower 48 onshore and offshore supplies.
[2]Includes lease condensate.
[3]Includes alcohols, ethers, petroleum product stock withdrawals, domestic sources of blending components, and other hydrocarbons.
[4]Represents volumetric gain in refinery distillation and cracking processes.
[5]Includes net imports of finished petroleum products, unfinished oils, other hydrocarbons, alcohols, ethers, and blending components.
[6]Total crude supply plus natural gas plant liquids, other inputs, refinery processing gain, and net petroleum imports.
[7]Includes consumption by cogenerators.
[8]Includes all electric power generators except cogenerators, which produce electricity and other useful thermal energy. Includes small power producers and exempt wholesale generators.
[9]Balancing item. Includes unaccounted for supply, losses and gains.

Note: Totals may not equal sum of components due to independent rounding.

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A, OGDEPL.D051200A, OGACCESS.D051200A, OGFRACC.D051200A, and OGRAPID.D051200A.

Table B15. Crude Oil Supply and Disposition, High Rocky Mountain Access Comparisons (Continued)
(Million Barrels per Day, Unless Otherwise Noted)

Supply, Disposition, and Prices	2015					2020				
			Accelerated Depletion					Accelerated Depletion		
				High Access					High Access	
	Reference	Accelerated Depletion	High Access	Improved Productivity Technology	Rapid Technology	Reference	Accelerated Depletion	High Access	Improved Productivity Technology	Rapid Technology
Lower 48 Average Wellhead Price[1]										
(1998 dollars per barrel)	**20.96**	**21.06**	**21.02**	**20.71**	**20.71**	**21.27**	**21.21**	**21.26**	**21.16**	**21.07**
Production[2]										
U.S. Total	**5.39**	**5.10**	**5.10**	**5.84**	**5.86**	**5.47**	**5.18**	**5.18**	**5.96**	**5.94**
Lower 48 Onshore	3.22	3.17	3.16	3.51	3.52	3.36	3.39	3.37	3.76	3.71
Conventional	2.54	2.49	2.48	2.72	2.72	2.65	2.67	2.65	2.96	2.92
Enhanced Oil Recovery	0.69	0.68	0.69	0.79	0.80	0.71	0.72	0.73	0.80	0.79
Lower 48 Offshore	1.54	1.30	1.31	1.50	1.51	1.60	1.33	1.34	1.54	1.57
Alaska	0.63	0.63	0.63	0.82	0.82	0.51	0.47	0.47	0.66	0.66
Net Crude Imports	**11.28**	**11.59**	**11.57**	**10.87**	**10.84**	**11.39**	**11.70**	**11.69**	**10.91**	**10.93**
Total Crude Supply	**16.67**	**16.68**	**16.67**	**16.70**	**16.70**	**16.86**	**16.88**	**16.88**	**16.87**	**16.87**
Natural Gas Plant Liquids	**2.28**	**2.17**	**2.20**	**2.34**	**2.45**	**2.38**	**2.07**	**2.13**	**2.41**	**2.66**
Other Inputs[3]	**0.30**	**0.29**	**0.29**	**0.30**	**0.31**	**0.32**	**0.31**	**0.31**	**0.32**	**0.32**
Refinery Processing Gain[4]	**1.11**	**1.10**	**1.10**	**1.11**	**1.11**	**1.12**	**1.11**	**1.10**	**1.12**	**1.10**
Net Product Imports[5]	**3.50**	**3.68**	**3.62**	**3.37**	**3.22**	**4.42**	**5.16**	**4.97**	**4.40**	**4.13**
Total Primary Supply[6]	**23.85**	**23.91**	**23.88**	**23.82**	**23.78**	**25.10**	**25.52**	**25.39**	**25.12**	**25.08**
Refined Petroleum Products Supplied										
Residential and Commercial	0.99	1.00	1.00	0.99	1.00	0.96	0.96	0.96	0.96	0.97
Industrial[7]	5.81	5.83	5.82	5.79	5.77	6.03	6.12	6.10	6.03	6.01
Transportation	16.89	16.85	16.86	16.90	16.92	17.94	17.90	17.88	17.95	18.02
Electric Generators[8]	0.18	0.27	0.24	0.16	0.11	0.17	0.56	0.47	0.18	0.09
Total	**23.87**	**23.95**	**23.92**	**23.84**	**23.80**	**25.10**	**25.54**	**25.42**	**25.12**	**25.08**
Discrepancy[9]	**-0.03**	**-0.03**	**-0.03**	**-0.02**	**-0.01**	**0.00**	**-0.02**	**-0.02**	**0.00**	**0.00**
L48 End Year Reserves (billion barrels)[2]	**14.05**	**13.41**	**13.41**	**14.93**	**14.97**	**13.86**	**13.45**	**13.46**	**14.97**	**14.88**

Appendix C

Comparison of National Petroleum Council and Energy Information Administration Natural Gas Studies

Introduction

The National Petroleum Council (NPC) recently published a significant study that examines the outlook for domestic natural gas. This appendix compares the methods and findings of that study with the analysis of accelerated depletion presented in the study by the Energy Information Administration (EIA).

The NPC study, *Natural Gas: Meeting the Challenges of the Nation's Growing Natural Gas Demand*, was prepared as an advisory report for the Secretary of Energy and was published in December 1999. The NPC study determined that "natural gas is poised to continue to make an important contribution to the nation's energy supply and its environmental goals through 2015 and beyond." The report provides a significant update to the previous (1992) NPC study on natural gas.

Discussion

Difference in Projections

Although the NPC and EIA studies use different analytical methodologies and resource databases, their findings are comparable, with some important differences.

- **The NPC study anticipates stronger near-term consumption of natural gas than does the EIA study.**

Projected gas consumption in 2015 in the NPC study is 2.5 trillion cubic feet higher than in EIA's Accelerated Depletion Case and 1.6 trillion cubic feet higher than in EIA's Reference Case (Table C1).

One reason for the higher projections of natural gas consumption in the NPC Study is that the NPC assumes a gross domestic product (GDP) growth rate of 2.5 percent per year, as compared with 2.2 percent in the EIA study. In support of the higher GDP growth rate, the NPC assumes a world oil price of about $16.50 per barrel for crude oil (in 1998 dollars), remaining flat from 2000 to 2015. The NPC world oil price is estimated from the price of West Texas Intermediate crude oil used in the NPC study, which is projected to remain constant at $18.50 per barrel. The EIA study assumes world oil prices of $20 to $21 per barrel (also in 1998 dollars) during the same period.

A major area of growth in U.S. gas consumption in the NPC study is gas-fired electricity generation. With dual-fuel combined-cycle and gas-fired combustion turbine capacity projected to grow from 25 gigawatts in 1998 to 140 gigawatts in 2015 in the NPC study, annual natural gas consumption in the electricity generation sector is projected to grow from 3.3 trillion cubic feet in 1998 to 7.8 trillion cubic feet in 2015. The NPC study points out that, should sufficient natural gas not be available to meet the fuel needs of new power plants, an additional 3.5 million barrels per day of distillate demand would be placed on the world market. The EIA study expects similar strong growth of gas demand in the electricity and independent power generation sectors.

The two areas that account for NPC's higher projections of natural gas consumption in 2015 are:

Table C1. Projected U.S. Consumption of Natural Gas, 1998-2020
(Trillion Cubic Feet per Year)

Year	NPC Study	EIA Study	
		Accelerated Depletion Case	Reference Case
1998	22.0	21.4	21.4
2005	26.3	23.4	23.6
2010	29.0	26.7	27.0
2015	31.3	28.8	29.7
2020	—	28.6	31.4

Sources: National Petroleum Council, *Natural Gas: Meeting the Challenges of the Nation's Growing Natural Gas Demand* (Washington, DC, December 1999); and Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A and OGDEPL.D051200A.

- 1.3 trillion cubic feet higher projected use of natural gas in the industrial sector, particularly in the chemicals, refinery, and primary metals industries—attributable in part to higher GDP growth
- 1.3 trillion cubic feet higher projected use of natural gas in the residential and commercial sectors—attributable to larger homes, increased air conditioning, and growth in the service sector

- **The NPC study anticipates higher levels of domestic natural gas production.**

NPC's projection of domestic natural gas production in 2015 is 2.7 trillion cubic feet higher than projected in EIA's Accelerated Depletion Case and 1.4 trillion cubic feet higher than in EIA's Reference Case (Table C2).

The primary reasons for the higher projections of domestic natural gas production in the NPC study are:

- The NPC study projects higher wellhead natural gas prices, ranging from $3 to nearly $4 per thousand cubic feet during the study period. In contrast, wellhead natural gas prices range from $2.50 to $3 per thousand cubic feet in the Reference Case of this study. The lower prices in the Reference Case reflect to a considerable degree the lower EIA consumption levels, because supply and demand are balanced in EIA's National Energy Modeling System (NEMS) to obtain a market price. Accordingly, a substantial amount of the "price-related" higher production is attributable to higher demand in the NPC study.
- The NPC study uses a somewhat larger remaining lower 48 natural gas resource base of 1,446 trillion cubic feet, as compared with the estimates of 1,280 to 1,362 trillion cubic feet used in the EIA study.

The NPC projections of natural gas production are higher in two major areas: unconventional and offshore gas. The NPC study projects 8.5 trillion cubic feet of annual production from unconventional gas wells, as compared with 6.5 trillion cubic feet projected in EIA's Reference Case and 5.9 trillion cubic feet in the Accelerated Depletion Case. Similarly, the NPC study projects 7.6 trillion cubic feet of annual production from unconventional gas wells (the majority from the deep water of the Gulf of Mexico), as compared with 6.7 trillion cubic feet in the Reference Case and 6.0 trillion cubic feet in the Accelerated Depletion Case of this study.

- **The NPC study projects considerably higher near- and mid-term natural gas prices.**

The NPC study projects a price path for natural gas (at the wellhead) for the next 15 years that is considerably higher than the natural gas prices projected in this study (Table C3).

Table C2. Projected U.S. Production of Natural Gas, 1998-2020
(Trillion Cubic Feet per Year)

Year	NPC Study	EIA Study	
		Accelerated Depletion Case	Reference Case
1998	19.0	18.9	18.9
2005	22.6	19.1	19.4
2010	25.1	22.3	22.7
2015	26.6	23.9	25.2
2020	—	23.0	26.5

Sources: National Petroleum Council, *Natural Gas: Meeting the Challenges of the Nation's Growing Natural Gas Demand* (Washington, DC, December 1999); and Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A and OGDEPL.D051200A.

Table C3. Projected Wellhead Natural Gas Prices, 2000-2020
(1998 Dollars per Thousand Cubic Feet)

Year	NPC Study[a]	EIA Study[b]	
		Accelerated Depletion Case	Reference Case
2000	3.14	2.48	2.48
2005	2.79	2.48	2.40
2010	3.14	2.62	2.48
2015	3.70	3.13	2.68
2020	—	4.12	2.79

[a]Henry Hub spot price.
[b]Average lower 48 wellhead price.
Sources: National Petroleum Council, *Natural Gas: Meeting the Challenges of the Nation's Growing Natural Gas Demand* (Washington, DC, December 1999); and Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A and OGDEPL.D051200A.

The higher near- and mid-term natural gas wellhead prices act to stimulate an early surge in well drilling and annual gas well completions in the NPC study.

Differences in Inputs, Assumptions, and Methodology

- **The NPC study uses a somewhat larger natural gas resource base.**

In the NPC study, the size of the underlying natural gas resource base was shown to have the largest single impact on future natural gas prices and gas consumption. Consequently, considerable attention is given here to this important comparison. The NPC study assumes a lower 48 natural gas resource base of 1,446 trillion cubic feet, about 100 to 200 trillion cubic feet larger than the 1,280 to 1,362 trillion cubic feet assumed in the EIA study (Table C4). For comparison purposes, the EIA resource categories have been reallocated in Table C4 to match the resource groupings used in the NPC study.

Conventional Natural Gas

The NPC study assumes an undeveloped conventional natural gas resource base of 855 trillion cubic feet, as compared with 703 trillion cubic feet in the EIA study (Table C5).

After adjusting the EIA offshore new field discoveries for associated gas and reducing NPC reserve growth values for unconventional (tight) gas in old plays, these two areas are comparable; however, other differences remain:

- The NPC study expects 376 trillion cubic feet of additional new field discoveries from the lower 48 onshore, particularly from deep gas formations. After allocating associated gas (for comparability with NPC categories), the EIA study expects only 200 trillion cubic feet of comparable new field discoveries.
- The NPC study includes 76 trillion cubic feet of lower 48 offshore resources from areas in the eastern Gulf of Mexico, the Atlantic Outer Continental Shelf, and the Pacific Outer Continental Shelf that are currently restricted from development. NEMS does not include resources or areas that are restricted from development.

Table C4. Assumed Lower 48 Natural Gas Resource Base as of January 1, 1998
(Trillion Cubic Feet)

Resource	NPC Study	EIA Study[a]	
		Accelerated Depletion Case	Reference Case
Proved Reserves[b]	157	157	157
New Field Discoveries	633	450	450
Reserve Growth	[c]222	253	253
Unconventional Gas	454	420	502
New Plays	371	—	—
Old Plays	[c]83	—	—
Total	**1,446**	**1,280**	**1,362**

aAfter allocating 124 trillion cubic feet of associated gas to new fields (94 trillion cubic feet) and reserve growth (30 trillion cubic feet). The estimated proved reserves of associated gas do not influence production in the NEMS Oil and Gas Supply Module but are included in the Resource Table to provide a total gas resource accounting that is consistent with other EIA reports.

[b]Total U.S. proved reserves are estimated at 167 trillion cubic feet in both studies.

[c]After allocating 83 trillion cubic feet of reserve growth in old tight gas plays to unconventional gas.

Sources: National Petroleum Council, *Natural Gas: Meeting the Challenges of the Nation's Growing Natural Gas Demand* (Washington, DC, December 1999); and Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A and OGDEPL.D051200A.

Table C5. Assumed Lower 48 Conventional Gas Resource Base as of January 1, 1998
(Trillion Cubic Feet)

Resource	NPC Study	EIA Study
New Field Discoveries	633	450
Onshore	376	200
Offshore	257	250
Shallow	118	70
Deep	139	180
Reserve Growth	222	253
Total	**855**	**703**

Sources: National Petroleum Council, *Natural Gas: Meeting the Challenges of the Nation's Growing Natural Gas Demand* (Washington, DC, December 1999); and Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A and OGDEPL.D051200A.

There are also considerable differences between the NPC and EIA estimates of the natural gas resource base for Alaska; however, Alaska's natural gas resources have no impact on the results through 2015, and they are not discussed here. A comparison of the total lower 48 natural gas resource assumptions used in the two studies is shown in Table C6.

Unconventional Natural Gas

In both the NPC and EIA studies, a significant portion of the increase in domestic natural gas production is expected from unconventional resources—tight gas, coalbed methane, and gas shales. The underlying in-place resource for these three gas supply sources is massive, approaching 10,000 trillion cubic feet; however, only a small portion of the resource (less than 10 percent) is judged to be of sufficient quality to be accessible with current exploration and production technology.

For the EIA study, the resource base, reserves, and production data for unconventional natural gas used in NEMS were updated. The updates captured geologic and development information on significant new gas plays—specifically, Powder River Basin coalbed methane, Wind River Basin tight gas, and Fort Worth Basin gas shales—increasing the total estimate of technically recoverable unconventional gas as of 1998 to 403 trillion cubic feet (Table C7).

After adjusting the NPC unconventional gas resource base for resource growth in old tight gas fields (as discussed in the 1992 NPC natural gas study), the NPC

Table C6. Assumed Lower 48 Total Natural Gas Resource Base as of January 1, 1998
(Trillion Cubic Feet)

Resource	NPC Study	EIA Study	
		As Reported	With Associated Gas Allocated
Proved Reserves	157	157	157
Conventional			
New Field Discoveries	633	356	450
Onshore	376	172	200
Offshore	257	184	250
Shallow	118	63	70
Deep	139	121	180
Reserve Growth	222	223	253
Unconventional	**454**	**502**	**502**
Tight Gas	230	351	351
Coalbed Methane	74	86	86
Gas Shales	52	65	65
Other	15	—	—
Reserve Growth	[a]83	—	—
Associated Gas	—	124	[b]—
Total	**1,446**	**1,362**	**1,362**

[a]Using unconventional gas resource growth of 83 trillion cubic feet to match aggregate values in summary tables.
[b]After allocating 94 trillion cubic feet to new fields and 30 trillion cubic feet to reserve growth.
Sources: National Petroleum Council, *Natural Gas: Meeting the Challenges of the Nation's Growing Natural Gas Demand* (Washington, DC, December 1999); and Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A and OGDEPL.D051200A.

Table C7. Assumed Lower 48 Unconventional Gas Resource Base as of January 1, 1998
(Trillion Cubic Feet)

Resource	NPC Study (Current Technology Resource Base)	EIA *AEO2000* Resource Base	EIA Study Updated Resource Base
Tight Gas	178	271	286
Coalbed Methane	59	55	62
Gas Shales	39	52	55
Subtotal	286	378	403
Growth of Tight Gas/Other Fields	98	[a]—	[a]—
Total	**384**	**378**	**403**

[a]Included in EIA resource values for tight gas, coalbed methane, and gas shales.
Sources: National Petroleum Council, *Natural Gas: Meeting the Challenges of the Nation's Growing Natural Gas Demand* (Washington, DC, December 1999); Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000) (Washington, DC, December 1999); and Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A and OGDEPL.D051200A.

Reference Case Current Technology Resource Base and this study's numbers for unconventional gas resources at the beginning of January 1998 are comparable.

The technically recoverable unconventional gas resource base increases with time and technology progress. The NPC study recognizes this by looking forward and establishing an unconventional gas resource base of 454 trillion cubic feet in 2015. The NPC calls this its Reference Case Advanced (Year 2015) Technology Resource Base, which is used throughout its 1999 report. The current EIA study uses a similar resource growth and technology progress methodology for unconventional gas resources. The projected resource base for unconventional gas in the Accelerated Depletion Case is 420 trillion cubic feet in 2015—less than the 502 trillion cubic feet used in the Reference Case in 2015 because of the smaller fields and slower technology progress established for the Accelerated Depletion Case. The projected resource base comparisons for 2015 are shown in Table C8.

- **The treatment of access to resources is fundamentally different in the NPC and EIA studies.**

For the lower 48 onshore, the NPC first looked at the environmental restrictions that either preclude or delay access to Rocky Mountain natural gas resources, concluding that 137 trillion cubic feet of natural gas in the area is affected by access issues—29 trillion cubic feet in areas closed to development and 108 trillion cubic feet in areas where access issues would add significant costs and an average 2-year delay to well drilling. In addition, the NPC identified 76 trillion cubic feet of natural gas resources in offshore areas that are currently inaccessible—21 trillion cubic feet in the Pacific, 31 trillion cubic feet in the Atlantic, and 24 trillion cubic feet in the Eastern Gulf of Mexico.

The EIA study uses a much broader definition of lack of access that includes restrictions and delays due to environmental regulations, lack of adequate pipeline outlet capacity, and other barriers to development. The restrictions in the EIA model are lifted over time. Although an exact comparison of the access restrictions assumed in the NPC and EIA studies is not possible, the EIA study finds that currently 108 trillion cubic feet of the Rocky Mountain natural gas resource is affected by environmental and other restrictions. With no lifting of access restrictions, the EIA study estimates that 97 trillion cubic feet of the Rocky Mountain gas resource will be inaccessible even by the year 2020. Providing "high access" to Rocky Mountain natural gas resources reduces the estimate of inaccessible Rocky Mountain resources to 18 trillion cubic feet by 2020. Currently restricted drilling areas, such as the Eastern Gulf of Mexico and the Alaskan National Wildlife Refuge, are not included in the EIA model.

- **The NPC and EIA studies assume different rates of improvement in exploration and production technology.**

The rate of technology progress (advance) was shown in the NPC study to have the second largest impact (after the size of the resource base) on projections of future natural gas consumption and prices. The NPC study used annual rates of technology progress for cost reductions and drilling success rates that are considerably higher than those used in the EIA study (Table C9); however, the rate of technical progress for reserve additions per conventional well in the EIA study is considerably higher than that in the NPC study.

Although the annual differences in the rates of technology progress are modest, their cumulative effects over the 17-year period from 1998 to 2015 are considerable. For example:

- The NPC study assumes a 2.5-percent annual reduction in drilling costs for unconventional gas wells, compared with 0.5 percent in the EIA study. The result is a 40-percent reduction in costs by 2015 in the NPC study, compared with 10 percent in the EIA study.
- The NPC study assumes a 2.1-percent annual increase in reserve additions per low-permeability

Table C8. Assumed Lower 48 Unconventional Gas Resource Base as of January 1, 2015
(Trillion Cubic Feet)

Resource	NPC Study	EIA Study	
		Accelerated Depletion Case	Reference Case
Tight Gas	230	304	351
Coalbed Methane	74	68	86
Gas Shales	52	58	65
Subtotal	356	420	502
Growth of Tight Gas/Other Fields	98	[a]—	[a]—
Total	**454**	**420**	**502**

[a]Included in EIA resource values for tight gas, coalbed methane, and gas shales.
Sources: National Petroleum Council, *Natural Gas: Meeting the Challenges of the Nation's Growing Natural Gas Demand* (Washington, DC, December 1999); and Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A and OGDEPL.D051200A.

gas well, compared with 1.5 percent in the EIA study. The result is a 35-percent increase in reserve additions per well by 2015 in the NPC study, compared with 25 percent in the EIA study.

- The NPC study assumes a 1-percent annual increase in reserve additions per conventional offshore well, compared with 4 percent in the EIA study. The result is a 16-percent increase in reserve additions per well by 2015 in the NPC study, compared with 80 percent in the EIA study.

Summary

Overall, the NPC study projects a higher level of natural gas production than is projected in the EIA study, either in the Reference Case or in the Accelerated Depletion Case. The NPC study starts with higher natural gas consumption met by higher domestic natural gas production, supported by higher natural gas prices at the wellhead, a larger domestic natural gas resource base, fewer restrictions on access to Rocky Mountain resources, and different rates of technology progress.

Table C9. Assumed Rates of Technology Progress for Costs, Drilling Success Rates, and Reserve Additions per Well for Lower 48 Natural Gas, 1998-2015
(Percent Improvement per Year)

Area of Improvement	NPC Study	EIA Study	
		Accelerated Depletion Case	Reference Case
Drilling and Completion Costs			
Onshore Wells	2.5	1.29	1.29
Shallow Offshore Wells	2.5	2.02	2.02
Deep Offshore Wells	3.0	2.02	2.02
Unconventional Gas Wells	2.5	0.50	0.50
New Field Exploration Success			
Conventional	1.5 to 2.2	0.50	0.50
Unconventional[a]	—	0.00	0.25
Reserve Additions per Well			
Conventional Onshore			
Shallow	1.0	0.27	0.27
Deep	1.0	1.61	1.61
Conventional Offshore	1.0	4.14	4.14
Low Permeability	2.1	0.25	0.25
Unconventional	1.5 to 3.0	0.25	0.75 to 1.75

[a]Combined exploration and development success for unconventional gas in the EIA study.

Sources: National Petroleum Council, *Natural Gas: Meeting the Challenges of the Nation's Growing Natural Gas Demand* (Washington, DC, December 1999); and Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A and OGDEPL.D051200A.

Appendix D

Reserve Additions

The Reserve Additions algorithm calculates units of oil and gas added to proved and inferred reserves. Reserve additions are calculated through a set of equations accounting for new field discoveries, discoveries in known fields, and incremental increases in volumetric recovery that arise during the development phase. There is a "finding rate" equation for each phase in each region and for each fuel type.

Each newly discovered field adds not only proved reserves but also a much larger amount of inferred reserves. Proved reserves are reserves that can be certified using the original discovery wells; inferred reserves are those hydrocarbons that require additional drilling before they are termed proved. Additional drilling takes the form of other exploratory drilling and development drilling. Within the model, other exploratory drilling accounts for proved reserves added through new pools or extensions, and development drilling accounts for reserves added through revisions.

The volumetric yield from a successful new field wildcat well is divided into proved reserves and inferred reserves. The proportion of reserves allocated to each category is based on historical reserves growth statistics. Specifically, the allocation of reserves between proved and inferred reserves is based on the ratio of the initial reserves estimated for a newly discovered field relative to ultimate recovery from the field.[23]

Functional Forms

Oil or gas reserve additions from new field wildcats are a function of the cumulative new field discoveries, the initial estimate of recoverable resources for the fuel, and the rate of technological change.

Total successful exploratory wells are disaggregated into successful new field wildcats and other exploratory wells based on a historical ratio. In this appendix, successful new field wildcats are designated by the variable $SW1$, other successful exploratory wells by $SW2$, and successful development wells by $SW3$.

The major inputs to the new field reserve addition equation are new reserve discoveries and the resource base. This approach relies on the finding rate equation:

$$FR1_{r,k,t} = FR10_{r,k,t} \times \left(1 - \frac{CUM\_U_{r,k,t}}{BIG\_U_{r,k}}\right)^{DELTA\_B_{r,k}}, \quad (1)$$

where

$$FR10_{r,k,t} = INITFR1_{r,k,t} \times FRTECH_{r,k,t} \times ECON_{r,k,t}, \quad (2)$$

and

$FR1$ = new field wildcats finding rate

$FR10$ = initial finding rate for new field wildcats

CUM_U = cumulative new field discoveries

BIG_U = ultimate recovery resource estimate

$DELTA\_B$ = hyperbolic decline rate

$FR10$ = initial finding rate adjusted for technology and economics

$INITFR1$ = initial finding rate

$FRTECH$ = technology adjustment

$ECON$ = economic adjustment

r = region

k = fuel type (oil or gas)

t = year.

Under the above specification, the yield from new field wildcat drilling in the absence of technological and economic change declines with cumulative discoveries. Technological progress is split into four regimes (2 past, 1 current, and 1 future) and is of the form

$$FRTECH_{r,k,t} = 1 + \frac{\alpha_{r,k}}{1 + e^{-\beta1_{r,k}(t - \beta2)}}, \quad (3)$$

where

α = peak impact

$\beta1$ = rate of change

$\beta2$ = peak year

r = region

k = fuel type

t = year.

The economic impact is defined by

[23] A more complete discussion of the topic of reserve growth for producing fields can be found in Energy Information Administration, *The Domestic Oil and Gas Recoverable Resource Base: Supporting Analysis for the National Energy Strategy*, SR / NES / 90-05 (Washington, DC, 1990), Chapter 3.

$$ECON_{r,k,t} \quad \frac{OFE_{r,k} \dfrac{CUM\_U_{r,k,t}}{CUM\_NFW_{r,k,t}} \quad POA_{r,k}}{OFE_{r,k} \dfrac{CUM\_U_{r,k,t}}{CUM\_NFW_{r,k,t}} \quad WHP_{r,k,t}} , \qquad (4)$$

where

OFE = assumed economic impact coefficient

CUM_U = cumulative new field discoveries

CUM_NFW = cumulative new field wildcats drilled

POA = historical average wellhead price

WHP = wellhead price.

The above equations provide a rate at which undiscovered resources are converted into proved and inferred reserves as a function of cumulative new field discoveries. Given an estimate for the ratio of ultimate recovery from a field to the initial proved reserve estimate, $X_{r,k}$, the $X_{r,k}$ reserve growth factor is used to separate newly discovered resources into proved and inferred reserves. Specifically, the change in proved reserves from new field discoveries for each period is given by integrating the finding rate with respect to wells drilled in each period:

$$R_{r,k,t} \quad \frac{1}{X_{r,k}} \int_0^{SW1_{r,k,t}} FR1_{r,k,t}\, d(SW1) \qquad (5)$$

$$\frac{1}{X_{r,k}} \int_0^{SW1_{r,k,t}} FR1_{r,k,t\ 1} (1 \quad 1) \exp(\quad 1_{r,k,t} \quad SW1_{r,k,t})\, d(SW1) \ ,$$

where

X = reserves growth factor

ΔR = additions to proved reserves.

The terms in Equation (5) are all constants in period t, except for the $SW1$. X is derived from historical data and it is assumed to be constant during the forecast period. $FR1_{r,k,t-1}$ and $\delta1_{r,k,t}$ are calculated, prior to period t, based on lagged variables and fixed parameters as shown in Equations (3) and (4).

Reserves are converted from inferred to proved with the drilling of other exploratory wells and developmental wells in a way similar to the way in which proved and inferred reserves are modeled as moving from the resource base, as described above. The volumetric return to other exploratory wells and developmental wells is shown in the following equations:

$$FR2_{r,k,t} \quad FR2_{r,k,t\ 1} \quad (1 \quad 2) \quad \left(\frac{whp_{r,k,t}}{avgwhp_{r,k}}\right)^{2} \qquad (6)$$

$$e^{\ 2_{r,k,t\ 1} \ SW2_{r,k,t}} \ ,$$

where

$FR2$ = other exploratory wells finding rate

$\beta2$ = technology parameter for $FR2$

$\alpha2$ = economic parameter for $FR2$

whp = wellhead price in year t

$avgwhp$ = historical average wellhead price

$\delta2$ = decline factor

$SW2$ = successful other exploratory wells;

and

$$FR3_{r,k,t} \quad FR3_{r,k,t\ 1} \quad (1 \quad 3) \quad \frac{whp_{r,k,t}}{avgwhp_{r,k}} \qquad (7)$$

$$e^{\ 3_{r,k,t\ 1} \ SW3_{r,k,t}} \ ,$$

where

$FR3$ = developmental wells finding rate

$\beta3$ = technology parameter for $FR3$

$\alpha3$ = economic parameter of $FR3$

$\delta3$ = *decline factor*

$SW3$ = successful developmental wells.

The decline rates for the exponentially declining functions are shown in the following equations for other exploratory drilling and developmental drilling, respectively:

$$2_{r,k,t} \quad (FR2_{r,k,t}) \quad [(I_{r,k} \quad (1 \quad TECH)^{t \ \ T} \quad CUMRES2_{r,k,t\ 1} \quad CUMRES3_{r,k,t\ 1}] \ , \qquad (8)$$

$$3_{r,k,t} \quad (FR3_{r,k,t}) \quad [(I_{r,k} \quad (1 \quad TECH)^{t \ \ T} \quad CUMRES2_{r,k,t\ 1} \quad CUMRES3_{r,k,t\ 1}] \ , \qquad (9)$$

where

I = initial inferred reserves estimate

$TECH$ = technological improvement rate applied to inferred reserves

$CUMRES2$ = cumulative inferred reserve additions from new discoveries

$CUMRES3$ = cumulative extensions and revisions.

The conversion of inferred reserves to proved reserves occurs as both other exploratory wells and developmental wells exploit a single stock of inferred reserves. The entire stock of inferred reserves can be exhausted through either the other exploratory wells or developmental wells alone. This extreme result is unlikely, however, given reasonable drilling levels in any one year. Nonetheless, the simultaneous extraction from inferred reserves by both drilling types could be expected to affect the productivity of both. Specifically, the more one drilling type draws down the inferred reserve stock, the more likely it is that there could be a corresponding acceleration in the productivity decline for the other type. In a given year, the same initial recoverable resource value (i.e., the denominator expression in the derivation of δ2 and δ3) is decremented by either type of drilling.

Total reserve additions in period t are given by the following equation:

$$RA_{r,k,t} = \frac{1}{X_{r,k}} \left[\int_0^{SW1_{r,k,t}} FR1_{r,k,t}\, d(SW1) + \int_0^{SW2_{r,k,t}} FR2_{r,k,t}\, d(SW2) + \int_0^{SW3_{r,k,t}} FR3_{r,k,t}\, d(SW3) \right] . \tag{10}$$

Finally, total end-of-year proved reserves for each period equal:

$$R_{r,k,t} = R_{r,k,t-1} - Q_{r,k,t} + RA_{r,k,t} , \tag{11}$$

where

R = reserves measured at the end of the year

Q = production.

Production-to-Reserves Ratio

The production of nonassociated gas in NEMS is modeled at the "interface" of the Natural Gas Transmission and Distribution Module (NGTDM) and the Oil and Gas Supply Module (OGSM). Oil production is determined within the OGSM. In both cases, the determinants of production include the lagged production-to-reserves (P/R) ratio and price. The P/R ratio, as the relative measure of reserves drawdown, represents the rate of extraction, given any stock of reserves.

For each year t, the P/R ratio is calculated as:

$$PR_t = \frac{Q_t}{R_{t-1}} , \tag{12}$$

where

PR_t = production-to-reserves ratio for year t

Q_t = production in year t, received from the NGTDM and the Petroleum Marketing Module (PMM)

R_{t-1} = end-of-year reserves for year t-1 or, equivalently, beginning-of-year reserves for year t.

PR_t represents the rate of extraction from all wells drilled up to year t (through year t-1). To calculate the expected rate of extraction in year t+1, the model combines production in year t with the reserve additions and the expected extraction rate from new wells drilled in year t. The calculation is given by:

$$PR_{t+1} = \{[R_{t-1} \cdot PR_t \cdot (1 - PR_t)] + (PRNEW \cdot RA_t)\} / R_t , \tag{13}$$

where

PR_{t+1} = expected P/R ratio for year t+1

$PRNEW$ = long-term expected P/R ratio for all wells drilled in the forecast

R_t = end-of-year reserves for year t or, equivalently, beginning-of-year reserves for year t+1.

The numerator, representing expected total production for year t+1, is the sum of two components. The first represents production from proved reserves as of the beginning of year t, or the expected production in year t, $R_{t-1} * PR_t$, adjusted by 1 - PR_t to reflect the normal decline from year t to year t+1. The second represents production from reserves discovered in year t. No production from reserves discovered in year t+1 is assumed for year t+1.

Under this option, PR_t is constrained not to vary from PR_{t-1} by more than 5 percent. It is also constrained not to exceed 30 percent.

The values for R_t and PR_{t+1} are passed to the NGTDM and the PMM for use in their market equilibration algorithms which solve for equilibrium production and prices for year t+1 of the forecast using the following short-term supply function:

$$Q_{r,k,t+1} = [R_{r,k,t}] \cdot [PR_{r,k,t} \cdot (1 + \beta_{r,k} \cdot \Delta P_{r,k,t+1})] , \tag{14}$$

where

R_t = end-of-year reserves in period t

PR_t = extraction rate in period t

β = estimated short-run price elasticity of supply

ΔP_{t+1} = proportional change in price from year t to t+1, given by $(P_{t+1} - P_t)/P_t$.

The P/R ratio for period t, PR_t, is assumed to be the approximate extraction rate for period t+1 under normal operating conditions. The product $R_{r,k,t}*PR_t$ is the expected, or normal, operating level of production for year t+1. Actual production in year t+1 will deviate from expected production, depending on the proportionate change in price from period t and on the value of the short-run price elasticity. The OGSM passes estimates of β to the NGTDM and PMM that can be used in solving for the market equilibria.

The P/R ratio is multiplied by beginning-of-year crude oil reserves to estimate production by region. This volume is then passed to the PMM for use in market equilibration.

Appendix E

Selected Model Assumptions

Reference Case

The Reference Case for this analysis is similar to the reference case for the *Annual Energy Outlook 2000* (*AEO2000*), with the following updates.

- The resource base for conventional natural gas sources in the Rocky Mountain region is lower than in *AEO2000* by 8 percent—the volume estimated to be subject to current environmental and other constraints that preclude industry access.

- In the Unconventional Gas Recovery Supply Submodule, the overall improvement in technology for enhanced coalbed methane recovery is assumed to be 30 percent for this analysis, up from 25 percent in *AEO2000*, and the enhanced technologies are made available in 2010 rather than 2015.

- World oil prices and natural gas wellhead prices in 1999 and 2000 have been updated according to data from the April 2000 *Short-Term Energy Outlook*. The 1999 world oil price is $17.13 per barrel, up from $16.98 per barrel in *AEO2000*, and the 2000 world oil price is $24.36 per barrel, up from $21.16 per barrel in *AEO2000*. The average natural gas wellhead prices in 1999 and 2000 are $2.07 and $2.48 per thousand cubic feet, respectively, revised from $2.12 and $2.17 per thousand cubic feet, respectively, in *AEO2000*.

Rapid and Slow Technology Cases

Two alternative cases were created for this analysis to assess the sensitivity of the projections in the Accelerated Depletion Case to changes in the assumed rates of progress in oil and natural gas supply technologies. To create these cases a number of parameters representing technological penetration in the Reference Case were adjusted to reflect more rapid and slower penetration rates. In the Reference Case, the underlying assumption is that technology will continue to penetrate at historically observed rates. Because technologies are represented somewhat differently, in different submodules of the Oil and Gas Supply Module, the approach for representing rapid and slow technology penetration varies as well. For instance, the effects of technological progress on conventional oil and natural gas parameters in the Reference Case—such as finding rates, drilling, lease equipment, and operating costs, and success rates—were adjusted upward and downward by 50 percent for the Rapid and Slow Technology Cases, respectively (Table E1).

The representations of enhanced oil recovery and unconventional natural gas recovery are described below. All other parameters in the model were kept at their Reference Case values, including technology parameters for other modules, parameters affecting foreign oil supply, and assumptions about imports and exports of liquefied natural gas and natural gas trade with Canada and Mexico.

Enhanced Oil Recovery

Two impacts of technology improvement are modeled to determine the economics for development of inferred enhanced oil recovery (EOR) reserves:

- An overall reduction in the costs of drilling, completing, and equipping production wells as a result of incremental improvements in drilling equipment and procedures, reservoir characterization, completion methods, and operation refinement

- Field-specific penetration of horizontal well technology, which represents a quantum improvement in recovery efficiency.

The specific parameters for the Reference Case and the Rapid and Slow Technology Cases are shown in Table E2.

The percentage of the remaining undiscovered recoverable resource determined to be technically amenable to gas-miscible EOR methods is set for each region at the beginning of the forecast, assuming current technology. The value is assumed to increase over the forecast period with advances in technology (Table E3).

Unconventional Gas Recovery

The Unconventional Gas Recovery Supply Submodule relies on the model's Technology Impacts and Timing functions to capture the effects of technological progress on costs and productivity in the development of gas from deposits of coalbed methane, gas shales, and tight sands. The numerous research and technology initiatives are combined into 11 specific "technology groups" that encompass the full spectrum of key disciplines—geology, engineering, operations, and the environment. The technology groups are characterized for the Reference, Accelerated Depletion, and Rapid and Slow

Table E1. Assumed Annual Rates of Technological Progress in the Reference and Rapid and Slow Technology Cases: Costs, Finding Rates, and Success Rates for Conventional Sources of Oil and Gas

(Percentage Improvement per Year)

Category	Natural Gas			Crude Oil		
	Reference Case	Rapid Technology Case	Slow Technology Case	Reference Case	Rapid Technology Case	Slow Technology Case
Costs						
Drilling						
Onshore	1.29	1.94	0.65	1.29	1.94	0.65
Offshore	2.02	3.03	1.01	2.02	3.03	1.01
Alaska	1.00	1.50	0.50	1.00	1.50	0.50
Lease Equipment						
Onshore	0.59	0.89	0.30	0.59	0.89	0.30
Offshore	1.40	2.10	0.70	1.40	2.10	0.70
Alaska	1.00	1.50	0.50	1.00	1.50	0.50
Operating						
Onshore	0.54	0.81	0.27	0.54	0.81	0.27
Offshore	0.60	0.90	0.30	0.60	0.90	0.30
Alaska	1.00	1.50	0.50	1.00	1.50	0.50
Finding Rates						
New Field Wildcats						
Onshore						
Shallow						
Northeast	0.50	0.75	0.25	0.50	0.75	0.25
Gulf Coast	2.00	3.00	1.00	2.00	3.00	1.00
Mid Continent	3.00	4.50	1.50	2.00	3.00	1.00
Southwest	3.00	4.50	1.50	4.00	6.00	2.00
Rocky Mountain	2.00	3.00	1.00	2.00	3.00	1.00
West Coast	1.00	1.50	0.50	1.00	1.50	0.50
Deep						
Northeast	--	--	--	--	--	--
Gulf Coast	1.00	1.50	0.50	--	--	--
Mid Continent	1.00	1.50	0.50	--	--	--
Southwest	6.00	9.00	3.00	--	--	--
Rocky Mountain	1.00	1.50	0.50	--	--	--
West Coast	--	--	--	--	--	--
Offshore	6.00	9.00	3.00	2.00	3.00	1.00
Other Exploratory						
Onshore						
Shallow	0.00	0.00	0.00	2.88	4.32	1.44
Deep	4.72	7.08	2.36	--	--	--
Offshore	4.14	6.21	2.07	4.14	6.21	2.07
Developmental						
Onshore						
Shallow	0.27	0.41	0.14	2.50	3.75	1.25
Deep	1.61	2.42	0.81	--	--	--
Offshore	4.14	6.21	2.07	4.14	6.21	2.07
Success Rate						
Exploratory	0.50	0.75	0.25	0.50	0.75	0.25
Developmental	0.00	0.00	0.00	0.00	0.00	0.00

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

Table E2. Assumed Rates of Technological Progress for Enhanced Oil Recovery Techniques

Item	Reference Case	Rapid Technology Case	Slow Technology Case
Drilling, Completion, and Equipping Costs (Percentage Decline per Year)	2	3	2
Horizontal Well Technology Penetration			
Start Date	1995	1995	NA
Penetration Period (Years)	40	20	None
Penetration Rate (Percent per Year)	2.5	5.0	0
Maximum Penetration of Inferred reserve Base (Percent)	90	90	0

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

Table E3. Assumed Rates of Technological Progress for Gas-Miscible Enhanced Oil Recovery Techniques (Annual Percentage Increase in Recoverable Resource)

Region	Reference Case	Rapid Technology Case	Slow Technology Case
Gulf Coast (Region 2)	2.5	3.5	0.0
Midcontinent (Region 3)	2.0	3.0	1.0
Southwest (Region 4)	2.0	3.0	1.0
Rocky Mountain (Region 5)	2.0	3.0	1.0

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

Technology Cases as summarized in Table E4. The 11 technology groups are described below:

1. **Basin Assessments:** Basin assessments increase the available resource base by (1) accelerating the time that hypothetical plays in currently unassessed areas become available for development, and (2) increasing the play probability for hypothetical plays—that portion of a given area that is likely to be productive.

2. **Play-Specific, Extended Reservoir Characterizations:** Extended reservoir characterizations increase the pace of new development by accelerating the pace of development for emerging plays, where projects are assumed to require extra years for full development relative to plays currently under development.

3. **Advanced Well Performance Diagnostics and Remediation:** Well performance diagnostics and remediation expand the resource base by increasing reserve growth for already existing reserves.

4. **Advanced Exploration and Natural Fracture Detection Research and Development:** Exploration and natural fracture detection research and development increases the success of development by (1) improving exploration and development drilling success rates for all plays, and (2) improving the ability to find the best prospects and areas.

5. **Geology/Technology Modeling and Matching:** Geology/technology modeling and matching matches the "best available technology" to a given play with the result that the expected ultimate recovery (EUR) per well is increased.

6. **More Effective, Lower Damage Well Completion and Stimulation Technology:** Improved drilling and completion technology improves fracture length and conductivity, increasing the EUR per well.

7. **Targeted Drilling and Hydraulic Fracturing Research and Development:** Targeted drilling and hydraulic fracturing research and development results in more efficient drilling and stimulation, which lowers well drilling and stimulation costs.

8. **New Practices and Technology for Gas and Water Treatment:** New practices and technology for gas and water treatment result in more efficient gas separation and water disposal, which lowers water and gas treatment operation and maintenance (O&M) costs.

9. **Advanced Well Completion Technologies:** Research and development in advanced well completion technologies such as cavitation, horizontal drilling, and multi-lateral wells (1) defines applicable plays, thereby accelerating the date such technologies are available, and (2) introduces an improved

Table E4. Assumed Rates of Technological Progress for Unconventional Gas Recovery in the Reference, Accelerated Depletion, and Rapid and Slow Technology Cases

Technology Lever	Item	Resource Type	Reference Case	Accelerated Depletion Case	Rapid Technology Case	Slow Technology Case
Reservoir Characterization and Well Performance Technology						
1. Basin Assessments	Date available	All types	2016	NA	2011	NA
2. Play-Specific, Extended Reservoir Characterizations	Development pace	Tight gas sands	-1.25 yr per year	-0.5 yr per year	-2.0 yr per year	-0.5 yr per year
	Development pace	Colabed methane	-1.0 yr per year	-0.5 yr per year	-1.5 yr per year	-0.5 yr per year
	Development pace	Gas shales	-1.0 yr per year	-0.5 yr per year	-1.5 yr per year	-0.5 yr per year
5. Geology/Technology Modeling and Matching	EUR per well	All types	5%	NI	5%	NI
6. More Effective, Lower Damage Well Completion and Stimulation Technology	EUR per well	All types	10%	5%	10%	5%
Optimization and Cost Reduction Technology						
3. Advanced Well Performance Diagnostics and Remediation	Reserve growth	Tight gas sands	2.0% per year	2.0% per year	3.0% per year	1.0% per year
	Reserve growth	Coalbed mathane	3.0% per year	3.0% per year	4.5% per year	1.5% per year
	Reserve growth	Gas shales	3.0% per year	3.0% per year	4.5% per year	1.5% per year
7. Targeted Drilling and Hydraulic Fracturing Research and Development	Cost per well	All types	-10%	-10%	-15%	-5%
8. New Practices and Technology for Gas and Water Treatment	Cost per Mcf	All types	-20%	-20%	-30%	-10%
Access to Resources						
11. Mitigation of Environmental Restraints	Acreage available	All types	Removed in 50 years (1%/yr)	NI	Removed in 25 years (2%/yr)	NI
Exploration/Breakthrough Technology						
4. Advanced Exploration and Natural Fracture Detection Research and Development	E/D success rate	All types	+0.25% per year from 2000	NI	+0.50% per year from 2000	NI
	Exploration efficiency	All types	Identify "best" 30% by 2017	NI	Identify "best" 30% by 2007	NI
9. Advanced Well Completion Technologies						
Horizontal Wells	Recovery efficiency	Tight gas sands	+10% in 2011	NI	+15% in 2011	NI
Advanced Cavitation	EUR per well	Coalbed methane	+20% in 2011	NI	+30% in 2006	NI
Multilateral Completions	Recovery efficiency	Gas shales	NI	NI	+15% in 2011	NI
10. Other Unconventional Gas Recovery Technologies	EUR per well	Tight gas sands	+10% in 2021	NI	+10% in 2016	NI
Enhanced Coalbed Methane Recovery Efficiency	Recovery efficiency	Coalbed methane	+30% in 2015	NI	+45% in 2010	NA
Enhanced Coalbed Mathane O&M Costs	Cost per Mcf	Coalbed methane	$1.oo per Mcf, incremental	NA	$0.75 per Mcf, incremental	NA
Other Technology		Gas shales	NA	NA	NA	NA

NA = not available. NI = no improvement.
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

version of the particular technology, which increases the EUR per well.

10. Other Unconventional Gas Recovery Technologies: Other unconventional gas recovery technologies, such as enhanced coalbed methane and enhanced gas shale recovery, introduce dramatically new recovery methods that (1) increase the EUR per well, (2) become available at dates accelerated by increased research and development, and (3) increase operation and maintenance (O&M) costs (in the case of coalbed methane) for the incremental gas produced.

11. Mitigation of Environmental Constraints: Environmental mitigation removes development constraints in environmentally sensitive basins, resulting in an increase in basin areas available for development.

Appendix F

Unconventional Gas Plays in the Rocky Mountains

The High Rocky Mountain Access Case for unconventional natural gas was modeled at the play level. Table F1 lists the plays that were affected in the High Rocky Mountain Access Case.

Table F1. Rocky Mountain Basins and Plays with Access Constraints

Basin	Tight Gas Shale	Coalbed Methane
Green River	Fort Union	Shallow—Coalbed Methane
	Lewis	Deep—Coalbed Methane
	Deep Mesaverde	
	Fox Hills/Lance	
	Shallow Mesaverde	
	Frontier (Moxa Arch)	
	Frontier (Deep)	
Piceance	South Basin WF/MV	Divide Creek
	North Basin WF/MV	White River Dome
	Basin Wide Iles/MV	Shallow—Coalbed Mathane
		Deep—Coalbed Mathane
Powder River		Shallow, Basin Margin
		Central Basin
Raton		Purgatory Ridge
		North Raton Basin
		South Raton Basin
San Juan	Picture Cliffs	North San Juan Basin, Colorado
	Central Basin / Dakota	Menefee Play
	Central Basin / MV	
Uinta	Tertiary West	Sego
	Deep Synclinal MV	Blackhawk
	Basin Flank MV	
Wind River	Fort Union / Lance Shallow	
	Mesaverde / Frontier Shallow	
	Mesaverde / Frontier Deep	

Source: Advanced Resources International, internal memorandum, 2000.

Appendix G

Accelerated Natural Gas Depletion Rates

Recent reports have emphasized that the decline in the rate of production from natural gas wells has increased in recent years. In *Depletion: The Forgotten Factor in the Supply Demand Equation: Gulf of Mexico Analysis*, David Pursell cites the increase in the rate of decline in natural gas production per well from less than 20 percent per year in 1970 and 1971 to 49 percent per year for wells completed in 1996.[24]

In Pursell's analysis, the increased rate of decline in the wells of the Gulf Shelf is attributable to the cumulative effects of depletion:

> *It should be no surprise that exploration and development opportunities diminish over time in a mature basin. We believe that the broad application of 3-D seismic and horizontal drilling technologies in the early 1990' s may have actually accelerated the decline rates. 3-D seismic allowed the geologists and geophysicists to "see" smaller structures that were previously not readily visible on conventional 2-D seismic. Horizontal drilling technology allowed many of these smaller reservoirs to be developed from the existing platforms with fewer wells, creating an illusion that technology was making it easier to exploit oil and gas on the GOM shelf. However, once the "low hanging fruit had been picked," the 3-D seismic technology was driving exploration of smaller (marginal) reservoirs.*

Data from natural gas wells in the Federal offshore Gulf of Mexico show an increase in the rate of decline after a well's peak. Wells drilled in 1996 are declining more quickly than wells drilled in 1972 (see Figure 4 in Chapter 1). Twenty-three months after reaching peak production in January 1997, the average production from natural gas wells that began producing in 1996 was 69 percent lower than it had been at its peak. In contrast, the decline in production over the 23 months after wells drilled in 1972 had reached their peak production was only 39 percent.

While the rate of decline from the peak appears to be increasing, that is only part of the story. The increase in decline rates has been accompanied by an increase in the peak rate of the average well's production. Average production from wells drilled in 1972 peaked at 4.2 million cubic feet per day. Average production from wells drilled in 1996 peaked at more than 6 million cubic feet per day. The trends toward higher peak production and faster decline from peak rates are apparent (Table G1.)

While wells are being developed in smaller fields than they have been in the past, they are also producing more quickly. The faster decline rate in the late 1990s is due not only to smaller fields but also to an increase in initial flow rates as the resources are developed more rapidly. Faster decline rates reflect the choice of producers to develop larger wells, as well as the underlying geology and the ongoing process of moving from the "low hanging fruit" to resources that are smaller and more difficult to recover.

The NEMS OGSM uses decline rates indirectly. The effect of increased well sizes drawing down smaller fields, which shows up as higher decline rates in Pursell and similar analyses, is modeled by reducing the amount of oil or gas that is added to reserves with each exploratory well drilled and increasing the fraction of the proved reserves that are produced each year.

The production-to-reserves ratio for natural gas varies between the Reference Case and the Accelerated Depletion Case (Figure G1).The ratio of natural gas produced to the level of proved resources is higher in the Accelerated Depletion Case than in the Reference Case. The ratio of production to proved reserves increases as depletion reduces the resources left to be developed. However, this ratio does not measure the ratio of

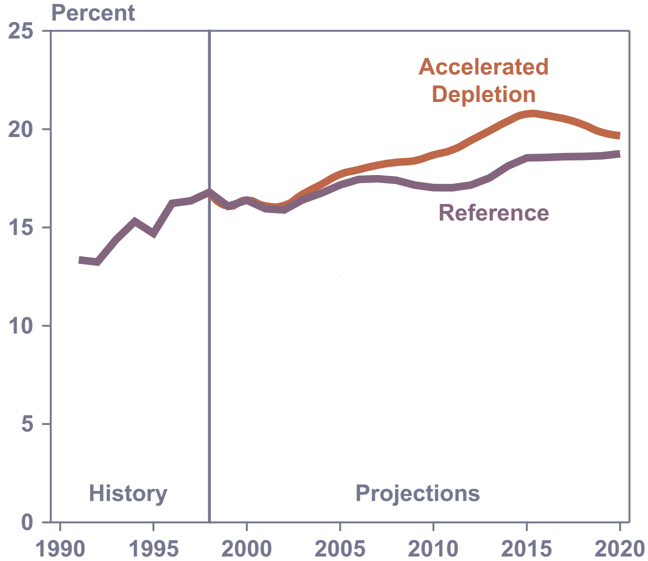
Table G1. Average Production from Wells in the Federal Offshore Gulf of Mexico, 1972 to 1996

Year	Peak Production (Thousand Cubic Feet per Day)	Percentage of Peak Production 23 Months Later
1972	4,198	0.633
1976	5,591	0.648
1980	5,533	0.502
1984	4,477	0.591
1988	4,915	0.497
1992	5,294	0.417
1996	6,070	0.314

Source: Energy Information Administration, Office of Oil and Gas, Reserves and Production Division (Dallas, TX).

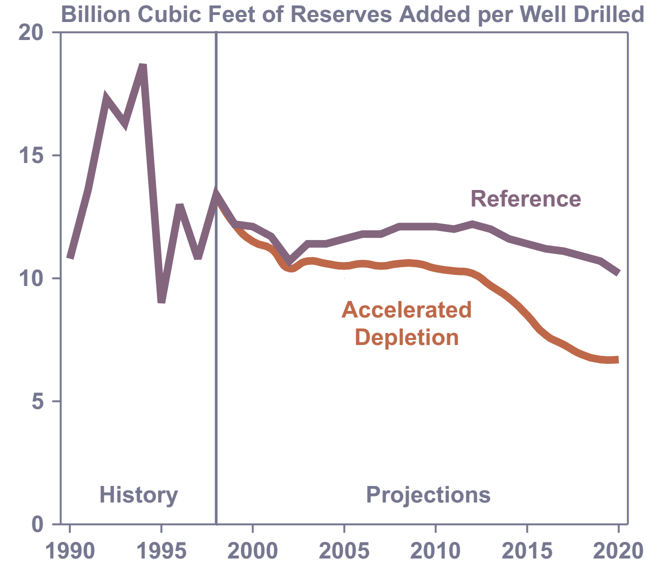
[24] David Pursell, *Depletion: The Forgotten Factor in the Supply and Demand Equation: Gulf of Mexico Analysis* (Houston, TX: Simmons and Company International, 1998), p. 10.

Figure G1. Ratio of Offshore Lower 48 Natural Gas Production to Proved Reserves, 1991-2020



Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A and OGDEPL. D051200A.

Figure G2. Finding Rate per Well for Offshore Lower 48 Natural Gas, 1990-2020



Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, National Energy Modeling System runs OGBASE.D051200A and OGDEPL. D051200A.

production to the total remaining resources in a region, and therefore the production-to-reserves ratio is not a direct measure of depletion.

The finding rate, or the average amount of natural gas added with each successful exploratory and development well, is higher in the Reference Case than in the Accelerated Depletion Case (Figure G2). While the projected amount of natural gas added per well in the offshore lower 48 falls by nearly 2 billion cubic feet per successful well between 1999 and 2020 in the Reference Case, the decline in the projected finding rates in the Accelerated Depletion Case is 5.5 billion cubic feet, or nearly three times greater.

In the Accelerated Depletion Case, wells with higher production-to-reserve ratios are used to develop smaller reservoirs of oil and gas than in the Reference Case. These factors are consistent with the expectation that decline rates in the Accelerated Depletion Case will be more rapid than decline rates in the Reference Case. As other analysts have found, the effects of depletion in years to come will require more domestic drilling than there is today if domestic production is to meet or exceed the current level. Depletion is accounted for in NEMS and influences projections in the Reference Case. The more pronounced effects of depletion assumed in the Accelerated Depletion Case lead to different projections than in the Reference Case, demonstrating how stronger-than-expected effects of depletion can lead to higher prices and lower production.