Engines of Growth:
Energy Challenges, Opportunities, and Uncertainties In the 21st Century

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Executive Summary

In the face of potential supply shortfalls, infrastructure constraints, and environmental limitations, policymakers and managers in the U.S. energy sector can expect complex multidimensional challenges in the years ahead. Using a technique known as scenario analysis, this study investigates key energy issues and decisions that could better position or weaken the ability of the United States to deal with any number of uncertainties that may challenge the U.S. economy during the next fifty years.

In this study, a computable general equilibrium model, the All-Modular Industry Growth Assessment model, also known as the AMIGA modeling system, is used to explore the driving forces and critical uncertainties that may shape U.S. energy markets and the economy for the next fifty years. Four scenarios have been developed representing a diverse range of future worlds, with each scenario quantified using the AMIGA model. The four scenario narratives are:

- *The Official Future;*
- *Cheap Energy Reigns Supreme;*
- *Big Problems Ahead; and*
- *Technology Drives the Market.*

The detailed results from the analysis (see section 8.3 of the Appendix) suggest that the range of feasible U.S. energy futures is broad, but that energy use is expected to grow under all scenarios. At the same time, the introduction of policies to encourage capital stock turnover and accelerate the commercialization of high-efficiency, low-emissions technologies can significantly reduce future primary energy demand in the United States.

Not surprisingly, the analysis suggests that low energy prices can lead to higher economic growth than might be characterized in standard reference case assumptions. But the analysis also finds that a smart investment path, one that emphasizes both energy efficiency improvements and advanced energy supply technologies, can provide an economic growth similar to lower energy prices. In other words, policies introduced to improve energy efficiency and accelerate the introduction of new technologies do not appreciably reduce the prospects for economic growth.

Public and private choices made today, together with external events outside the control of the United States, can affect the cost of responding to future surprises. The findings of this research project suggest that a smart investment path, emphasizing both energy efficiency improvements and advanced energy supply technologies, can better position the U.S. economy to more quickly respond to unexpected outcomes or external events.

1 Introduction

"Energy is closely linked to economic prosperity," began the George H.W. Bush Administration's *National Energy Strategy* more than 12 years ago.[1] In recent months, the link between energy and the economy has never been more evident as energy-related events seriously affected economic performance in several regions of the country.

Beginning with the California energy crisis in 2001, thirty million Americans were subjected to a roller-coaster ride of price spikes and rolling blackouts. Municipal and state government officials, unable to acquire stable supplies of electricity, were forced to disrupt or cancel vital public services. Across the state, businesses of all types were put under severe stress and several of California's historically stable utilities were driven to the brink of bankruptcy. Early in the summer of 2003, the rupture of a single gasoline pipeline outside Phoenix, Arizona left thousands to sit in endless lines at fueling stations, enduring unorganized rationing of gasoline supplies and a tripling of gasoline prices. In August 2003, the Northeast Blackout left as many as fifty million Americans and Canadians without electricity for days on end. In September 2003, Hurricane Isabel disrupted the power grid and overwhelmed many antiquated segments of the electricity distribution system in the Mid-Atlantic States.

Concurrently, researchers and scholars have warned that global shortfalls in the availability of conventional energy resources could occur as early as 2030.[2] The major concern is not that the world is running out of all energy resources, but rather that the major non-renewable supplies of oil, gas, and arable lands are being rapidly and irreversibly depleted. Very likely a huge investment in both Research and Development (R&D) and infrastructure will be needed over the next several decades to ensure adequate energy availability and to commercialize the technologies that will replace cheap fossil fuels. Technologies likely to receive the most attention include unconventional fossil fuels, hydrogen, renewables, advanced nuclear power technology, and new energy efficiency systems.

Given the potential impacts on the U.S. economy of disruptions or shortfalls in energy supply, it is prudent to explore the mix of energy investments most likely to achieve three essential and complementary national goals: energy security, economic robustness, and environmental quality. Widespread concerns about the security of the U.S energy infrastructure, the vulnerability of its economy to price spikes or fuel supply disruptions, and the environmental impacts of energy supply anticipate a future of uncertainty and surprises. The underlying forces that create current concerns will inevitably interact with uncertainties regarding public policy choices, private investment decisions, future advances in energy technology, and the problematic behavior of uncontrollable foreign actors. Taken together, these forces will shape the U.S. energy future. The purpose of this analysis is to help decision-makers to prepare for these surprises by identifying policy strategies that remain robust across the range of possible futures.

[1] U.S. Department of Energy, 1991.
[2] Abt, 2002; Hoffert et al., 2002; and Metz , et al., 2001

Using a technique known as scenario analysis, this study builds upon recent work by the authors that was commissioned by the Pew Center on Global Climate Change.[3] The present study investigates key energy issues and decisions that could better position or weaken the ability of the United States to deal with any number of uncertainties that may challenge the U.S. economy during the next fifty years.

2 The U.S. Energy Sector: Current Context

The United States is not close to running out of fuel or electricity in absolute terms. This nation has rich and abundant resources of fossil fuels, nuclear power, and renewable energy. Yet, the events of the last two years highlight the sensitivity of the U.S. economy to even short-lived disruptions in the supply of key energy resources. Mismatches occur between the energy that is available at a particular time and in a given form compared to the market demand for that energy at a different time and perhaps in a different form. As the examples cited above indicate, breakdowns in energy supply can create discontinuities that disrupt markets and generate economic hardships for governments, businesses, and individuals.

In the short term, domestic and imported energy supplies are adequate to meet U.S. energy demands. However, future energy demands are another matter. U.S. energy consumption dominates world energy markets and the U.S. economy's voracious thirst for fuel and electricity continues to grow. In 2000, the United States consumed about 100 Quads of primary energy.[4] If current trends continue, U.S. consumption could be more than 50 percent higher by 2050.

2.1 Oil Import Dependence and Energy Security

Oil supply is a big part of the problem. The United States produced approximately 2.6 billion barrels of oil in 2002, more oil than any other country but two: Saudi Arabia and the Russian Federation.[5] Yet, in order to meet the domestic demand for petroleum products, the United States still needed to import nearly 4 billion additional barrels of oil in 2002 — more than the total 2002 consumption of Brazil, China, and India combined.[6] Further complicating the problem of oil import dependence, production from U.S. wells in the lower-48 states has been declining slowly but steadily over the last two decades. Given expected growth of future U.S. demand for oil and petroleum products, the weight of U.S. imports on international markets will inevitably increase. New finds, especially

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[3] Mintzer, Leonard, and Schwartz, 2003. The Pew Center's scenario planning exercise was designed to stimulate thinking about alternative U.S. energy futures, not to forecast the impacts of climate change policies on the U.S. economy. The Pew Center's economics program is undertaking a separate multi-year effort to model projected costs of actual policy proposals.

[4] One Quad equals one million billion (10^{15}) British Thermal Units or approximately 0.95 Exajoules (10^{18} Joules).

[5] British Petroleum, 2003a.

[6] Ibid.

in Alaska, may help to offset the decline in production from the Lower-48. But even if the economically recoverable estimates of oil reserves in the Alaskan National Wildlife Refuge (ANWR) prove out at six billion barrels, it will not change the U.S. situation for long.[7] At current levels of consumption, supplying the six billion barrels from ANWR to U.S. markets would offset U.S. imports for less than two years.

2.2 Aging Infrastructure and Energy System Reliability

Strained and aging energy infrastructure is another problem. Despite significant domestic resources of oil, natural gas, coal, and hydropower, the United States may be rapidly outdistancing the ability of its existing infrastructure to deliver energy to end-users in a reliable and efficient fashion. The recent experiences of the Northeast blackout and the Phoenix pipeline failure indicate that systemic failures can fan out from a simple mechanical problem and create a regional crisis. Rebuilding the national infrastructure of transmission lines, distribution systems, and regulatory institutions to avoid or contain such failures in the future will be a slow and costly process. But without this investment, the likelihood of unanticipated systemic failures in the future will increase.

2.3 Environmental Impacts of Energy-Related Emissions

Environmental constraints pose additional challenges. One of the challenges involves the ability of the environment to act as a sink for pollutants. The United States may be close to exceeding the ability of its immediate environment to tolerate the wastes -- solid, liquid, gaseous, and thermodynamic -- that result from energy supply and use. In the eastern United States, especially Appalachia, major coal-mining companies maintain that they can remain profitable only if allowed to remove entire mountaintops and to dispose of the “overburden” in local waterways and valleys. These new mountaintop removal techniques raise important new risks for surface water quality and for the health of local ecosystems.

Another challenge involves the impacts of pollutant emissions on public health. Across the country, combustion-related air pollutant emissions increase the risk of serious negative health consequences (including asthma and acute respiratory distress) among vulnerable populations, particularly the very young and the very old. In some parts of the southern United States, spillage and runoff from refineries has turned up in the form of organic pollutants in local groundwater supplies, raising significant new concerns about energy-related risks to public health.

[7] Koomey, et al., 2002 which cited oil prices at about $25 per barrel in 1996 dollars, or about $30 per barrel in 2003 dollars.

2.4 Summary

In the face of potential supply shortfalls, infrastructure constraints, and environmental limitations, policymakers and managers in the U.S. energy sector can expect complex multidimensional challenges in the years ahead. Among the focal questions are the following:

- How can the United States best meet the escalating demand for fuel and electricity in the economy over the next fifty years?
- What combination of public policy strategies and investment decisions will allow the country to meet these demands reliably — without raising prices astronomically, encumbering exorbitant risks to our national security, or polluting our environment in damaging ways?
- What technologies can be most useful in this regard?
- How will the decisions of other actors outside U.S. borders affect the ability to achieve national goals?

There are no absolute answers to these questions. Building energy production and distribution facilities, or changing the stock of major energy end-use devices, takes years -- often over a decade to design, organize, finance, build, and operate.[8] Furthermore, the presence of persistent and profound uncertainties makes it extremely difficult to forecast the energy future of the United States with confidence. Decision-makers in both the government and the private sector need additional ways to grapple with these complex questions.

Scenario analysis is one of the most useful tools for informing strategic decisions. The Shell International Petroleum Company developed the scenario analysis approach originally in the 1970s. It was refined and elaborated into its current form through work by such groups as the Global Business Network (GBN).[9] Section three below describes the basic elements and historical development of the scenario analysis approach. Sections four and five below apply this approach to the strategic problems of energy in the United States.

3 Why Use Scenarios to Explore the Future?

"*Predicting the future is decidedly more difficult than explaining the past....*"[10]

Everyone wonders what the future will bring. It is the subject of dinner table conversation and science fiction writing. But some institutions and individuals have a responsibility to look into the future in a more sober and serious way. Policy-makers and investors use a variety of approaches to consider their options and make judgments among alternatives. Typically, consideration of the future is based on simple forecasts with straight-line extrapolations of past or current trends. In a relatively stable world,

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[8] Abt, 2002. Page 77.
[9] See further Wack, 1985a; Schwartz, 1991; Liam and Fahey, 1998; Ringold, 1998.
[10] Cooper and Layard, 2002, page 3

where change is slow as well as incremental, and surprises rarely disrupt the tranquility of the day, this approach is reasonably adequate.

3.1 A Tool for Investigating the Future in Times of Rapid Change

But in times like ours, when competing social or economic forces converge, when disruptive, market-transforming technologies enter the marketplace, and when unexpected events turn conventional wisdom on its head, conventional forecasts and straight-line extrapolations are rarely accurate. As U.S. policy-makers and investors look out over the next decade or two, and especially if they look out fifty years, they will confront an array of deep challenges and profound uncertainties that cannot be resolved using traditional forecasts or computer models of the future, no matter what level of detail these tools produce.

In times when strongly competing forces lead to rapid and discontinuous change, narrow forecasts of the future are worse than just inaccurate. By seeing the future as a simple extension of the past, such forecasts tend to mislead decision-makers about the depth of existing uncertainties and the dynamics of emergent or continuing conflicts. They lull the mind into a false sense of security, causing the decision-maker to miss key shifts in the environment and overlook clues about what must be done. [11]

3.2 An Alternative to Extrapolation and Forecasting

Scenario analysis is an alternative approach to straight-line extrapolation of the future. Peter Schwartz, Chairman of the Global Business Network and a leading scenario analyst, argues that when scenarios are designed to be logical, credible, realistic, and provocative, they can be exceptionally useful tools for ordering one's perceptions about the future.[12] Such scenarios can promote explicit consideration of a variety of contingencies and uncertainties -- even surprises. Research on specific questions raised by the scenario development process tests the scenario logic. The research provides a fundamental discipline and ensures the accuracy of parameters used to describe the world faced by the decision-maker. In this way, scenarios allow their users to identify and develop robust strategies to meet the challenges of an uncertain future.

Scenario analysis supports decision-makers by helping them to see things that might otherwise remain outside their perceptual field. According to Pierre Wack, one of the seminal thinkers on scenario analysis, "scenarios deal with two worlds, the world of facts and the world of perceptions. They explore the facts but aim at perceptions inside the

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[11] A scenario is one specific realization of a dynamic, stochastic process. We may have significant gaps in our knowledge of the process, and the process may include major surprises. Thus, it is unrealistic to think that a full statistical specification of the future is possible. Some of the most important random variables that are of interest for future energy scenarios include oil and gas resource availability, rates of advance on new technologies, and stability in world energy markets. These are some of the unknowns that we explore using scenario analysis in this study.

[12] Schwartz, 1991.

head of [each] decision-maker … and transform information of strategic significance into fresh perceptions."[13] Scenario analysis is a process for helping decision-makers to learn about the future and to make choices today based on an improved understanding about how the future may play out.[14] Highlighting the role of uncertainties and surprises along a variety of dimensions, scenarios integrate consideration of key driving forces, critical uncertainties, shifting consumer and investor values, as well as unchanging "verities."

3.3 Framing Strategic Choices

Scenarios are believable stories about how the future may unfold, complete mental microcosms that can be used by a decision-maker to sort out the available options when faced with a critical strategic choice. Schwartz emphasizes that they are not predictions of the future, but a device for "ordering one's perceptions about alternative future environments."[15]

Each scenario thus becomes a practical teaching tool, bounding the envelope of possibilities within which government policy-makers, business leaders, and other individuals can frame strategic responses to the challenges ahead. The purpose of scenarios is to prepare the decision-maker for confronting the profound uncertainties that may characterize the collective future and that cannot be readily represented in a mechanistic model. When well executed, scenarios lay the groundwork for making better strategic choices.

3.4 The Scenario Development Process

The process of scenario development should lead to several provocative yet plausible scenarios. Each scenario represents "an internally consistent view of what the future might turn out to be" -- a structured story describing a future world that might unfold if specific strategic choices were made or options pursued.[16] The key to scenario analysis is learning which of the outcomes -- among the myriad possibilities – will help the decision-maker to choose robust strategies for confronting an uncertain future. Pierre Wack, viewed the scenario development process as analogous to building a "wind tunnel" – as a device for testing policy choices or business plans.

The scenario development process typically involves the following series of steps:

Characterize the strategic decision. Scenario analysis is not research for its own sake: it is a process explicitly designed to support strategic decision-making. The first step in that process is characterizing the focal decision or issue. It is most useful to focus on the

[13] Wack, 1985b.
[14] Schwartz, 1991.
[15] Schwartz, 1991
[16] Porter, 1985.

specific problem or issue that the decision-maker is confronting, and then build outward toward the larger environment.

Identify key factors affecting the immediate microenvironment of the decision-maker. Choosing robust strategies requires that decision-makers understand the forces that shape the immediate business or policy environment, and don't just assume that the future will look like the past.[17] The key factors for public policy decisions may include sectoral circumstances, national economic conditions, resource availability, and population, or even unemployment levels. The key factors affecting a business or investment decision may include the competitive position of the firm, its available technology and human resources, its access to capital, its relationship to its customers, and its historical asset base. The principal actors are the ones who play key roles in the scenario. These may be individuals, business organizations, institutions, cohorts in the population, or entire cultures.

Understand the driving forces in the macro environment. To ensure that scenarios are not just passionate dinner-table conversation or exercises in creative writing, the key driving forces in the larger macro-environment as well as the key factors in the local environment must be carefully identified and characterized. These driving forces in the macro-environment often propel the story in a particular direction and set the pace with which the scenario unfolds. Driving forces can include economic, social, cultural, ecological, political, and technological events; recent developments; and emerging trends.[18]

Separate the predetermined elements from uncertainties. The development of the scenario narrative builds upon the "facts" of the world as we know it today. In Wack's view, scenarios divide one's mental map of the world into predetermined and uncertain elements.[19] Some of the most important elements are those that will remain true regardless of how the story unfolds, (called predetermined elements or verities). Although some elements of the future are predetermined, there are seldom enough of these elements to support a single-line forecast that encompasses all the important uncertainties.[20]

Equally critical to scenario development are the uncertainties that may dramatically affect the outcome of the story. Ian Wylie characterizes this element of the scenario development process as "means weaving the unknown around the known."[21]

But not all uncertainties are equally relevant to decision-making strategies. Often, the most important uncertainties are those elements that will resist rigorous quantification or probabilistic analysis, especially those that may lead to unanticipated outcomes or major surprises. Wack emphasizes the importance of these game-changing events. He

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[17] Wack, 1985a
[18] Fahey and Randall, 1998
[19] Wack, 1985b
[20] Wylie, 2002
[21] Wack 1985a

concludes that by studying some carefully selected uncertainties, the scenario developer gains a deeper understanding of the interplay among the uncertainties and is better able to separate what is inevitable from what is uncertain or impossible.[22] The rapid introduction and widespread use of a competing mode of personal transportation, for example, Star-Trek-like teleportation devices, is a game-changing event in a scenario about the long-term future of the automobile; but the introduction of on-board entertainment systems or performance-enhancing equipment for the vehicle's engine is not.

Develop the scenario logic. Once the cast of characters is set, the driving forces identified, and the critical uncertainties investigated, the scenario developer lays out the rationales that underpin the "plot" of the scenario narrative.[23] Elaborating and vetting this scenario logic allows the scenario developer to explain why specific forces or players behave in the ways ascribed to them in the narrative. Rigorously challenging the underlying scenario logic and testing the dynamics of interaction among driving forces ensures that the scenario developer understands what can happen in the future, and what cannot.[24]

Select leading indicators of change and explore the implications of strategic choices. Each scenario tells a unique story and contains a plot that links the known present to the uncertain future. The plot explains how the strategic decisions that are taken by the principal actors interact with the identified driving forces and key uncertainties, and allows for the introduction of significant surprises. This combination leads the storyline to a particular end-state. This plot fleshes out the chain of events, carrying the decision-maker into a new mental microcosm. The end-state provides a snapshot of what could be expected to happen in a particular future world at a specific point in time, and provides a common basis for comparison among a set of scenarios.

Quantify the scenarios. Quantifying the implications of events that unfold in a scenario, although not essential to building scenario narratives, ensures an important measure of discipline in the process of scenario analysis. The value of using simulation is discussed in Section 3.5 below.

Challenge the scenario logic and explore the likely responses. More can be learned from a set of scenarios by introducing a significant stressor or strategic challenge that is sufficient to motivate a change in the behavior of key actors. The response to this challenge can be simulated and tracked, allowing analysis of the impacts on the dynamics of the scenario and creating, in effect, a new set of scenarios. In this study, such tests are referred to as "challenge and response" cases.

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22 Ibid.

23 Liam and Fahey, 1998

24 Wack, 1985a

3.5 Quantifying Scenario Impacts

The process of combining structured narratives rooted in the present with careful quantification of the future implications of key decisions is useful in understanding the interactions among key social, political, institutional, technological, and environmental driving forces. Leading indicators, signposts of change, and critical parameters – when identified, calibrated, and observed over the course of the scenario period – foster better understanding of key relationships. This quantitative analysis applied to each scenario provides the basis for drawing meaningful comparisons among alternative future worlds and enables the decision-maker to navigate what Wack calls the "rapids" of unanticipated surprises as the future unfolds.[25]

In this study, an innovative tool of economic analysis is used to explore the quantitative implications of alternative U.S. energy futures. The tool, a computable general equilibrium model called AMIGA (the All-Modular Industry Growth Assessment model) contains a detailed database of capital assets in the U.S. energy and transportation sectors. For additional details on the AMIGA model, see section 8.1 in the Appendix as well as Hanson (1999) and Hanson and Laitner (2003).

The AMIGA model translates the events and relationships from the scenario narratives into quantitative terms, calculating the impacts of strategic policy and investment choices on fundamental macroeconomic parameters and energy demand. It projects the future magnitude of U.S. Gross Domestic Product (GDP) and generates time series data on the economic value of future investment, consumption, government spending, imports and exports, as well as expenditures on fuel and electricity. The AMIGA model also highlights the changing mix of technologies in the U.S. vehicle fleet, the characteristics of primary energy demand in the industrial and residential sectors, and the contributions of various fuels to future electricity supply. When generated for each decade in the scenario period, these projections become key indicators of the state of the economy as the scenario unfolds. These projections facilitate the orderly comparison of very different future worlds on a common basis.

4 Scenarios of Four Future Worlds

In order to explore the driving forces and critical uncertainties that may shape U.S. energy markets and the economy for the next fifty years, four scenarios have been developed representing a diverse range of future worlds. Three of these fictional U.S. energy futures draws from the scenario analysis conducted jointly by the Global Business Network and the Pew Center on Global Climate Change and extends the timeframe to 2050.[26] The fourth scenario, a reference or benchmark case, is developed from the principal scenario presented in the U.S. Department of Energy's *Annual Energy Outlook,*

[25] Ibid.
[26] Mintzer, Leonard, and Schwartz, 2003.

2002, and extends it to 2050.[27] Each scenario has been quantified using the AMIGA model with detailed results for each scenario found in section 8.3 of the Appendix.

The four scenario narratives are:

- *The Official Future;*
- *Cheap Energy Reigns Supreme;*
- *Big Problems Ahead; and*
- *Technology Drives the Market.*

4.1 The Official Future

The Official Future is a reference scenario reflecting conventional wisdom about the future patterns of U.S. energy supply and demand. In developing this scenario, existing U.S. policies, trends in market structure, and the market shares of various technologies were extrapolated beyond 2020 to 2050. Like each of the scenarios that follow, *The Official Future* is not a prediction or a forecast. It simply represents an internally consistent view of the way in which U.S. energy markets could evolve over time if current policies remain unchanged for the next fifty years. The presentation of this scenario is not intended to imply any endorsement by the U.S. Department of Energy or its Energy Information Administration. In this study, *The Official Future* is used as a benchmark or reference case for purposes of comparison with the other scenarios described below.

The following driving forces influence this scenario:

- Rising demand for oil to fuel a growing fleet of automobiles (both in the United States and in other countries);
- Expanding use of natural gas for electricity production as well as for heating; and
- Increasing electrification in the residential, commercial, and industrial sectors.

Principal actors and driving forces. The principal actors in this scenario include U.S. government policy-makers, business-leaders in the energy industry, and foreign governments responsible for decisions on oil and gas supply to Western markets. The U.S. government maintains a "firm hand on the tiller" of both energy and economic policy, making the choices necessary to expand energy supplies, control inflation, and promote steady economic growth. Energy companies cooperate with public policies to ensure the efficient workings of a competitive domestic energy market and foreign governments promote the development and international sales of fuel resources. OPEC is successful managing the global supply of oil in the face of rising global demand. International trade in gas expands, bringing unconventional gas to U.S. markets from various sources — Arctic fields, unmineable coal seams, tight formations, and municipal solid waste.

[27] *U.S. DoE, Energy Information Administration 2002b.* The Energy Information Administration's reference case scenario covers the period from 2000 to 2020. It has since been extended through 2025 in later publications. For all practical purposes, neither the extended time horizon nor the small differences in reference case assumptions provide any significant change in the results discussed here.

Table 1 illustrates key parameters in *The Official Future* basecase scenario.

Table 1
The Official Future
Scenario Summary

	2000	2010	2020	2050
Primary Energy Demand (in Quads)	100	115	129	157
Gross Domestic Product (GDP in Trillions of 2000US$)	$9.9	$13.1	$17.7	$36.9
World Oil Price ($ per barrel)	$27.72	$23.40	$24.30	$26.7
Average Wellhead Natural Gas Price ($ per thousand cubic feet)	$2.76	$2.75	$2.90	$5.38
Average Electricity Price ($/MWh)	67	60	61	79
Light Duty Vehicle Miles Traveled (Billions of Miles per year)	2,400	3,300	3,720	4,590
Average Fossil Fuel Heat Rate (BTUs per Kilowatt-hour)	10,730	9,710	9010	7,040

There are no major conflicts in this scenario. Federal policies on energy and economic development achieve their goals. New technologies enter the market gracefully, with incumbent technologies readily adjusting to all new challenges. Foreign governments seek to cooperate with U.S. policy in the interest of stimulating global economic growth.

Energy supply and demand. In *The Official Future*, U.S. energy demand increases at a slow and gradual rate of about 0.9 percent per year for the entire 50-year period. Total U.S. primary energy demand rises from approximately 100 Quads in 2000 to 157 Quads in 2050. During the same period, the U.S. economy grows at an average rate of about 2.7 percent per year, experiencing few shocks and no significant disruptions. At this annual rate of growth, U.S. GDP increases from just under $10 trillion in 2000 to about $37 trillion in 2050 (measured in constant year 2000 dollars).

Patterns of housing, urban development, and agriculture all continue to follow recent trends in *The Official Future*. Average house size increases and electric "plug loads" grow to feed bigger appliances, more entertainment devices, and additional office equipment in the home. Commercial development focuses on regional malls, with a continuing decline of retail trade in aging urban cores. Workers drive longer distances to work sites and families travel more miles each year by car. Air travel increases, both for business and for pleasure.

Fluid fuels and light duty vehicles. U.S. oil production in the lower-48 declines slowly but steadily. Imports of petroleum and petroleum products double from the year 2000 level and represent nearly 75 percent of U.S. consumption in 2050. Domestic production of natural gas doubles by 2050 but imports of natural gas increase by almost 300 percent. By 2050, imported natural gas represents approximately 25 percent of U.S. supply.

Despite this increasing reliance on imported oil and gas, energy security does not become a major issue for U.S. policy.

OPEC follows a strategy of political cooperation with the United State throughout this scenario. As a result, oil prices fall at the start of the scenario, and then increase in a very gradual fashion. International oil prices level off in 2030 at about 5 percent below their year 2000 level, and hold steady in constant dollar terms until the end of the scenario period. By contrast, the wellhead price of natural gas doubles from 2000 to 2050, due to the rapid increase in demand for natural gas. There are no significant degradations of electric system reliability over the next fifty years, and the average price of electricity increases by only 20 percent.

Engineering improvements in vehicle efficiency are very limited in *The Official Future*. Average on-road fuel economy for cars and light trucks increases by 15 percent from 2000 to 2010 then remains flat for the next forty years as improvements in vehicle drive train efficiency are offset by a continuing shift to larger and heavier vehicles for personal transportation (most notably to light trucks and sport-utility type vehicles). Economy-wide, the total vehicle miles traveled by all light-duty vehicles increases from about 2,400 billion miles in 2000 to 4,600 billion miles in 2050. Hybrid gasoline-electric and diesel-electric vehicles slowly begin to enter the market in *The Official Future*, reaching about 5 percent of new vehicle sales in 2025 and staying level at about 1 million new vehicles per year from 2025 to 2050. Fuel cell vehicles never reach commercial status in this scenario.

Energy and the economy. GDP grows steadily in *The Official Future,* growing from $10 Trillion in 2000 to almost $37 Trillion in 2050. Expenditures on fuel and electricity rise steadily in *The Official Future*, increasing at an average annual rate of approximately 1.4 percent. The largest portion of this increase in demand occurs in the residential and commercial sectors of the economy. For the economy as a whole, energy expenditures double between 2000 and 2050, from about $700 billion to more than $1.4 trillion.

Despite the growth in energy demand, this scenario is marked by a lack of policy to promote energy efficiency improvements or the development of low-emissions technologies. Nonetheless, the private sector continues to invest in R&D, leading to engineering advances for many energy technologies. The general economy continues its historical shift from manufacturing to services, leading to a 60% decline in overall energy intensity (based on the amount of energy needed to generate $1,000 of annual GDP).

Environmental impacts of energy supply and use. Improvements in the energy intensity of the economy notwithstanding, the overall effect of economic growth (and the increased use of fossil fuels) is to increase air pollutant emissions. Emissions of local air pollutants (including oxides of sulfur and nitrogen plus particulates) grow steadily with the rising demand for energy in general and for fossil fuels in particular. Fossil-fuel related emissions of CO_2 increase from about 1,550 million metric tons of carbon equivalent (MMTC) in 2000 to 2,470 MMTC in 2050. Despite the increasing burden of these anthropogenic emissions on the environment, the U.S. economy escapes with minimal negative impacts from global or local pollution.

Summary. *The Official Future* is an optimistic, surprise-free scenario, a world of "more of the same," with no major discontinuities or disruptive technologies. There are no significant resource shortfalls and no noticeable dislocations to derail the progress of economic growth. Prices remain steady, and adequate supplies of fuels are always available. Foreign countries seek innovative ways to cooperate with the United States in managing global markets, opening their domestic markets to U.S. companies, and helping the United States expand its influence in the world.

4.2 Cheap Energy Reigns Supreme

Cheap Energy Reigns Supreme is a more extreme version of the world foreseen in *The Official Future.* This is a scenario in which abundant and inexpensive supplies of oil and gas continue to fuel the engines of economic growth in America. American foreign policy is designed to provide continued access to low-cost supplies of oil and gas, placing great emphasis on stability in oil-producing regions. American consumers sustain their historical dependence on cheap fuels and disregard the occasional breakdown of energy supply and delivery systems. Environmental impacts of energy supply and use are considered to be the unavoidable consequences of economic growth.

Principal actors and driving forces. Similar to the world of *The Official Future*, the principal actors in this scenario are federal policy-makers, business-leaders in energy companies, and foreign government officials. U.S. consumers also play a leading role.

Table 2 illustrates key parameters describing the *Cheap Energy Reigns Supreme* basecase.

Table 2
Cheap Energy Reigns Supreme
Scenario Summary

	2000	2010	2020	2050
Primary Energy Demand (in Quads)	100	116	129	165
Gross Domestic Product (GDP in Trillions of 2000US$)	$9.9	$13.7	$19.7	$39.8
World Oil Price ($ per barrel)	$27.72	$23.20	$23.50	$22.90
Avg Wellhead Natural Gas Price ($ per thousand cubic feet)	$2.76	$2.68	$2.69	$6.13
Light Duty Vehicle Miles Traveled (Billions of Miles per year)	2,400	3,310	3,840	5,440
Average Fossil Fuel Heat Rate (BTUs per Kilowatt-hour)	10,730	9,657	8,680	6,890

Cheap Energy Reigns shares certain driving forces with *The Official Future:* rising demand for oil, increasing use of natural gas, and expanding electrification. In addition, consumer values are a significant force in this scenario. The continuing confidence of the American consumer in his or her "right" to cheap energy drives the nation's energy-intensive lifestyle. U.S. consumers see no significant connections among their individual choices about vehicles, their driving habits, and any important environmental or security consequences.

The key uncertainties shaping the future in *Cheap Energy Reigns Supreme* are:

- The willingness of OPEC producers to lower their share of the "take" on oil resources shipped to the United States and other oil-importing countries;
- The quantity, quality, and cost of unconventional oil and gas resources (including supplies from the Arctic Plains, Outer Continental Shelf, Canadian tar sands, unmineable coal seams, and tight formations);
- The capability of the U.S. energy infrastructure to deliver increased energy flows reliably to end-users; and
- The willingness of U.S. energy companies to invest in the pipelines, transmission systems, ports, and other facilities needed to deliver oil and gas supplies to the Lower 48 states.

Fluid fuels and light duty vehicles. As this scenario unfolds, OPEC leaders determine that their interests align closely with those of the United States and other industrialized, oil-importing countries. Thus, they seek to maximize output while keeping prices low enough to promote sustained economic growth in these countries. Confident of continuing increases in world oil demand, OPEC manages the world oil market in order to discourage R&D on new or alternative technologies that could lower future oil demand and, in so doing to delay the commercialization of potentially competitive technologies.

United States imports of petroleum and petroleum products grow even more rapidly in this scenario than they do in *The Official Future*, driven primarily by low prices. Oil prices fall by about 15 percent at the beginning of the scenario to $23 per barrel. They remain at this depressed level (in constant dollar terms) until 2050. Total imports of petroleum and petroleum products reach almost 50 Quads in 2050, compared to 24 Quads in 2000.

In *Cheap Energy Reigns Supreme*, advances in new drilling and extraction technology open up vast new resources of natural gas in North America and along its outer continental shelf. Successful R&D programs by U.S. and other international oil companies make it possible to drill safely in the Arctic Plains of Alaska, to extract gas from previously inaccessible "tight" formations, and to drill economically in offshore waters that are as much as 5,000 feet deep. These rapid successes allow the United States to meet an ever-growing share of energy demand with inexpensive continental gas supplies.

Still more dramatic changes occur in the natural gas market. All major uncertainties concerning gas supplies are resolved positively and at low cost by the end of this scenario. Gas demand triples in *Cheap Energy Reigns Supreme,* rising from 23 Quads in 2000 to 70 Quads in 2050. Two-third of the increase is achieved through expansion of domestic production, with rapid advances in exploration and production technology allowing U.S. energy companies to open up unconventional resources in tight formations, off-shore fields, unmineable coal seams, and the Arctic basins. Substantial private investments in new pipeline and distribution infrastructure, begun in the 1990s and continued throughout this scenario, allow these new resources to be delivered to end-users in the Lower 48.

Engineering success in exploration and production technology combines with the availability of significant new supplies to lower gas prices by 10 percent from 2000 to 2005 and stay below $3 per million BTU (MMBTU) until nearly 2035. From 2035 to 2050, gas prices rise steadily in *Cheap Energy Reigns Supreme,* reaching twice their year 2000 level in 2045 and continuing to increase to $6.13 per MMBTU in 2050.

There are no policy-based incentives to improve vehicle efficiency in *Cheap Energy Reigns Supreme.* Absent such incentives, overall on-road efficiency of new light-duty vehicles (LDVs) increases by less than 10 percent in 50 years and nearly 95 percent of the new LDVs purchased in 2050 are still conventional, gasoline- and diesel-powered vehicles.

With cheap fossil fuels available in seemingly unlimited quantity, middle class Americans continue to move away from the cities and into ever-larger suburban "MacMansions." They equip these homes with all manner of electrical gadgets and appliances, increasing demand for heat, cooling, and electricity. Commuting distances increase steadily during this scenario.

Energy and the Economy. With seemingly unlimited supplies of cheap oil and gas readily and steadily available, U.S. total primary energy demand grows at an average rate of about one percent per year in *Cheap Energy Reigns Supreme,* reaching nearly 165 Quads per year in 2050. Fueled by cheap energy, the U.S. economy grows at an annual average rate of approximately 2.8 percent during the same period. At this rate, the U.S. economy expands by a factor of four, from about $10 trillion in 2000 to nearly $40 trillion in 2050.

As in *The Official Future,* there are no major conflicts or disturbances in this scenario. The U.S. government is able to preserve a stable and secure international environment for economic growth. World peace promotes cooperation in all international markets. Competition among suppliers of basic commodities works to keep prices down, while industrialized countries negotiate trade agreements to keep prices high for manufactured goods. Slow growth in developing countries provides a seemingly unlimited pool of low cost labor for the United States (and for other industrialized countries) while tight controls on immigration allow industrialized country governments to ensure that they control the composition of their new labor force and keep down wages for foreign labor.

The availability of cheap fuels notwithstanding, the U.S. general economy continues its historic shift from manufacturing to services. Knowledge-intensive industries displace energy-intensive manufacturing, causing energy use in industry to grow less rapidly than demand in either the residential or commercial sector.

Total expenditures for fuel and electricity increase at an average rate of 1.5 percent per year in *Cheap Energy Reigns Supreme,* reaching $1.5 trillion in 2050. The largest portions of expenditures arise in the residential and commercial sectors, which depend heavily on increased use of natural gas and electricity. In this scenario, energy-related investment more than doubles by 2050. Most of the new investment underwrites purchases of new vehicles.

In this world of cheap energy and domestic tranquility, the federal government makes no effort to promote energy efficiency or low-emissions technologies. Nonetheless, the private sector invests significantly in efficiency improvements as part of a generalized campaign to improve profitability in the industrial and commercial sectors. Economy-wide, approximately $540 billion — or 40 percent of aggregate, energy-related investment — is devoted to purchases of efficient equipment in 2050.

Environmental impacts of energy supply and use. With increasing use of all types of fossil fuels, it is not surprising that air pollutant emissions increase in *Cheap Energy Reigns Supreme.* Emissions of particulates, oxides of nitrogen, and oxides of sulfur increase by hundreds of millions of tons per year. Carbon dioxide emissions from fossil fuel combustion grow from 1,560 MMTC in 2000 to almost 2,600 MMTC in 2050. Unambiguous signs of global warming emerge in many regions with significant increases in the frequency and severity of extreme weather events. Despite the accretion of scientific evidence and the observation of repeated episodes of severe weather events, federal policy continues to affirm that the risks of global warming remain uncertain and that the United States is not liable for the atmospheric buildup of CO_2. From a policy perspective, the federal government continues to ignore energy efficiency and low-emissions technologies.

Summary. In sum, *Cheap Energy Reigns Supreme* is a scenario characterized by inexpensive and seemingly limitless supplies of oil and gas. This surprise-free scenario exposes the United States to no major discontinuities or disruptive technologies. Oil prices initially fall, then gradually rise and remain stable for most of the scenario period, as OPEC manages the world oil market to ensure cheap fuels for its American patrons. Living comfortably under *Pax Americana*, foreign governments cooperate with the United States in managing most global markets, eagerly opening their domestic markets to U.S. companies, and seeking favorable trade treatment from the world's one remaining superpower

4.3 Big Problems Ahead

Big Problems Ahead is a chaotic, event-driven scenario. Domestic policy is disjointed and episodic, buffeted by forces beyond U.S. shores. Similar to *Cheap Energy Reigns Supreme*, principal actors in this scenario include U.S. policy-makers and U.S. business leaders as well as leaders of foreign governments. But in addition, sub-national groups also play a role in this scenario.

Principal actors and driving forces. In contrast to *Cheap Energy Reigns Supreme*, foreign governments and terrorist groups do not support U.S. policy goals or cooperate with U.S. leaders in *Big Problems Ahead*. They envision their interests strongly in conflict with the U.S. regime and see U.S. policies as designed to promote the imperial ambitions of the United States. They have no interest in preserving a tranquil environment to support U.S. economic growth. As a consequence of these conflicting visions, many foreign actors take steps to limit U.S. access to resources and to disrupt international trade in energy resources.

Early in this scenario, a rising tide of Islamic fundamentalism leads to the overthrow of the monarchy in Saudi Arabia and to the subsequent fall of feudal regimes in several other Persian Gulf states. The inward-looking regimes that follow the ouster of the old leadership are mainly concerned with re-establishing religious orthodoxy in national life; they are not particularly interested in promoting international trade in oil.

Chronic instability among these Gulf regimes leads to a roller-coaster ride of rapid oil price surges, stressing the U.S. energy sector. Intermittent cutoffs of oil supply from the Gulf cause discontinuities in the path of economic development for both industrialized and developing countries.

Table 3 illustrates key parameters describing the *Big Problems Ahead* basecase.

Table 3
Big Problems Ahead
Scenario Summary

	2000	2010	2020	2050
Primary Energy Demand (in Quads)	100	111	113	124
Gross Domestic Product (GDP in Trillions of 2000US$)	$9.9	$12.4	$16.1	$32.3
World Oil Price ($ per barrel)	$27.72	$58.60	$46.60	$40.50
Avg Wellhead Natural Gas Price ($ per thousand cubic feet)	$2.76	$4.04	$3.46	$6.25
Light Duty Vehicle Miles Traveled (Billions of Miles per year)	2,400	3,260	3,500	3,740
Average Fossil Fuel Heat Rate (BTUs per Kilowatt-hour)	10,730	9,970	9,580	7,570

American citizens and political leaders feel besieged by both confrontational leaders in other countries and by instabilities in the global economy. For many, concerns focus on issues of energy security – including both the security of U.S. energy facilities and the risks of oil import dependence.

Energy security concerns drive energy policy. To protect U.S. interests in Middle Eastern oil, the U.S. government intervenes to liberate several of the states bordering the Persian Gulf and stations large permanent garrisons in Saudi Arabia, Iraq, Kuwait, and Iran. The former British naval base at Diego Garcia becomes an American protectorate, a major air force base, and a regional headquarters for the Navy's Sixth Fleet.

In a further effort to limit U.S. vulnerability to oil supply disruptions in the Persian Gulf, U.S. and international energy companies work aggressively to find new oil and gas resources in frontier areas of North America and in countries outside the Gulf. Unfortunately, most of these efforts turn up "dry holes." Exploration and production from promising finds in the Caspian Sea basin, South America, and parts of southern Africa are severely hampered by chronic civil strife and political corruption. In Alaska, after oil spills following major pipeline ruptures on the North Slope kill off large numbers of the native caribou, salmon, and polar bears, the political backlash causes the U.S. Congress to close the Arctic National Wildlife Refuge to any further development.

Efforts to develop new energy resources in the Lower 48 also encounter unexpected shocks. For example, the federal government's attempt to reinvigorate the 1980's era synfuels program fails. The program, which was designed to turn vast amounts of Wyoming shale into liquid fuel for vehicles, founders due to poor planning, poor judgment, and subsequent ecological disaster. Faced with higher than expected costs for acquiring process water, the Synfuels Corporation seeks to economize on waste disposal costs, dumping thousands of tons of toxic waste into pits, and allowing organic toxins to leach into local groundwater. Toxic runoff turns up in local wells, poisoning children and senior citizens. Political backlash causes the Department of Energy to close down the Synfuels Corporation.

Reeling in another direction, the federal government decides to expand a small "Freedom Fuel" research effort into a national "crash" program to advance the technology of hydrogen production and use. This multi-billion dollar effort – one of the few successful federal energy initiatives — funds R&D on producing hydrogen from coal and accelerates commercialization of new fuel-cell technologies by U.S. companies.

In general, a sense of frustration and malaise characterizes *Big Problems Ahead*. Anxiety about the future discourages investment in new technology. Most startup companies fail and most new "miracle" technologies deliver far less than was originally claimed by their proponents. Private R&D investments prove insufficient to overcome the difficulties inherent in efforts to commercialize new technologies. New technologies falter due to unexpected engineering challenges. Environmental impacts of the new systems generate significant public resistance to their widespread use. Institutional failures in managing the commercialization process ensure a lack of success for the new technology in the marketplace.

Fluid fuels and light duty vehicles. U.S. oil imports continue to grow, increasing more than 100 percent from 2000 to 2050, and putting severe pressure on other oil-importing countries. A worldwide economic slowdown reduces world oil demand, allowing oil prices to remain largely flat in constant dollar terms over the scenario period. The market share of imports in U.S. oil consumption increases in this scenario from about 55 percent in 2000 to 73 percent in 2050. To reduce the pressure on oil imports, federal policy promotes the introduction of fuel cell vehicles after 2020. By 2050, fuel cell vehicles capture almost two-thirds of new light-duty vehicle sales.

Both natural gas demand and wellhead gas prices double during the scenario period. Imports of natural gas increase from about 7 percent to 25 percent of total demand.

Energy and the economy. The financial sector is also buffeted by shocks. Several major U.S. commercial banks are closed by the Comptroller of the Currency midway through the scenario because of the proportion of bad loans held in their portfolio. Investigation of the bad loans creates a ripple effect through the U.S. financial services sector. A collection of hedge funds, venture capital funds, and real estate investment trusts close up shop to avoid prosecution. Liquidity drains from the economy and the new housing market collapses in 2020. Americans begin to retrench, avoid unnecessary travel, and reduce their purchases of consumer goods.

In this environment, the federal government abandons any pretense of a cohesive national energy strategy, and retreats into crisis management. The volume of both public and private investment in R&D declines steadily and the prospect of deflation looms over the economy. Despite these unsettling tendencies, the momentum of the U.S. economy causes it to continue growing, albeit in a somewhat stuttering fashion.

The incessant string of severe stresses and periodic shocks slows the rate of economic growth in *Big Problems Ahead.* GDP grows at an average rate of 2.4 percent per year, from about $10 trillion in 2000 to $32 trillion in 2050. During the same period, energy demand increases at a rate of about 0.5 percent per year, from 100 Quads in 2000 to just 124 Quads in 2050.

Summary. *Big Problems Ahead* is a chaotic future beset with shocks, stresses, and discontinuities. Economic growth is slowed worldwide. U.S. energy policy is disjointed. Concerns about energy security keep everyone on edge. Rising U.S. oil imports increase U.S. dependence on unstable world regions. And U.S. responses to these challenges make it appear that the United States has become an arrogant and imperial player on the world stage, reducing the inclination toward international cooperation in many countries.

4.4 Technology Drives the Market

Technology Drives the Market is a scenario in which a variety of forces converge to reshape the market architecture of the U.S. energy sector.

Principal actors and driving forces. The promise of commercial and environmental benefits from new technologies motivates state officials to reform regulatory policy and eliminate barriers that hinder commercialization of new technologies. Implementation of institutional and regulatory reform sets the new and improved technologies on a level playing field alongside mature technologies in U.S. energy markets, allowing incumbent companies in these markets to embrace the new technologies. Engineering advances in the design and development of efficient, low-emissions technologies capture the imagination of business leaders, state officials, and individual consumers. Private investment by U.S. energy companies combines with rapid technical progress and value shifts by U.S. consumers to drive the new technologies to rapid market acceptance and widespread commercial applications.

Table 4 illustrates key parameters in *Technology Drives the Market* basecase.

Table 4
Technology Drives the Market
Scenario Summary

	2000	2010	2020	2050
Primary Energy Demand (in Quads)	100	112	113	128
Gross Domestic Product (GDP in Trillions of 2000US$)	$9.9	$13.7	$19.7	$39.8
World Oil Price ($ per barrel)	$27.72	$22.90	$22.50	$21.30
Avg Wellhead Natural Gas Price ($ per thousand cubic feet)	$2.76	$2.64	$2.65	$4.82
Light Duty Vehicle Miles Traveled (Billions of Miles per year)	2,400	3,270	3,560	3,990
Average Fossil Fuel Heat Rate (BTUs per Kilowatt-hour)	10,730	9,930	9,460	7,550

In *Technology Drives the Market*, state regulators overcome historical tendencies and work together. Early in this scenario, state leaders establish an integrated set of tariff policies for energy efficiency systems, renewable energy technologies, and distributed electricity generation schemes. State governments work together to implement standardized equipment requirements for connecting the new technologies to local utility grids. Net metering programs, currently implemented in more than a dozen states, spread across the country and facilitate arrangements in which on-site generators sell electricity back to the grid through simplified accounting transactions. Improved techniques for real-time load-flow analysis facilitate time shifting of local loads and the introduction of regional sub-networks of micro-grids. These local micro-grids lower the stress on aging transmission systems and increase the reliability of utility generating networks. Strict environmental permitting standards are applied to both new and traditional technologies, limiting the energy sector's impact on the regional and global environments.

Energy supply and demand. Engineering advances play a key role in this scenario, improving the technical performance and reducing the effective costs of a diverse array of small, distributed energy-producing technologies. The following technologies achieve commercial success:

- Building-integrated photovoltaic power systems;
- Medium to large wind machines (i.e., machines with rated capacity of 5 kW to 5 MW);
- Small methane-reforming appliances (located at local fueling stations that produce hydrogen for fuel cells from natural gas);
- Fuel cells for mobile and stationary applications; and
- Biomass energy systems to produce both heat and electricity.

In particular, the introduction of "smart building" technology improves the efficiency of energy end-use in the residential and commercial sector. These systems also alter building load profiles, lowering peak demands and reducing stress on the electric transmission system. In addition, advances in control system technology give consumers real-time information about their discretionary electric loads and the actual cost of performing certain tasks at particular times of the day, such as running dishwashers, washing machines, and clothes dryers. Additional control system technology breakthroughs broaden the usefulness of small, distributed micro-grids, assisting utilities in efficiently managing the flow of electricity within a neighborhood by making optimal use of both local and remote generating resources.

In *Technology Drives the Market,* one of the implications of changing consumer values is a shift in the trends of housing patterns. Instead of moving farther and farther out from urban core centers and commuting longer distances each day to work, middle class and working class households in *Technology Drives the Market* look for "in-fill" housing, limiting urban sprawl and co-locating homes with worksites in their communities. In addition, the growing trend toward telecommuting also helps to reduce the need for a daily commute to work.

Fluid fuels and light duty vehicles. In the transportation sector, the most dramatic improvements emerge in the light-duty vehicle arena. Shifting consumer values place increasing importance on reducing the environmental footprint of each consumer, making hybrid gasoline-electric or diesel-electric cars appear much more "cool" to the average consumer than would a large, heavy inefficient sport-utility vehicle. As this scenario progresses, the growing success of methane-reforming appliances coupled with the increasing reliability and durability of fuel cells in mobile applications leads to a growing market share for efficient, low-emissions vehicles.

The on-road fleet efficiency of new light-duty vehicles improves dramatically in *Technology Drives the Market*, increasing from around 20 mpg in 2000 to nearly 43 mpg in 2050. Partly this is due to an improvement in conventional car and truck efficiency.

But the biggest contribution results from the introduction of high efficiency vehicles into the new light-duty vehicle fleet. Whereas more than 99 percent of the new light-duty vehicles (LDVs) sold in the United States in 2000 employed conventional internal combustion engines, by 2050 combined sales of advanced diesels, hybrid vehicles, and fuel cell vehicles represent more than 70 percent of the all new LDVs sold in *Technology Drives the Market*.

As consumer purchasing preferences shift to small and efficient vehicles, oil demand in the U.S. transportation sector plummets while personal mobility is maintained. The new hybrid vehicles use much less gasoline (or diesel) for the same amount of driving, while the new fuel cell vehicles derive their power from domestic natural gas. This has significant positive implications for energy security as the demand for imported fuel begins to decline steadily.

Energy and the economy. Imports of petroleum and petroleum products actually decline by almost 15 percent in *Technology Drives the Market*, from 24 Quads in 2000 to just 21 Quads in 2050. Imports of natural gas increase over the same period, but less than in any other scenario, reaching only 12 Quads in 2050. Economy-wide expenditures on fuel and electricity increase by 50 percent in *Technology Drives the Market*, rising from $700 billion in 2000 to about $1.1 trillion in 2050.

Driven by massive public and private investment in new technologies, the U.S. economy grows more rapidly in *Technology Drives the Market* than in *Big Problems Ahead,* where continuing uncertainty depresses investment. Similar to *Cheap Energy Reigns Supreme,* U.S. GDP in *Technology Drives the Market* increases from $10 trillion in 2000 to almost $40 trillion in 2050. However, the effect of investment in efficient technology combines with shifts in consumer values and behavior to slow the rate of growth in energy consumption in *Technology Drives the Market.* Thus, the energy intensity of the U.S. economy is much improved.

Summary. *Technology Drives the Market* is a scenario in which a variety of forces converge to bring a host of advanced, efficient, low-emissions technologies to commercial readiness. The introduction of these technologies is made possible by a sustained commitment to R&D among private investors and a dedicated effort on the part of state officials to lower the barriers to commercialization of new technologies. In addition, consumers recognize added value in technologies perceived to be clean, safe, reliable, and convenient. As a consequence, although the general economy grows rapidly and steadily in this scenario, primary energy use grows much more slowly than does the overall economy, reducing expenditures on energy.

5 Concerns about a Sudden Surprise Could Change the Game

Each of the four scenarios described above is one among many possible US energy futures. Though not inclusive of all possible outcomes, these four scenarios, taken together, represent much of the range of future possibilities. But more can be learned from these scenarios if a strategic challenge sufficient to motivate major change in the behavior of key actors is introduced. The response to this challenge can then be simulated and tracked in three additional scenarios (referred to in this study as "challenge and response" cases), allowing analysis of the impacts on the general economy and on key energy-related sectors.

Introducing a strategic challenge. The risk of abrupt climate change could plausibly represent one such challenge. Concerns about this low probability, high consequence event are not unreasonable in the face of recent scientific research. For the last several years, oceanographers and geophysicists have observed a change in the salinity of the North Atlantic Ocean and an associated slowing of the thermohaline circulation that is centered in an area west of the Norwegian Sea. These scientists warn that if the associated process called North Atlantic Deep Water (NADW) formation slows further or comes to a halt, human societies may face a period of abrupt climate change, with rapid cooling experienced in New England, the Mid-Atlantic region and Northwest Europe. They suggest that the continued buildup of greenhouse gases due to the combustion of fossil fuels increases the risk, not just of global warming, but also of the extreme regional cooling that would be associated with a shutdown of the thermohaline circulation in the North Atlantic. Many scientists believe that an abrupt climate change could occur during the next several decades and merits attention from policymakers.

- **A postulated response.** The basecase scenarios (*Cheap Energy Reigns Supreme, Big Problems Ahead,* and *Technology Drives the Market)* contain no explicit consideration of the risks of climate change or of controls on emissions of greenhouse gases. However, in the "challenge and response" cases, the potential for abrupt climate change is introduced as a major stressor or challenge. This study postulates that consideration of the possibility of abrupt climate change causes national policymakers to accelerate the implementation of substantial steps to slow the buildup of greenhouse gases.[28] In each of the challenge and response scenarios, U.S. policy-makers implement energy policies designed to:
    - Promote diversity in energy supply;
    - Decrease U.S. dependence on foreign oil;
    - Improve U.S. energy security;
    - Increase efficiency in all energy-intensive sectors of the economy through the introduction of conservation measures and advanced technologies;
    - Accelerate capital stock turnover particularly in the electricity and transportation sectors;
    - Sustain economic growth, and
    - Decrease CO_2 emissions resulting from energy supply and use.

Similar policies and measures are introduced in all three scenarios to achieve these targets, but are implemented with differing degrees of stringency in the three "challenge

[28] Baranzini, Chesney, and Morisset, 2003.

and response" cases.[29] The response of key actors to these initiatives depends upon the fundamental dynamics and underlying logic of each scenario as well as on the conditions that are present when the policies are introduced. Section 8.2 in the Appendix outlines the specific policies and measures implemented to achieve the targets.

The set of initiatives implemented to achieve the chosen targets in the three "challenge and response" cases were selected to address historic concerns about energy security and energy system reliability as well as to counter public concerns about the risk of abrupt climate change. These initiatives have the effect of reducing oil imports, accelerating the turnover of fully amortized capital stock, and encouraging the early commercialization of low-emissions technologies, especially in the electric power and transportation sectors – the largest consumers of energy and biggest sources of CO_2 in the U.S. economy. As in the base cases, the AMIGA model was used to quantify the impact of these policies on key energy-related sectors of the economy in each "challenge and response" case.

The following paragraphs lay out the challenge and response cases associated with the *Cheap Energy Reigns Supreme, Big Problems Ahead, and Technology Drives the Market* basecase scenarios. Again, detailed results are reported in section 8.3 of the Appendix.

5.1 Cheap Energy Reigns Supreme: Challenge and Response

Implementation of the postulated policies in the *Cheap Energy Reigns Supreme — Challenge and Response* case has immediate and lasting impacts. These impacts are felt most strongly in the electricity and transportation sectors, but percolate throughout the economy. Table 5 summarizes the key parameters describing this challenge and response case.

Table 5
Cheap Energy Reigns Supreme: Challenge and Response Case
Scenario Summary

	2000	2010	2020	2050
Primary Energy Demand (in Quads)	100	112	104	106
Gross Domestic Product (GDP in Trillions of 2000US$)	$9.9	$13.7	$19.5	$39.3
World Oil Price ($ per barrel)	$27.72	$23.00	$21.40	$15.13
Avg Wellhead Natural Gas Price ($ per thousand cubic feet)	$2.76	$2.80	$2.25	$2.42
Light Duty Vehicle Miles Traveled (Billions of Miles per year)	2,400	3,270	3,530	3,880
Average Fossil Fuel Heat Rate (BTUs per Kilowatt-hour)	10,730	9,720	8,680	7,900

[29] These emissions targets were imposed in three of the scenarios described above: *Cheap Energy Reigns Supreme, Technology Drives the Market,* and *Big Problems Ahead.* They were not applied to *The Official Future. The Official Future* is used solely as a benchmark or reference case in this study. None of these scenarios are intended to reflect likely outcomes; nor should the postulated response be seen as a recommended policy target. The scenario descriptions should be taken for their heuristic value only.

Electricity. Introduction of a CO_2 cap and trade system for large stationary sources shifts the fuel mix in the power sector away from coal, allowing natural gas, wind, and various forms of distributed generation to capture a larger share of demand. Over time, this cap-and-trade program stimulates significant additional investments in energy efficiency systems for the residential, commercial, and industrial sectors. One of the impacts of these investments in energy efficiency is to reduce the rate of growth in electricity demand. In *Cheap Energy Reigns Supreme: Challenge and Response,* total electricity demand in 2050 is approximately 6,250 terawatt-hours (TWh), compared to almost 8,200 TWh in 2050 for the *Cheap Energy Reigns Supreme* basecase and to the historical level of about 3,800 TWh in 2000. The cap-and-trade program shifts the application of capital in the power sector toward larger investment in non-combustion technologies, including geothermal energy, wind power, and other forms of renewable energy. It also encourages investment in high-efficiency gas turbines, cogeneration systems, and various forms of distributed generation. As a result, demand for coal-derived electricity falls by about 65 percent in 2050, relative to the year 2000 level, while the amount of electricity produced from natural gas triples. Electricity production from wind power increases seven-fold and geothermal electricity production expands by a factor of five.

Fluid fuels and light duty vehicles. The introduction of tradable efficiency standards for vehicles has dramatic effects on the composition of the U.S. light-duty vehicle fleet. In *Cheap Energy Reigns Supreme*, conventional light-duty vehicles capture more than 94 percent of new car sales during the scenario period. Hybrid gasoline- and diesel-electric vehicles achieve a small but significant market presence, the only type of advanced vehicles to do so. Nonetheless, their share of the new car market stays below the 5 percent level through 2050. By contrast, in *Cheap Energy Reigns Supreme: Challenge and Response,* the introduction of tradable energy efficiency standards encourages a boom in advanced vehicle sales, overwhelming the sales of new conventional LDVs after 2020. Hybrid vehicles capture more than half of the new LDV market by 2020, with advanced diesels and fuel cell vehicles capturing smaller but still significant shares of this market. By 2050, the hybrid vehicle market share has declined to less than 50 percent of the new car market, but still represents more than 9 million vehicles sold in that year. New fuel cell vehicles take a prominent place in the market, expanding from 15 percent of new LDV sales (about 2.8 million vehicles in 2020) to about 42 percent of LDV sales (more than 8 million new cars and light trucks) in 2050.

The shifting composition of the new car fleet raises the estimated on-road fleet efficiency of new U.S. LDVs from about 23 miles per gallon (mpg) in 2010 to nearly 64 mpg in 2050. This increased efficiency reduces U.S. demand for motor gasoline and diesel fuel in 2050 — from about 42 Quads in its basecase to just 12 Quads in the challenge and response case. This decline in oil demand causes a consequent reduction in energy expenditures for imported petroleum and petroleum products. In *Cheap Energy Reigns Supreme basecase,* U.S. consumers spend more than $225 billion on oil and petroleum product imports in 2050, compared to only $36 billion in the same year in the *Challenge and Response* case. Declining U.S. dependence on imported oil has important energy security benefits in *Cheap Energy Reigns Supreme – Challenge and Response,* reducing

U.S. vulnerability to price spikes or supply disruptions resulting from foreign political decisions.

Energy and the economy. The cost of achieving the selected policy goals is substantial in the *Cheap Energy Reigns Supreme: Challenge and Response*, mainly because low energy prices in the basecase have discouraged investments in energy efficiency and led to very high levels of energy-related emissions. Although the general economy grows steadily in the *Cheap Energy Reigns Supreme: Challenge and Response* case, by 2050 annual GDP is approximately $500 billion lower in the challenge and response case than in its basecase, but still substantially higher than GDP in *The Official Future.*

5.2 Big Problems Ahead: Challenge and Response

The pattern of impacts resulting from implementing the set of policies and measures in the *Big Problems Ahead* scenario is broadly similar to the pattern observed in the *Cheap Energy Reigns Supreme: Challenge and Response* case. In both cases, the biggest impacts of implementing policies to limit CO_2 emissions are observed in the electricity and transportation sectors. However, the magnitudes of these impacts are different in the two cases. The differences reflect the influence of the trajectories that the two scenarios were following when the set of policies and measures was imposed in 2010.

Table 6 illustrates some of the key parameters describing the *Big Problems Ahead: Challenge and Response* case.

Table 6
Big Problems Ahead: Challenge and Response
Scenario Summary

	2000	2010	2020	2050
Primary Energy Demand (in Quads)	100	109	97.6	106
Gross Domestic Product (GDP in Trillions of 2000US$)	$9.9	$12.4	$16.0	$32.0
World Oil Price ($ per barrel)	$27.72	$58.60	$45.90	$37.80
Avg Wellhead Natural Gas Price ($ per thousand cubic feet)	$2.76	$4.10	$3.49	$4.87
Light Duty Vehicle Miles Traveled (Billions of Miles per year)	2,400	3,260	3, 440	3,410
Average Fossil Fuel Heat Rate (BTUs per Kilowatt-hour)	10,730	9,947	9,180	9,230

Electricity. In *Big Problems Ahead: Challenge and Response,* the imposition of the emissions cap-and-trade program for large stationary sources leads to increased investment in energy efficiency systems and then to shifts in capital commitments for various electric generating technologies. Overall, energy-related investment in 2050 increases by about 4 percent in *Big Problems Ahead: Challenge and Response* compared to its basecase, reaching about $1.2 trillion in 2050, compared to the historical level of $600 billion in 2000. The largest increase, almost $100 billion in 2050, goes to the purchase of additional energy-efficient equipment for the residential, commercial, and industrial sectors. Approximately 40 percent of this investment is for industrial efficiency improvements, 30 percent for improvements in commercial energy efficiency, and 30 percent for efficiency improvements in the residential sector. Investments in energy-related infrastructure, by contrast, decline by 87 percent in *Big Problems Ahead — Challenge and Response,* falling to just $9.5 billion in 2050, compared to nearly $73 billion in 2050 for the basecase of *Big Problems Ahead*.

Fluid fuels and light duty vehicles. Federal policies designed to accelerate capital stock turnover and reduce emissions also have a big impact on the transportation sector in the *Big Problems Ahead: Challenge and Response case.* In 2005, conventional gasoline and diesel vehicles captured more than 98 percent of new car sales in its basecase, but by 2020, fuel-efficient vehicles (including advanced diesels, hybrid electrics, and fuel cell vehicles) represented more than 50 percent of new car sales. For comparison, from 2020 onward, sales of fuel-efficient vehicles drive conventional car and light truck sales virtually to zero in the *Big Problems Ahead: Challenge and Response* scenario. As purchases of fuel-efficient vehicles dominate sales of new light-duty vehicles, the average on-road fleet efficiency of LDVs in this scenario increases to almost 69 mpg in 2050, compared to 50 mpg in its basecase.

The introduction of all these fuel-efficient vehicles reduces demand for motor gasoline and diesel fuel in *Big Problems Ahead: Challenge and Response* to just 8.4 Quads in 2050, less than half the 17 Quads consumed in 2050 in its basecase. This reduction in transportation fuel demand has major consequences for the general economy, reducing oil imports and freeing up substantial funds for productive long-term investments. Total imports of oil and petroleum products are reduced to just $50 billion for in *Big Problems Ahead: Challenge and Response* scenario in 2050, i.e., to approximately one-third the level of expenditures for petroleum-related imports projected in its basecase for the same year.

Energy and the economy. Despite the savings on oil imports, implementation of the suite of emissions-reducing policies and measures still has a significant cost for the general economy. In *Big Problems Ahead: Challenge and Response,* aggregate GDP is approximately $250 billion lower in 2050 than is projected in its basecase. The cost of achieving the selected policy objectives is only about half as much in the *Big Problems Ahead* scenario as was the case in *Cheap Energy Reigns Supreme.* This is largely because the economy starts out on a lower trajectory of energy-related emissions in *Big Problems Ahead* basecase than is projected for *Cheap Energy Reigns Supreme* basecase.

5.3 Technology Drives the Market: Challenge and Response

Even though the *Technology Drives the Market* basecase scenario already includes substantial investment in energy efficiency and advanced, low-emissions technologies, the implementation of national emissions-control policies has additional significant impacts. As in the *Cheap Energy Reigns Supreme* and *Big Problems Ahead* scenarios, the transportation and electric power sectors experience the most significant impacts in the respective "challenge and response" cases.

Table 7 illustrates some of the key parameters describing the *Technology Drives the Market: Challenge and Response* case.

Table 7
Technology Drives the Market: Challenge and Response
Scenario Summary

	2000	2010	2020	2050
Primary Energy Demand (in Quads)	100	109	98.9	102
Gross Domestic Product (GDP in Trillions of 2000US$)	$9.9	$13.7	$19.7	$39.7
World Oil Price ($ per barrel)	$27.72	$22.70	$21.40	$18.40
Avg Wellhead Natural Gas Price ($ per thousand cubic feet)	$2.76	$2.81	$2.71	$3.19
Light Duty Vehicle Miles Traveled (Billions of Miles per year)	2,400	3,260	3,500	3,750
Average Fossil Fuel Heat Rate (BTUs per Kilowatt-hour)	10,730	9,685	8,341	8,550

Electricity. Federal energy policies implemented in *Technology Drives the Market: Challenge and Response* lower electricity demand and shift the fuel mix in the electric sector, compared to the basecase scenario. Aggregate electricity demand in 2050 (including cogeneration and distributed generation) is projected to be approximately 5,725 TWh in *Technology Drives the Market — Challenge and Response,* compared to 7,115 TWh in 2050 in its basecase, a decline in overall demand of about 20%.

Electricity supplied by conventional cogeneration facilities falls by about 3 percent, compared to its basecase. This decline (about 35 TWh) is more than compensated for by an increase of 20 TWh in output generated from fuel cell cogeneration units plus an increase of 130 TWh produced by building-integrated photovoltaic systems. Output from wind power plants increases by 50 percent in the *Challenge and Response case,* supply of electricity from geothermal plants increases by 10 percent, and power from biomass gasification by 15 percent, compared to its basecase. But the biggest change from the base case to the *Challenge and Response case* occurs in the coal sub-sector, which sees an 80 percent drop in coal-fired electricity production in 2050, compared to its basecase.

Fluid fuels and light duty vehicles. Implementation of the emissions cap-and-trade program in *Technology Drives the Market: Challenge and Response* results in both an overall reduction in energy-related investment and a shift in the composition of that investment. In 2050, annual energy-related investment in *Technology Drives the Market basecase* is approximately $1.4 trillion. In *Technology Drives the Market: Challenge and Response,* annual energy-related investment in 2050 is approximately $1.3 trillion, nearly 15% less. In the basecase of *Technology Drives the Market*, approximately 55 percent of energy-related investment is applied to vehicle purchases, and 38 percent is devoted to purchasing energy-efficiency improving equipment. By contrast, in *Technology Drives the Market: Challenge and Response,* the balance is reversed: 51 percent of the energy-related investment is committed to efficiency-improving equipment and 44 percent to buying new vehicles.

Because of early and sustained investments in efficient vehicles in its basecase, the impacts of federal policies on the LDV fleet are more complex in this challenge and response case than in either of the other two challenge and response cases. Conventional gasoline and diesel vehicles captured over 98 percent of the market for new LDVs in 2005 in *Technology Drives the Market* and, by 2050, the conventional share of new light-duty vehicles sales falls to about 29 percent of total LDV sales in this basecase. By contrast, in *Technology Drives the Market — Challenge and Response,* conventional vehicle sales fall to zero by 2020 and stay at this level for the remainder of the scenario. Hybrid gasoline- and diesel-electric vehicles move rapidly into the U.S. market during this scenario, reaching 41 percent of new LDV sales in 2020. However, sales of fuel-cell vehicles rapidly displace hybrids in this challenge and response case. The hybrid vehicle share falls steadily after 2020, sinking to less than 20 percent of annual LDV sales in 2050. Fuel cell vehicles pick up the slack, reaching 52 percent of annual LDV sales in 2020, and then climbing steadily to 70 percent of new LDV sales in 2050.

The commercialization of hybrid gas-electric and diesel-electric vehicles, along with the rapid introduction of fuel cell vehicles, has positive impacts in this scenario. Sales of motor gasoline and diesel fuel in 2050 are only about 9 Quads in *Technology Drives the Market: Challenge and Response,* compared to 20 Quads in its basecase. Largely as a consequence of this change, projected expenditures for imports of oil and petroleum products decline in 2050 from about $80 billion in the *Technology Drives the Market* basecase to approximately $26 billion in *Technology Drives the Market: Challenge and Response*. This projected decline in oil imports has beneficial implications for U.S. energy security, reducing U.S. vulnerability to price fluctuations and supply interruptions.

6 Implications and Conclusions: Lessons Learned

Several implications and conclusions can be drawn from a comparison of the basecase scenarios, the challenge and response scenarios, and the reference case.

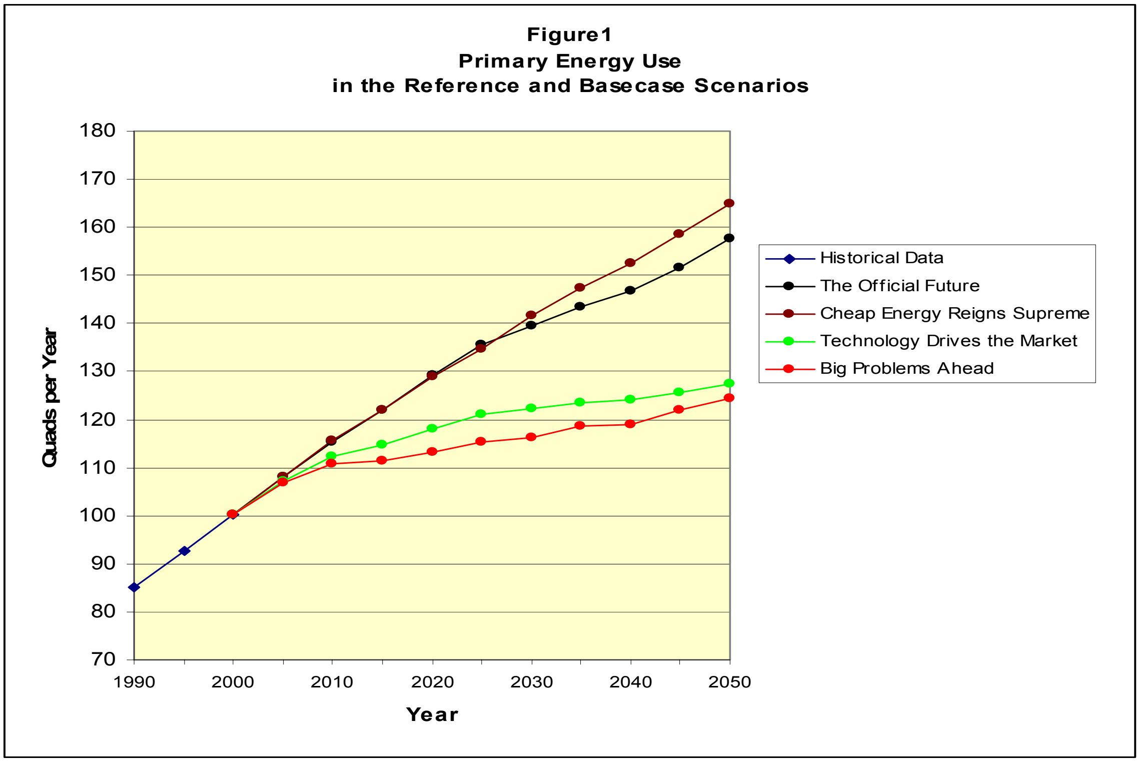
6.1 Scenario analysis can be an important tool for investigating U.S. energy futures

The pattern of future evolution for U.S. energy markets is highly uncertain at this time. Critical uncertainties include future rates of technological advance, levels of private investment in new technologies, strategies of foreign actors (especially oil suppliers), and directions of state and federal policy. A range of unexpected events or surprises may affect the ways that these uncertainties play out. Scenario analysis allows explicit consideration of these critical uncertainties and the dynamics of their interaction with the key driving forces affecting the evolution of U.S. energy markets. Quantification of the resulting scenarios allows direct comparison of the consequences that may arise as these scenarios unfold.

6.2 The range of feasible U.S. energy futures is broad, but energy use is expected to grow under all scenarios.

Interactions among the forces driving evolution of U.S. energy markets may lead to many different paths of technology development, market architecture, and consumer demand. Uncertainties persist concerning the interactions of these forces. Nonetheless, analysis of all three basecase scenarios, which span a broad range of possible paths, indicates that U.S. economic activity and energy demand will continue to increase in the period from 2000 to 2050 in the absence of specific energy policies to accelerate capital stock turnover and the commercialization of low-energy and low-emissions technologies.

If the U.S. economy grows as indicated in the basecase scenarios investigated in this study and no new energy policies are instituted, primary energy demand would be expected to increase by 25 to 65 percent in 2050, relative to the historical level in 2000. Primary energy demand increases less rapidly in the *Technology Drives the Market* and *Big Problems Ahead* scenarios. By contrast, energy demand grows fastest in *Cheap Energy Reigns Supreme* and the reference case, *The Official Future*. Figure 1 below illustrates the trajectory of primary energy use in the three basecase scenarios and in the reference case.



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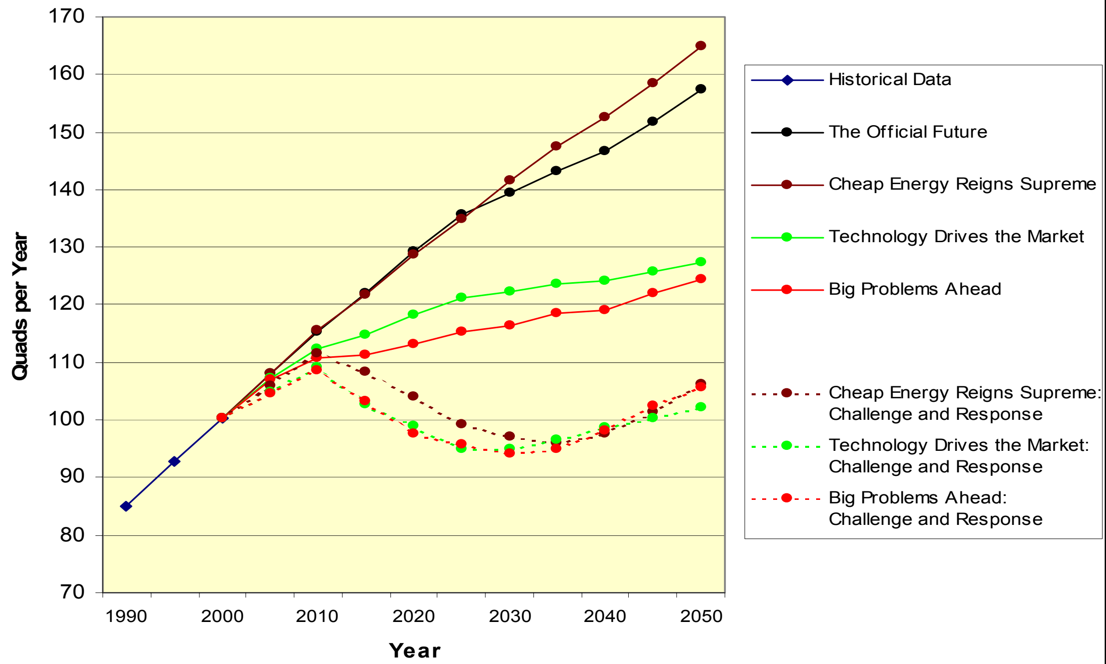
6.3 Introduction of policies to encourage capital stock turnover and accelerate the commercialization of high-efficiency, low-emissions technologies can significantly reduce future primary energy demand in the United States.

Policies accelerating introduction of more efficient technologies and demand-reducing measures applied in the three challenge and response scenarios slow growth in primary energy demand. By 2050, primary energy demand remains close to the year 2000 level in these cases. The corresponding increase in the three basecase scenarios and in *The Official Future* ranged from 25 to 65 percent. Figure 2 that follows illustrates the trajectories of primary energy use in the challenge and response cases, and compares them to the higher trajectories of energy growth in the basecase scenarios.

Figure 2
Primary Energy Use
in the Reference, Basecase, and Challenge Scenarios



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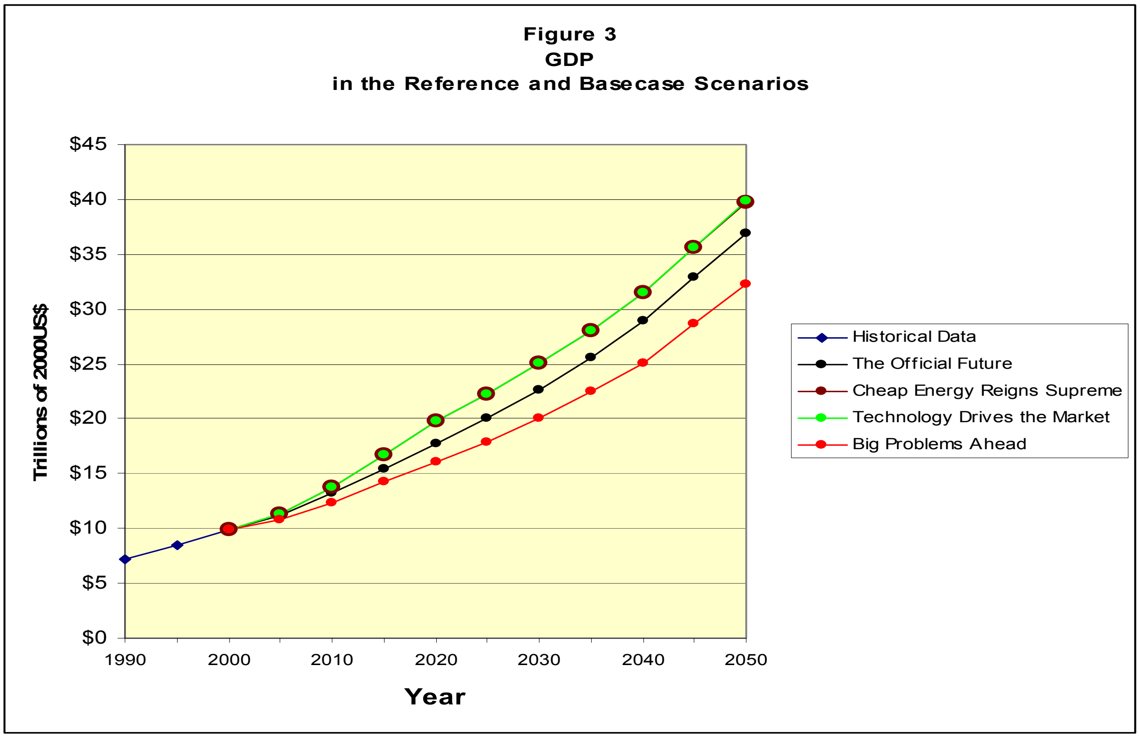
6.4 Low energy prices can lead to high economic growth. But so can a smart investment path emphasizing energy efficiency improvements and advanced technologies.

Each of the basecase scenarios investigated in this study involves continued and sustained economic growth — U.S. GDP grows at 2.4 – 2.8 percent per year from 2000 to 2050. Figure 3 illustrates that U.S. GDP in the basecase scenarios reaches approximately $32 – 40 trillion by 2050, compared to about $10 trillion in 2000. In both the *Cheap Energy Reigns Supreme* and *Technology Drives the Market* basecase scenarios, GDP growth is at the high end of the range for the entire scenario, reaching approximately $40 trillion in 2050. *The Official Future* attains just $37 trillion, and GDP grows the least in *Big Problems Ahead*, to $32 trillion. This demonstrates that in scenarios without substantial policy intervention, strong GDP growth can be sustained either by low energy prices or by continuing investment in advanced technology.



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6.5 Policies introduced to improve energy efficiency and accelerate the introduction of new technologies do not appreciably reduce the prospects for economic growth.

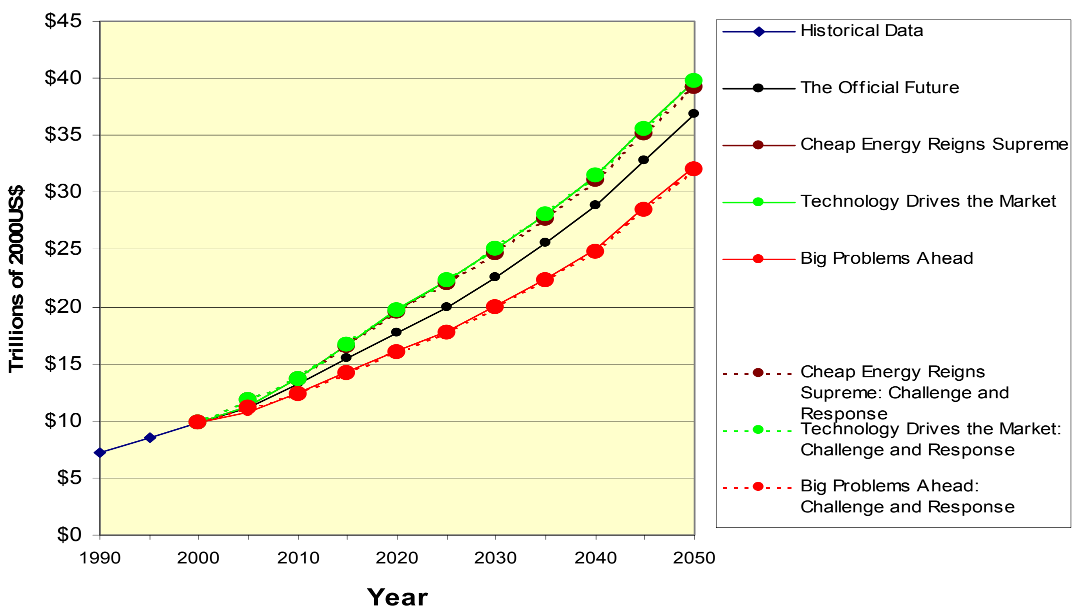
Surprisingly, despite the introduction of policies to promote capital stock turnover and to limit CO_2 emissions, GDP in the challenge and response cases reaches approximately the same level in 2050, as is achieved in the their respective basecase scenarios. The projected differences are only 0.3 to 1.3 percent after 50 years. (See Figure 4 below.)

Smart policy and investment choices made today will accelerate the turnover of fully amortized capital stock and can stimulate substantial economic growth. A balanced portfolio of market-oriented policies would likely include a combination of efficiency or performance standards for vehicles, appliances, and industrial equipment; a cap-and-trade program for large stationary sources; and a series of information initiatives and barrier-busting policies to level the playing field for commercialization of new technologies.

Early development of advanced low-emissions technologies and the widespread introduction of energy efficiency measures can significantly reduce the aggregate costs of fueling economic development, as do policies that reduce dependence on oil imports. Low fossil fuel prices discourage these investments in energy efficiency.

Investment that accelerates the commercialization of cost-effective energy-efficiency measures or advanced, emissions-reducing technologies can increase the flexibility of society to respond to the risks of future climate change. Investments made today in critical energy technologies are likely to remain robust across a diverse set of possible futures and strengthen the prospects for economic growth.

Figure 4
GDP
in the Reference, Basecase, and Challenge Scenarios



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6.6 Public and private choices, along with external events, affect the cost of responding to future surprises

One thing is certain: The United States will face surprises in the future, just as it has in our past. Some of those surprises may be unfortunate or even catastrophic. One such "game-changing" surprise is represented by the risk of abrupt climate change. Another such surprise might result from a complete cutoff of Middle East oil exports to the OECD perhaps precipitated by a series of successful Islamic revolutions in the region.

Low fossil fuel prices will discourage investments in energy efficiency and can make the task of responding to future surprises both harder and more expensive. Should a major, disruptive surprise occur, large investments in adaptive responses and a rapid transition to new energy technologies could very well become necessary. Such a rapid transition would be both more expensive and more disruptive if steps are not taken soon to decrease

U.S. oil import dependence and to invest in advanced energy technologies and energy efficiency measures. Expenditures made early can reduce the costs of responding to unexpected problems in the future.

7 References

Abt, C., 2002. "The Future of Energy from the Perspective of the Social Sciences," in Richard N. Cooper and Richard Layard, editors, *What the Future Holds: Insights from Social Science*, The MIT Press, Cambridge, MA.

Agence France Presse, 2003. "*Bill to U.S. Economy for Power Outages Seen in the Billions,"* Available online at www.yahoo.com, (August 15, 2003).

Baranzini, A., M. Chesney, and J. Morisset, 2003. "The impact of possible climate catastrophes on global warming policy," in *Energy Policy,* Elsevier Science Ltd, Utrecht, the Netherlands, volume 31, pp. 691-701.

BP, 2001. *BP Statistical Review of U.S. Energy, 2001*. Available online at www.bp.com/centres/energy2002/ or in paper from Morgan Guaranty Trust Company of New York, P.O. Box 8420006, Boston, MA 02284-2006.

Cooper, Richard N. and Richard Layard, 2002."Introduction," in Richard N. Cooper and Richard Layard, editors, *What the Future Holds: Insights from Social Science*, The MIT Press, Cambridge, MA.

Fahey. L., and Robert M. Randall, 1998. *"Learning from the Future: Competitive Foresight Scenarios,"* John Wiley and Sons, New York, NY.

Hanson, D. 1999. *A Framework for Economic Impact Analysis and Industry Growth Assessment: Description of the AMIGA System.* Policy and Economic Analysis Group, Decision and Information Sciences Division, Argonne National Laboratory, Argonne, IL.

Hanson, D. and J. Laitner, 2003. "An Integrated Analysis of Policies That Increase Investments in Advanced Energy-Efficient/Low-Carbon Technologies," *Energy Economics (forthcoming)*.

Hoffert, Martin I., et al., 2002. "Advanced Technology Paths to Global Climate Stability: Energy for a Greenhouse Planet, *Science*, Vol. 298, 1 November 2002, pp. 981-987.

Merrill Lynch, 2003. "Implications of the Northeast Blackout," askmerrill.ml.com/res_article1,2271,18645,00.html

Metz, Bert, et al., editors, Climate Change 2001: Mitigation: Contribution of Working Group III to the third assessment report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge UK, 2001.

Mintzer, I., J.A. Leonard, and P. Schwartz, 2003. *U.S. Energy Scenarios for the 21st Century*, Pew Center on Global Climate Change, Arlington, VA.

Porter, M., 1985. *Competitive Advantage*. Free Press, New York, NY.

Ringland, G., 1998. *Scenario Planning: Managing for the Future.* John Wiley and Sons, Chichester, UK.

Schwartz, Peter, 1991. *The Art of the Long View: Planning for the Future in an Uncertain World*, Doubleday Currency, New York, NY.

Schwartz, Peter, 2003. *Inevitable Surprises.* Doubleday Books, New York, NY.

Schwartz, Peter, 2002. "The River and that Billiard Ball: History, Innovation, and the Future," in Richard N. Cooper and Richard Layard, editors, *What the Future Holds: Insights from Social Science*, The MIT Press, Cambridge, MA.

Strategic Energy Policy Challenges for the 21st Century, 2001. Report of an Independent Taskforce sponsored by the James A. Baker III Institute for Public Policy of Rice University and the Council on Foreign Relations, Council on Foreign Relations, New York, NY.

UNFCCC, 1992. *The United Nations Framework Convention on Climate Change.* United Nations, New York, NY. (The Framework Convention was ratified in the U.S. Senate by a vote of 99-0 in 1994 and entered legally into force in 1995.)

U.S. DoC, 2003. *Details of Fixed Asset Investment in Non-residential Sectors.* Bureau of Economic Analysis, U.S. Department of Commerce, Washington, DC. Available at: www.bea.doc.gov/bea/dn/faweb/Details/xls/detailnonres_inv1.xls

U.S. Department of Energy, 1991a. *National Energy Strategy: Powerful Ideas for America.* First Edition 1991/1992. Washington, DC.

U.S. Department of Energy, 1991b. *National Energy Strategy: Technical Annex 2.* First Edition 1991/1992. Washington, DC.

U.S. DoE, 2001. *State Energy Price and Expenditure Report, 1999.* Energy Information Administration, Washington, DC.

U.S. DoE, 2002a. *International Energy Annual, 2000.* Table 8.1. Energy Information Administration, Washington, DC.

U.S. DoE, 2002b. *Annual Energy Outlook, 2002.* Report DOE/EIA-0383(2002), Energy Information Administration, Washington, DC.

U.S. DoE, 2003a. *Annual Energy Outlook, 2003.* Energy Information Administration, Washington, DC.

U.S. DoE, 2003b. *International Energy Outlook, 2003.* Energy Information Administration, Washington, DC.

U.S.EPA, 2003. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2001.* Report no. EPA 430R03004.U.S. Environmental Protection Agency, Washington, DC.

Wack, P. 1985a. "Scenarios: Uncharted Waters Ahead," *Harvard Business Review,* September-October, 1985.

Wack, P. 1985b. "Scenarios: Shooting the Rapids," *Harvard Business Review,* November-December, 1985.

Wirth, Timothy E., C. Boyden Gray,and John D. Podesta, 2003. "The Future of Energy Policy," Foreign Affairs, Vol. 82, No. 4, July/August 2003, pp. 132-155.

Wylie, I., 2002. "There Is No Alternative To. . ." Fast Company, July 2002, pp. 106-10.

Wonacott, P., 2003. "China's Weight on Oil Markets Grows as It Gobbles Up Crude," *Wall Street Journal,* New York, NY, August 21, 2003.

8 Appendix – Quantifying the Scenarios with the AMIGA Model

8.1 Background on the AMIGA Model

The **AMIGA** model, the **A**ll-**M**odular **I**ndustry **G**rowth **A**ssessment Modeling System developed by the U.S. Department of Energy's Argonne National Laboratory, is a multi-sector general equilibrium model of both the U.S. and the world economy.[30] AMIGA captures the interactions of 200 sectors of the U.S. economy, including a detailed technology representation of the building, industry, transportation, and electricity sectors of the U.S. economy. The structural representation of the model includes a database representing the installed capital stock in the transportation, electricity, and buildings sectors. The core of the model is a series of behavioral equations that affect the acquisition, deployment, and retirement of energy-using capital stock in each sector that allows the model to estimate the demand for energy services both by individual sector and for the economy as a whole.

The AMIGA model describes the competitive behavior of U.S. energy markets. This includes the assessment of capital and operating costs of existing power plants and other capital stock. The model also captures and evaluates the cost of policies including research and development, carbon cap and trade programs, efficiency standards, and a range of voluntary, information, and technical assistance programs. Finally, the model includes data on the cost characteristics and performance of specific facilities or typical technologies to simulate the supply of primary energy and electricity. The model iterates between estimates of energy demand and energy supply in each year to produce an internally consistent set of market-clearing prices. Iterations continue until the energy markets are in equilibrium — that is, when supply equals demand for any given year. At this point, the model calculates various indicators of economic performance, including personal consumption, private investment, net imports, and government spending which it then aggregates into Gross Domestic Product (GDP). In addition, the model calculates primary energy demand by sector and fuel, electricity production by fuel and technology, and new vehicle purchases in each market segment. Finally, AMIGA also estimates the economy-wide greenhouse gas emissions — including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and the so-called fluorinated gases — and electricity sector emissions of sulfur dioxide (SO_2), oxides of nitrogen (NO_x), and mercury (Hg).[31]

For both the reference case and each of the three base case scenarios, key parameters such as the rate of growth in economic activity, technology cost and performance, and fuel supply and demand curves were specified at levels consistent with the story logic that underpinned each of the scenarios. The "challenge and response" cases imposed a

[30] As this report goes to print, AMIGA now covers the U.S., other Developed Counties, the former Soviet Union and the Eastern European economies, and the rest of the world. Plans are now in place to expand this coverage to 15 world regions, including the United States. For more detailed information on the AMIGA modeling system, please visit the website http://amiga.dis.anl.gov.

[31] Plans also include expanding the coverage of criteria pollutants to the entire economy. At this time, however, the air emissions are limited to the electricity sector.

portfolio of policies (described below) on each of the three base case scenarios. In each of the base case and its "challenge and response" scenario, the transportation and electricity sectors were given special attention because of the size of their contributions to U.S. carbon emissions. For example, the analysis included a special effort to test the potential for reducing emissions from cars and light trucks. Toward that purpose, the AMIGA model tracked the capital stock of light-duty vehicles (separately from heavy trucks and buses). It allowed that capital stock to accumulate new vehicles through the purchase and retirement of such vehicles on a year-by-year basis. In the electricity sector, AMIGA simulated the annual retirements of existing U.S. power plants, based on a complete vintaged database. As plants retired, and new electricity demand emerged, the model selected the least-cost expansion plan from among more than two dozen types of new generation technologies, including advanced fossil fuel technologies, renewable energy technologies, advanced nuclear power plants, natural gas-fired turbines, integrated gasification and combined cycle turbines, and combined heat and power plants.

For the purposes of this analysis, the AMIGA model was modified to evaluate the effects of a carbon cap and emission allowance trading system on the capital stock of electric power plants in the United States. Additional analytic modules were added to evaluate the impact of targeted federal spending programs as well as to simulate the effects of energy efficiency initiatives within the residential, commercial, and industrial sectors.

The reference case was calibrated to the Energy Information Administration's *Annual Energy Outlook 2002* reference case. This calibration process centers primarily on the adjustment of different inputs for each scenario according to the specific characteristics of that scenario. The first set of key inputs is fossil fuel prices. Oil prices and natural gas prices, for example, are specified throughout each time-period for the three base cases. In the challenge and response scenarios, however, both sets of prices were allowed to vary (up or down) in response to the assorted economic drivers within each policy case. The second input category are the initial capital costs of major energy-using capital including electricity plant and transportation equipment, both personal and freight. The third major input category is the initial efficiencies of energy-using capital in the electricity and transport sectors.

Another set of model inputs, but with less influence on investment and technology choices, include operation and maintenance (O&M) costs, energy infrastructure costs and efficiencies, and the distribution of plant lifetimes. Finally, there are a number of key model inputs that are driven by the model structure. For example, end-use efficiencies of the myriad equipment types in the industrial, commercial, and residential sectors are driven by the substitution elasticity between capital and energy. This determines what change in energy prices or an equivalent change in investment hurdle rate is required to change energy use. These elasticities are highest in the commercial sector, followed by the industrial sector, with the residential sector having the lowest elasticity. This reflects that fact that the residential sector is least likely to respond to energy price changes, due to lack of information and available funds for efficiency investments among other reasons. A related and key model parameter is the investment hurdle rate (or discount rate). This varies between 12 percent and 25 percent according to the level of energy costs and the various programs designed to remove non-price barriers to investment.

8.2 Policies Implemented to Reduce Energy Demand and Oil Dependence

The portfolio of energy policies imposed on the "challenge and response" scenarios include a carbon emissions allowance cap-and-trade program for some sectors and a set of sector-specific equipment-efficiency credit trading programs. Other elements include R&D investments, targeted tax incentives, efficiency standards for residential, commercial, and industrial equipment, and some additional programs to reduce market imperfections. These are further described in the paragraphs that follow.

Cap and Trade

The carbon emissions cap-and-trade program establishes a limit (or cap) on carbon emissions from utility electric generation and from industrial sources. It distributes tradable allowances or permits to emit the designated amount of CO_2, and requires CO_2 emitters to surrender a quantity of allowances equal to their annual emissions. This program incorporates a flexible design similar to that of the U.S. EPA's Sulfur Dioxide (SO_2) allowance-trading program, with a fixed quantity of emissions allowances distributed on an annual basis. The emission allowances can be traded across product lines and among manufacturers.

The price of carbon emission allowances affects energy prices throughout the economy. Thus, the allowance price affects the operations of and investments in both energy supply technologies and energy end-use systems. The allowance price for carbon emissions accelerates the adoption of energy efficiency-improving technologies in both the buildings and the industrial sectors. It also increases research and development (R&D) investments in new, low-emissions, energy supply technologies. Energy supply technologies benefiting from these R&D investments include nuclear energy technologies, renewable energy technologies, distributed generation systems, hydrogen energy systems, and bio-fuels.

Other Tradable Permits

Other tradable credits introduced in this study are based on technology performance and carbon emissions standards for manufactured products. Performance can be averaged between product lines and permits traded between manufacturers. This tradable credits program uses estimates of the average life and emissions of each manufacturer's products to translate over-compliance with a standard into a stream of vintaged emissions allowances. Conversely, the program translates a failure to achieve the standard into an annualized deficit of credits that must be offset by credits purchased in the market. This is a "capped" tradable credits program, under which policymakers set a cap on the total emissions associated with particular types of newly manufactured products. To sell products subject to the capped standard, manufacturers would have to obtain or surrender credits to ensure that they were in compliance at the end of each model year.

In the transportation sector, efficiency-trading programs for new equipment purchases are represented as the means for achieving sector-wide fuel economy targets. In effect, they allocate emissions credits on the basis of specified fuel efficiency targets for light-duty vehicles, heavy-duty vehicles, rail systems, and aircraft. These vehicle efficiency programs complement the carbon emissions allowance cap-and-trade program, resulting in lower carbon allowance prices.

R&D Investments

Investment in R&D significantly affects the rate of commercialization for efficiency-improving and emissions-reducing technologies in the "challenge and response" cases. The impact of these R&D expenditures is to lower the economic cost and improve the engineering performance of the targeted technologies. Varying amounts of public and private spending are devoted to R&D in each of the three "challenge and response" cases. Included among the technologies that receive targeted R&D support in the "challenge and response" cases are:

(1) Transportation-related equipment (e.g., hybrid gasoline-electric and diesel-electric vehicles, medium- and heavy-duty trucks, heavy rail systems, and aircraft);

(2) A Manhattan Project-like effort to promote the commercialization of fuel cells;

(3) Hydrogen production, transmission, and distribution technology;

(4) Renewable energy technologies;

(5) Integrated gasification and combined cycle turbine technology; and

(6) Carbon capture and sequestration technology

Targeted Tax Policies

In addition, targeted tax incentives are used in the "challenge and response" cases to accelerate the market penetration of key technologies. These include:

(1) Investment tax credits for highly efficient vehicles; and

(2) Tax credits for hydrogen production.

(3) Efficiency standards tax incentives for residential, commercial, and industrial equipment help to raise the average efficiency of appliances, motors, lights, and other key energy-using devices. The model can represent energy service companies that are paid to manage energy waste reduction in these sectors.

Additional Policy Sets

Some additional programs to reduce market imperfections complement the programs described above. These so called "barrier-busting" programs are assumed to be necessary to achieve the cost trajectories for critical energy technologies that are incorporated in the "challenge and response" cases. They include:

(1) Information dissemination programs explaining the benefits of low-emission vehicles;

(2) Freight management programs to reduce idling by medium- and heavy-duty trucks;

(3) Improved fuel economy labels to inform the purchasers of new vehicles;

(4) Transportation management programs to reduce vehicle miles traveled in each vehicle class;

(5) Training programs for operating engineers in commercial buildings; and

(6) Programs to eliminate regulatory barriers to distributed generation, e.g., national inter-connect standards and net metering.

Additional policies, not explicitly modeled in this study, could assist in overcoming remaining energy market imperfections. Overcoming these imperfections would increase economic efficiency in energy markets and further reduce carbon permit prices. Such policies include:

(7) Information and marketing programs for building owners and businesses;

(8) Energy-efficiency ratings for houses, appliances, and major energy consuming devices;

(9) Energy-efficiency mortgages to finance incremental investments in energy efficiency; and

(10) Cooperative industry programs including expanded programs of the type now known as EnergyStar and GasStar.

8.3 Detailed Scenario Results

Technology Drives the Market

Big Problems Ahead

Cheap Energy Reigns Supreme

Technology Drives The Market	2000	2010				2020				2030				2040				2050			
		Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg
Macroeconomic Variables (bil 2000$)																					
Real Consumption	6,699	8,801	9,161	9,125	-36	11,719	12,728	12,604	-124	14,724	16,183	16,052	-131	18,478	20,615	20,456	-159	23,179	25,762	25,603	-159
Real Investment	1,898	2,751	2,959	2,980	22	4,305	4,878	5,005	127	5,769	6,704	6,806	102	7,749	8,734	8,826	92	10,414	11,488	11,559	71
Real Govt Purchases	1,684	2,084	2,084	2,087	3	2,439	2,439	2,454	15	2,846	2,846	2,869	23	3,320	3,320	3,348	28	3,872	3,872	3,899	27
Real Exports	1,213	2,291	2,292	2,292	0	4,945	5,014	5,008	-6	6,664	6,713	6,706	-7	8,478	8,530	8,523	-7	9,443	9,498	9,491	-7
Real Imports	1,620	2,733	2,772	2,776	4	5,704	5,311	5,352	41	7,396	7,390	7,431	41	9,160	9,687	9,730	43	10,056	10,818	10,866	48
Real GDP	9,873	13,194	13,723	13,707	-16	17,704	19,748	19,719	-29	22,608	25,056	25,003	-53	28,865	31,512	31,423	-89	36,852	39,801	39,687	-114
Program Spending (bil 2000$)																					
Deployment Programs	0.0	0.0	0.0	1.2	1.2	0.0	0.0	6.4	6.4	0.0	0.0	11.6	11.6	0.0	0.0	14.5	14.5	0.0	0.0	14.5	14.5
Technology R&D	0.0	0.0	0.0	1.8	1.8	0.0	0.0	6.0	6.0	0.0	0.0	7.2	7.2	0.0	0.0	7.4	7.4	0.0	0.0	7.4	7.4
Macroeconomic Investment Components (bil 2000$)																					
Aggregate Investment Totals																					
Electric Utility	4.3	18.0	11.8	10.7	-1.1	22.0	16.0	22.5	6.5	27.2	22.8	27.5	4.7	40.7	31.7	27.6	-4.1	47.1	36.5	24.4	-12.1
Infrastructure	0.0	22.9	25.2	17.6	-7.6	27.9	36.3	40.6	4.3	29.8	52.2	44.5	-7.7	31.4	53.4	44.0	-9.4	33.6	66.6	36.3	-30.3
Efficient Equipment	212.8	249.0	252.0	276.5	24.6	335.2	343.6	405.4	61.8	373.7	383.7	447.1	63.4	450.4	462.5	534.8	72.3	538.4	552.6	636.4	83.8
Vehicle Purchases	383.6	453.4	655.4	453.6	-201.8	506.7	724.4	578.5	-145.9	539.5	746.5	557.5	-189.0	562.5	764.3	546.7	-217.6	586.5	786.8	553.6	-233.2
Total Energy-Related I	600.7	743.3	944.4	758.4	-186.0	891.8	1,120.3	1,047.0	-73.3	970.2	1,205.2	1,076.7	-128.5	1,084.9	1,311.8	1,153.2	-158.6	1,205.6	1,442.4	1,250.8	-191.6
Detailed Investment Totals																					
Electric Facilities - Fos	4.1	15.1	7.8	4.8	-3.0	16.2	7.6	10.8	3.2	17.9	9.2	9.3	0.1	30.4	16.7	7.8	-8.9	37.0	21.9	5.0	-16.9
Renewable Electricity	0.1	2.8	4.1	5.8	1.8	5.8	8.4	11.8	3.5	9.3	13.6	18.2	4.6	10.3	15.0	19.8	4.8	10.1	14.6	19.5	4.9
Distributed Generation	0.0	1.5	4.2	4.5	0.3	3.7	10.2	10.8	0.6	4.1	11.1	11.9	0.8	4.7	12.3	13.4	1.1	5.4	13.9	15.4	1.5
Hydrogen Infrastructur	0.0	0.0	0.0	6.3	6.3	0.0	3.3	31.4	28.1	0.0	17.5	38.9	21.4	0.0	17.2	41.6	24.4	0.0	28.3	42.7	14.4
Fuel Supply	0.0	21.5	21.1	20.6	-0.5	24.2	22.8	19.8	-3.0	25.7	23.5	19.1	-4.4	26.7	23.9	19.9	-4.0	28.3	24.4	20.2	-4.2
Sequestration Investm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	2.3	0.0	0.0	8.2	8.2	0.0	0.0	13.6	13.6	0.0	0.0	17.3	17.3
Residential Efficient E	77.4	91.0	92.0	97.3	5.3	122.1	125.0	137.5	12.5	135.2	138.6	151.1	12.6	161.5	165.6	179.9	14.3	191.7	196.5	213.1	16.6
Commercial Efficient E	71.9	83.1	84.2	90.0	5.8	112.6	115.9	136.1	20.2	123.7	127.7	149.0	21.4	148.4	153.2	178.1	24.9	177.0	182.6	212.0	29.4
Industrial Efficient Equ	63.5	75.0	75.8	89.2	13.4	100.4	102.7	131.8	29.1	114.8	117.5	147.0	29.5	140.4	143.7	176.9	33.2	169.6	173.5	211.3	37.8
Freight & Air Efficiency	0.0	0.0	0.0	8.2	8.2	0.0	0.0	35.8	35.8	0.0	0.0	41.5	41.5	0.0	0.0	44.8	44.8	0.0	0.0	46.2	46.2
Business Light-Vehicle	172.6	204.0	203.4	200.4	-3.0	228.0	224.8	244.2	19.4	242.8	231.7	232.2	0.5	253.1	237.2	225.8	-11.4	263.9	244.2	228.3	-15.9
Non-Energy Productio	0.0	0.0	0.0	-13.8	-13.8	0.0	0.0	-23.8	-23.8	0.0	0.0	-33.7	-33.7	0.0	0.0	-44.5	-44.5	0.0	0.0	-59.3	-59.3
Expenditures on Imported Oil and Gas (bil 2000$)																					
Crude Oil Imports	91.8	91.3	87.5	86.3	-1.2	98.7	84.5	70.9	-13.6	105.4	79.6	40.0	-39.6	111.3	71.6	22.3	-49.3	118.3	68.4	15.8	-52.6
Petroleum Product Imp	30.9	44.1	33.1	29.9	-3.2	65.2	24.9	11.6	-13.3	85.1	11.9	10.7	-1.2	103.1	11.6	10.2	-1.4	125.0	11.5	10.0	-1.5
Natural Gas Imports	10.4	15.3	14.4	15.8	1.5	21.1	17.7	18.5	0.8	39.7	32.2	20.5	-11.7	56.6	46.6	25.9	-20.7	69.6	57.0	27.2	-29.8
Light-Duty Vehicle Purchases (bil 2000$)																					
Household Vehicles	211.0	249.4	248.6	245.0	-3.6	278.7	274.8	298.5	23.7	296.7	283.1	283.8	0.7	309.4	289.9	276.0	-13.9	322.6	298.4	279.0	-19.4
Business Light-Vehicle	172.6	204.0	203.4	200.4	-3.0	228.0	224.8	244.2	19.4	242.8	231.7	232.2	0.5	253.1	237.2	225.8	-11.4	263.9	244.2	228.3	-15.9
Total Light-Vehicles	383.6	453.4	452.0	445.4	-6.6	506.7	499.6	542.7	43.1	539.5	514.8	516.0	1.2	562.5	527.1	501.9	-25.2	586.5	542.6	507.4	-35.2
Avg Price per Vehicle	22,103	24,124	24,999	24,978	-21	24,894	26,819	29,921	3,102	24,969	26,953	28,097	1,144	25,014	27,049	27,108	59	25,059	27,294	27,186	-108
Energy Expenditures by Major Sector (bil 2000$)																					
Residential	143.6	148.7	146.5	176.8	30.3	172.7	164.1	201.9	37.8	211.0	198.8	213.9	15.1	264.5	244.9	262.5	17.6	326.9	292.6	305.3	12.7
Commercial	117.8	116.1	114.1	141.3	27.2	140.1	132.0	158.4	26.4	171.1	159.2	159.6	0.4	217.3	197.7	192.9	-4.8	267.7	235.7	223.9	-11.8
Industrial	183.3	200.3	186.1	240.0	53.9	222.8	188.7	246.2	57.5	263.6	209.6	234.0	24.4	313.6	246.5	250.0	3.5	370.0	281.1	258.9	-22.2
Transportation	264.5	339.2	319.9	334.4	14.5	381.5	304.3	328.7	24.4	413.1	280.5	260.5	-20.0	438.9	265.8	224.4	-41.4	468.5	261.6	217.7	-43.9
Total Economy-wide	709.1	804.2	766.6	892.6	126.0	917.1	789.1	935.2	146.1	1058.9	848.1	868.0	19.9	1,234.4	954.9	929.9	-25.0	1,433.1	1,071.0	1,005.8	-65.2
Average Primary Ener	$7.07	$6.97	$6.82	$8.18	$1.36	$7.10	$6.68	$9.46	$2.78	$7.59	$6.94	$9.16	$2.22	$8.41	$7.69	$9.43	$1.75	$9.10	$8.40	$9.84	$1.44
Energy Consumption (Quads)																					
Petroleum Products	38.1	46.0	43.4	42.4	-1.0	50.9	41.2	35.4	-5.9	55.2	38.0	26.6	-11.4	58.8	36.0	21.1	-14.9	63.1	35.1	18.9	-16.3
Natural Gas	23.4	29.4	28.9	29.6	0.7	36.1	34.6	34.9	0.4	42.6	40.1	35.7	-4.5	47.4	44.6	37.8	-6.8	50.6	47.5	38.4	-9.1
Coal	23.4	25.4	25.0	21.8	-3.2	27.4	25.2	11.3	-13.9	26.1	23.7	9.9	-13.9	23.8	20.2	11.9	-8.2	26.2	19.3	13.0	-6.3
Renewable Energy	6.9	7.2	7.4	7.8	0.4	8.1	9.7	10.6	0.9	9.7	13.1	15.8	2.7	11.4	16.8	20.8	4.0	12.9	19.5	25.1	5.6
Nuclear Power	8.1	7.2	7.5	7.3	-0.2	6.3	7.1	6.3	-0.9	5.7	6.9	6.5	-0.4	5.0	6.3	6.6	0.3	4.4	5.7	6.4	0.8
Other	0.4	0.4	0.4	0.4	0.0	0.4	0.4	0.4	0.0	0.4	0.4	0.4	0.0	0.4	0.4	0.4	0.0	0.4	0.4	0.4	0.0
Total Primary Energy	100.3	115.4	112.4	109.2	-3.3	129.1	118.2	98.9	-19.3	139.5	122.2	94.8	-27.4	146.8	124.2	98.6	-25.6	157.5	127.5	102.2	-25.3
TPE / GDP (kBtu / 200	10.16	8.75	8.19	7.96	-0.23	7.29	5.98	5.01	-0.97	6.17	4.88	3.79	-1.09	5.08	3.94	3.14	-0.8	4.27	3.2	2.57	-0.63
Carbon Emissions (MtC)																					
Transportation Carbon	511	656	633	612	-21	741	620	512	-108	803	578	365	-213	852	537	284	-253	914	521	269	-252
End Use Carbon	458	521	506	498	-8	612	576	495	-81	678	640	501	-139	711	680	526	-154	775	708	508	-200
Central Station Carbor	589	695	668	606	-62	757	664	381	-283	765	620	311	-309	747	540	332	-208	782	512	350	-162
Captured & Sequester	0	0	0	0	0	0	0	-38	-38	0	0	-137	-137	0	0	-227	-227	0	0	-289	-289
Total Carbon Emissior	1,559	1,872	1,807	1,716	-91	2,110	1,860	1,349	-511	2,246	1,838	1,041	-797	2,310	1,757	914	-843	2,471	1,741	839	-902
Carbon-to-GDP Ratio (grams / 2000$)																					
Emissions per $ Outpu	158	142	132	125	-7	119	94	68	-26	99	73	42	-31	80	55	29	-26	67	43	21	-22

Technology Drives The Market	2000	2010				2020				2030				2040				2050			
		Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg
ENERGY PRICE AND SUPPLY TABLES																					
Carbon Charge (2000$)																					
Carbon Price ($/metric	0	0	0	137	137	0	0	197	197	0	0	218	218	0	0	241	241	0	0	266	266
Carbon Price in Gas ($	0	0	0	2	2	0	0	2.88	2.88	0	0	3	3.18	0	0	3.52	3.52	0	0	3.88	3.88
Carbon Price in Coal (	0	0	0	3.42	3.42	0	0	4.93	4.93	0	0	5	5.45	0	0	6.02	6.02	0	0	6.65	6.65
World Oil Price (2000$	27.72	23.39	22.87	22.71	-0.16	24.34	22.46	21.37	-1.09	25.18	21.78	19.83	-1.95	25.9	21.41	18.84	-2.57	26.74	21.26	18.44	-2.82
Crude Oil Price (2000$	4.66	3.93	3.84	3.82	-0.02	4.09	3.78	3.59	-0.19	4.23	3.66	3.33	-0.33	4.35	3.6	3.17	-0.43	4.49	3.57	3.1	-0.47
Petroleum Supply (Quads)																					
Domestic Crude Oil	15.0	14.8	14.5	14.4	-0.1	15.4	14.2	13.5	-0.7	15.9	13.8	12.6	-1.2	16.4	13.6	11.9	-1.6	16.9	13.5	11.7	-1.8
Imports Crude Oil	19.7	23.2	22.8	22.6	-0.1	24.1	22.4	19.7	-2.6	24.9	21.8	12.0	-9.8	25.6	19.9	7.0	-12.9	26.3	19.2	5.1	-14.1
Imports Petroleum Pro	4.7	8.0	6.2	5.6	-0.6	11.4	4.7	2.3	-2.4	14.4	2.3	2.3	0.0	16.9	2.3	2.3	0.0	19.9	2.3	2.3	0.0
Natural Gas Supply (Quads)																					
Domestic Gas Product	19.6	23.7	23.3	23.8	0.5	28.7	27.7	28.0	0.2	32.3	30.7	27.9	-2.8	35.3	33.6	29.3	-4.3	37.3	35.4	29.6	-5.7
Imports of Gas	3.9	5.7	5.6	5.8	0.2	7.4	6.9	7.0	0.1	10.3	9.4	7.7	-1.7	12.1	11.0	8.6	-2.5	13.2	12.1	8.7	-3.4
Total Gas Demand	23.4	29.4	28.9	29.6	0.7	36.1	34.6	34.9	0.4	42.6	40.1	35.7	-4.5	47.4	44.6	37.8	-6.8	50.6	47.5	38.4	-9.1
Natural Gas Prices (2000$)																					
Wellhead Gas Price ($	2.76	2.75	2.64	2.81	0.17	2.93	2.65	2.71	0.06	3.95	3.51	2.70	-0.81	4.81	4.31	3.10	-1.21	5.38	4.82	3.19	-1.63
Industrial Gas Price ($	3.65	3.36	3.23	5.42	2.19	3.47	3.13	6.09	2.96	4.63	4.11	6.36	2.25	5.6	5.03	7.12	2.09	6.23	5.58	7.58	2
Commercial Gas Price	7.39	5.36	5.13	7.47	2.34	4.89	4.36	7.36	3	6.38	5.61	7.38	1.77	7.31	6.5	8.02	1.52	7.59	6.74	8.15	1.41
Residential Gas Price	8.51	6.48	6.25	8.59	2.34	6.01	5.48	8.48	3	7.50	6.73	8.50	1.77	8.43	7.62	9.14	1.52	8.71	7.86	9.27	1.41
Electric Utility Gas Price ($/MBtu)																					
Without Carbon Charg	3.19	3.18	3.05	3.24	0.19	3.38	3.05	3.13	0.08	4.55	4.05	3.12	-0.93	5.54	4.97	3.57	-1.4	6.21	5.56	3.68	-1.88
With Carbon Charge	3.19	3.18	3.05	5.23	2.18	3.38	3.05	6.01	2.96	4.55	4.05	6.30	2.25	5.54	4.97	7.09	2.12	6.21	5.56	7.56	2
Avg Electricity Price (2	67	60	61	73	12	61	63	84	21	62	65	87	22	70	74	97	23	79	82	107	25
Industrial Electricity Pr	45	44	44	57	13	44	46	67	21	45	48	71	23	53	56	80	24	61	64	90	26
Commercial Electricity	73	60	61	73	12	62	64	85	21	62	65	88	23	71	74	98	24	79	83	108	25
Residential Electricity I	81	75	76	88	12	76	78	99	21	76	79	102	23	85	88	112	24	94	98	123	25
TOTAL PRIMARY ENERGY BY FUEL AND SECTOR																					
Petroleum Products (Quads)																					
Transport Petroleum	25.7	32.9	31.8	30.7	-1.0	37.1	31.1	25.7	-5.4	40.2	28.9	18.3	-10.6	42.6	26.9	14.2	-12.7	45.7	26.1	13.5	-12.6
Other Petroleum	12.4	13.1	11.6	11.7	0.0	13.8	10.2	9.7	-0.5	15.0	9.1	8.3	-0.8	16.2	9.1	6.8	-2.3	17.4	9.1	5.4	-3.7
TOTAL PETROLEI	38.1	46.0	43.4	42.4	-1.0	50.9	41.2	35.4	-5.9	55.2	38.0	26.6	-11.4	58.8	36.0	21.1	-14.9	63.1	35.1	18.9	-16.3
Natural Gas (Quads)																					
Central Station Natura	4.2	6.6	5.5	6.8	1.3	7.8	4.8	9.4	4.6	10.5	4.2	7.2	3.0	13.8	5.3	5.0	-0.2	13.2	5.5	4.1	-1.4
Sector Natural Gas	19.2	22.7	23.3	22.7	-0.6	28.1	29.7	25.1	-4.6	31.9	35.6	27.1	-8.5	33.4	38.5	31.7	-6.9	37.1	40.9	33.6	-7.3
Transport Natural Gas	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.2	0.1	0.1	0.0	0.2	0.2	0.1	0.0	0.3	0.2	0.2	0.0
NGas reformed to hyd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.0	0.3	1.3	1.0	0.0	0.7	1.0	0.3	0.0	0.9	0.5	-0.4
TOTAL NATURAL	23.4	29.4	28.9	29.6	0.7	36.1	34.6	34.9	0.4	42.6	40.1	35.7	-4.5	47.4	44.6	37.8	-6.8	50.6	47.5	38.4	-9.1
Coal (Quads)																					
Coal Generation	20.8	22.9	22.5	19.3	-3.2	25.1	23.0	9.2	-13.8	23.9	21.6	6.4	-15.2	21.8	18.0	6.5	-11.5	24.3	16.5	6.4	-10.2
Other sector Coal	2.6	2.5	2.4	2.4	0.0	2.3	2.3	1.8	-0.5	2.2	2.1	1.4	-0.7	2.0	1.9	1.0	-0.9	1.9	1.8	0.6	-1.1
IGCC for hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	2.0	2.0	0.0	0.3	4.4	4.2	0.0	1.0	6.1	5.0
TOTAL COAL	23.4	25.4	25.0	21.8	-3.2	27.4	25.2	11.3	-13.9	26.1	23.7	9.9	-13.9	23.8	20.2	11.9	-8.2	26.2	19.3	13.0	-6.3
Renewable Energy (Quads)																					
Trans Renewable Ene	0.2	0.2	0.2	0.5	0.3	0.2	0.7	1.3	0.6	0.3	0.8	1.4	0.5	0.3	0.8	1.1	0.3	0.3	0.7	1.0	0.3
Electric Generation Re	3.8	3.7	3.9	4.0	0.1	4.3	5.1	5.1	0.1	5.3	7.0	8.1	1.1	6.5	9.1	11.7	2.6	7.3	10.2	14.1	3.9
Wind Power to produc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.2	1.1	0.9	0.0	0.6	0.9	0.3	0.0	0.7	0.4	-0.3
On Site Renewable Er	2.9	3.2	3.2	3.2	0.0	3.6	3.9	3.8	-0.1	4.1	5.1	5.3	0.2	4.7	6.4	7.2	0.8	5.3	7.9	9.7	1.8
TOTAL RENEWAB	6.9	7.2	7.4	7.8	0.4	8.1	9.7	10.6	0.9	9.7	13.1	15.8	2.7	11.4	16.8	20.8	4.0	12.9	19.5	25.1	5.6
Hydrogen Production (Quads)																					
Hydrogen fr Natural Ga	0	0	0	0	0	0	0.01	0.28	0.27	0.0	0.2	1.0	0.79	0.00	0.53	0.78	0.25	0.00	0.67	0.37	-0.30
Hydrogen fr Renewabl	0	0	0	0	0	0	0.00	0.09	0.09	0.0	0.1	0.3	0.26	0.00	0.18	0.26	0.08	0.00	0.22	0.12	-0.10
Hydrogen fr Coal Gasi	0	0	0	0	0	0	0.00	0.14	0.14	0.0	0.0	0.9	0.90	0.00	0.12	1.99	1.87	0.00	0.46	2.72	2.26
TOTAL HYDROGE	0	0	0	0	0	0	0.02	0.52	0.50	0.0	0.3	2.2	1.96	0.00	0.82	3.04	2.22	0.00	1.35	3.22	1.87

Technology Drives The Market	2000	2010				2020				2030				2040				2050			
		Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg
ELECTRICITY SUPPLY TABLES																					
1. Electricity Supply-Demand Balance (BkWh)																					
Electricity End-Use De	3,569	4,371	4,298	4,209	-89	5,078	4,874	4,307	-567	5,778	5,443	4,417	-1,026	6,575	6,061	4,898	-1,163	7,481	6,789	5,488	-1,301
large CHP	369	410	464	460	-4	421	598	587	-11	423	733	716	-17	430	843	822	-21	438	918	894	-24
Dist Gen - excl Winc	2	26	87	98	11	104	305	331	26	228	625	676	51	350	923	1,009	86	482	1,230	1,368	138
Total large CHP and o	370	436	551	558	7	525	903	919	16	652	1,358	1,393	35	781	1,766	1,831	65	919	2,148	2,262	114
Amount for Own Use	187	231	292	296	4	280	482	491	9	352	733	752	19	421	953	988	35	496	1,160	1,222	62
Sales to grid	183	205	259	262	3	245	421	428	7	300	625	641	16	359	812	842	30	423	988	1,041	53
Electric Generators Lo	3,458	4,211	4,013	3,910	-103	4,824	4,217	3,597	-620	5,438	4,351	3,223	-1,128	6,152	4,587	3,282	-1,305	6,973	4,966	3,464	-1,502
Net Imports	35	35	35	35	0	35	35	35	0	35	35	35	0	35	35	35	0	35	35	35	0
Total to grid	3,676	4,451	4,307	4,208	-99	5,104	4,672	4,060	-612	5,772	5,010	3,899	-1,111	6,546	5,434	4,159	-1,275	7,431	5,989	4,539	-1,450
Sales from grid	3,382	4,140	4,006	3,913	-93	4,798	4,392	3,816	-576	5,426	4,710	3,665	-1,045	6,153	5,108	3,909	-1,199	6,985	5,629	4,267	-1,362
T&D Losses	294	312	302	295	-7	306	280	244	-36	346	301	234	-67	393	326	250	-76	446	359	272	-87
2. CHP and Other Distributed Generation (TWh)																					
Conventional CHP	356	419	518	524	6	473	714	714	0	520	878	862	-16	554	998	969	-29	576	1077	1041	-36
Municiple Solid Waste	14	14	14	14	0	12	12	12	0	11	11	11	0	10	10	10	0	10	10	10	0
Fuel Cell CHP	0	0	13	13	0	18	126	132	6	48	305	320	15	70	430	450	20	81	493	517	24
Building Integrated PV	1	3	6	8	2	23	50	62	12	73	164	201	37	146	328	401	73	252	568	694	126
3. Electricity Generation, excl. CHP and other DG (TWh)																					
Coal	1,907	2,225	2,181	1,913	-268	2,540	2,310	947	-1,363	2,539	2,238	575	-1,663	2,544	1,981	504	-1,477	3,298	2,069	435	-1,634
Gas and Oil	533	878	697	844	147	1,114	629	1,290	661	1,592	596	963	367	2,114	776	692	-84	2,034	816	628	-188
Biomass Gasification	0	0	0	0	0	0	1	1	0	14	21	24	3	55	80	92	12	139	201	233	32
Nuclear	752	737	752	752	0	702	752	752	0	677	752	752	0	652	752	752	0	627	752	752	0
Hydro	321	321	321	321	0	321	321	321	0	321	321	321	0	321	321	321	0	321	321	321	0
Wind	9	36	46	64	18	119	166	245	79	220	311	467	156	310	440	662	222	364	517	779	262
Geothermal	16	15	16	16	0	27	37	40	3	74	112	122	10	156	237	259	22	189	289	315	26
TOTAL Load	3,458	4,211	4,013	3,910	-103	4,824	4,217	3,597	-620	5,438	4,351	3,223	-1,128	6,152	4,587	3,282	-1,305	6,973	4,966	3,464	-1,502
4. Fuel Use, excl. CHP and other DG (Quads)																					
Coal	20.8	22.9	22.5	19.3	-3.2	25.1	23.0	9.5	-13.5	23.9	21.6	8.5	-13.2	21.8	18.2	10.9	-7.3	24.3	17.6	12.4	-5.2
Petroleum	1.2	0.6	0.6	0.6	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas	4.2	6.6	5.5	6.8	1.3	7.8	4.8	9.4	4.6	10.5	4.2	7.2	3.0	13.8	5.3	5.0	-0.2	13.2	5.5	4.1	-1.4
Biomass Cofiring and (	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0
Net Imports Btu Equiva	0.4	0.3	0.4	0.3	0.0	0.3	0.3	0.3	0.0	0.3	0.3	0.3	0.0	0.3	0.3	0.3	0.0	0.3	0.3	0.3	0.0
Fossil HeatRate (Btu/k	10,729	9,711	9,930	9,685	-245	9,008	9,464	8,341	-1,123	8,348	9,104	8,632	-472	7,642	8,394	8,750	356	7,036	7,546	8,553	1,007
5. Conventional Air Emissions																					
SO2 (thous tons)	12,767	10,366	7,282	7,024	-258	8,618	5,576	1,992	-3,584	6,667	4,149	877	-3,272	4,187	2,110	663	-1,447	2,553	971	499	-472
NOx (thous tons)	5,905	4,622	3,249	3,179	-70	4,088	2,750	1,285	-1,465	3,316	2,206	715	-1,491	2,269	1,378	545	-833	1,509	820	347	-473
Mercury (tons)	48.6	48.9	27.3	26.1	-1.2	42.3	19.5	7.2	-12.3	33.4	14.5	3.2	-11.3	21.2	8.3	2.4	-5.9	12.7	5.1	1.9	-3.2
6. Investment Flows (mil 2000$)																					
Gas Facilities	4,124	7,987	3,453	2,306	-1,147	9,920	3,847	4,728	881	11,619	5,641	770	-4,871	8,854	4,396	687	-3,709	6,051	4,169	665	-3,504
Coal Facilities	0	7,154	4,336	2,521	-1,815	6,322	3,765	6,037	2,272	6,280	3,589	8,577	4,988	21,498	12,285	7,134	-5,151	30,959	17,691	4,318	-13,373
Renewable Facilities	126	2,820	4,048	5,847	1,799	5,788	8,355	11,756	3,401	9,323	13,609	18,160	4,551	10,296	15,020	19,795	4,775	10,093	14,629	19,466	4,837
Total (non DG) Faciliti	4,251	17,961	11,838	10,674	-1,164	22,030	15,967	22,520	6,553	27,222	22,838	27,507	4,669	40,648	31,700	27,616	-4,084	47,103	36,489	24,449	-12,040
Total Distributed Gene	0	1,453	4,182	4,492	310	3,730	10,200	10,830	630	4,134	11,108	11,940	832	4,673	12,321	13,422	1,101	5,393	13,942	15,404	1,462
7. Operating & Maintenance (mil 2000$)																					
Coal Facilities	17,760	19,881	19,606	17,741	-1,865	20,652	19,126	8,790	-10,336	19,041	17,242	6,861	-10,381	17,100	14,005	7,665	-6,340	20,384	14,129	7,906	-6,223
Gas Facilities	1,141	2,806	2,148	2,135	-13	4,141	2,535	3,842	1,307	5,996	2,791	3,212	421	7,678	3,357	2,171	-1,186	7,437	3,459	1,618	-1,841
Hydro Facilities	3,120	3,120	3,120	3,120	0	3,120	3,120	3,120	0	3,120	3,120	3,120	0	3,120	3,120	3,120	0	3,120	3,120	3,120	0
Renewable Facilities	391	593	704	862	158	1,553	2,164	2,923	759	3,500	5,079	6,683	1,604	6,311	9,274	11,799	2,525	8,466	12,445	15,654	3,209
Total O&M costs	22,412	26,400	25,578	23,857	-1,721	29,466	26,945	18,675	-8,270	31,658	28,233	19,876	-8,357	34,209	29,756	24,756	-5,000	39,407	33,153	28,297	-4,856
TRANSPORTATION AND ENERGY TABLE																					
Vehicle Miles Traveled (LDVs incl Light Commercial Trucks)																					
VMT (billions)	2,396	3,295	3,269	3,262	-7	3,715	3,557	3,501	-56	4,095	3,755	3,637	-118	4,367	3,883	3,703	-180	4,588	3,993	3,753	-240
New Vehicle On-Road Average Fuel-Economy Calculations																					
New Car Avg Fuel-Ecc	22.8	25.3	34.8	34.8	0	25.6	40.9	63.4	22.5	25.6	45.1	71.2	26.1	25.6	48	74.3	26.3	25.5	49.4	77.7	28.3
New Light Truck Avg F	17.0	19.1	26.1	26.1	0	19.3	30.5	42.7	12.2	19.3	34.4	53.5	19.1	19.2	36.5	57.3	20.8	19.2	37.7	64.8	27.1
Overall LDV On-Road	19.8	22	30.1	30.1	0	22.1	35.1	51.6	16.5	22.0	39.0	61.7	22.7	21.9	41.4	65.5	24.1	21.9	42.7	71.4	28.7
New Light-Duty Vehicle Additions by Technology (1000)																					
Conventional Vehicle	17,256	17,988	14,181	13,966	-215	19,239	8,824	0	-8,824	20,383	6,692	0	-6,692	21,175	5,925	0	-5,925	21,990	5,661	0	-5,661
Dedicated CNG Vehicl	48	76	73	72	-1	122	112	109	-3	174	154	148	-6	221	191	182	-9	280	238	223	-15
Advanced Diesel & oth	0	0	2,492	2,477	-15	0	3,939	4,114	175	0	4,585	2,969	-1,616	0	4,840	2,847	-1,993	0	4,945	1,743	-3,202
Hybrid Electric Vehicle	52	730	1,334	1,317	-17	991	4,522	4,310	-212	1,050	4,700	4,777	77	1,091	3,887	4,545	658	1,133	2,904	3,570	666
FCV with on-board refo	0	0	0	0	0	0	936	3,458	2,522	0	569	0	-569	0	0	0	0	0	0	0	0
hydrogen FCV	0	0	0	0	0	0	297	6,147	5,850	0	2,401	10,471	8,070	0	4,642	10,940	6,298	0	6,131	13,126	6,995
Electric Vehicles	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL LDV Sales	17,355	18,794	18,080	17,833	-247	20,353	18,630	18,138	-492	21,607	19,101	18,366	-735	22,487	19,486	18,514	-972	23,403	19,879	18,662	-1,217

Technology Drives The Market

	2000	2010				2020				2030				2040				2050			
		Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg
Transportation Energy Consumption by Fuel Type (excluding pipeline natural gas use) - Quads																					
Motor Gasoline	15.8	19.9	18.7	18.9	0.1	21.8	15.2	12.5	-2.6	23.5	11.9	6.3	-5.7	24.9	9.9	3.7	-6.2	26.1	8.7	3.1	-5.6
Diesel Fuel	5.2	7.3	7.3	6.5	-0.8	8.7	9.4	7.4	-2.0	9.5	10.4	6.7	-3.7	10.2	10.8	5.9	-4.9	11.3	11.2	5.8	-5.4
Jet fuel	3.6	4.5	4.5	4.2	-0.4	5.3	5.2	4.5	-0.8	5.9	5.3	4.1	-1.2	6.1	4.9	3.4	-1.5	7.1	5.0	3.4	-1.6
Residual and other Pe	1.1	1.2	1.2	1.2	0.0	1.3	1.3	1.3	0.0	1.3	1.3	1.3	0.0	1.3	1.3	1.3	0.0	1.3	1.2	1.2	0.0
Petroleum Subtota	25.7	32.9	31.8	30.7	-1.0	37.1	31.1	25.7	-5.4	40.2	28.9	18.3	-10.6	42.6	26.9	14.2	-12.7	45.7	26.1	13.5	-12.6
Natural Gas Fuel	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.2	0.1	0.1	0.0	0.2	0.2	0.1	0.0	0.3	0.2	0.2	0.0
Biofuels replace gasoli	0.1	0.2	0.2	0.4	0.2	0.2	0.4	0.8	0.4	0.2	0.5	0.8	0.3	0.2	0.4	0.6	0.2	0.2	0.4	0.5	0.1
Bio-Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.2	0.1	0.0	0.1	0.2	0.1	0.0	0.1	0.2	0.0
Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.3	2.2	2.0	0.0	0.8	3.0	2.2	0.0	1.4	3.2	1.9
Electricity	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0
Total Delivered E	25.9	33.2	32.0	31.2	-0.8	37.5	31.7	27.3	-4.5	40.6	30.0	21.7	-8.3	43.1	28.5	18.3	-10.2	46.2	28.2	17.6	-10.6
New Light-Duty Vehicle Shares by Technology (pct)																					
Conventional Vehicle	99.4	95.7	78.4	78.3	-0.1	94.5	47.4	0	-47.4	94.3	35.0	0.0	-35.0	94.2	30.4	0	-30.4	94	28.5	0	-28.5
Dedicated CNG Vehicl	0.3	0.4	0.4	0.4	0	0.6	0.6	0.6	0	0.8	0.8	0.8	0.0	1	1	1	0	1.2	1.2	1.2	0
Advanced Diesel & oth	0.0	0	13.8	13.9	0.1	0	21.1	22.7	1.6	0.0	24.0	16.2	-7.8	0	24.8	15.4	-9.4	0	24.9	9.3	-15.6
Hybrid Electric Vehicle	0.3	3.9	7.4	7.4	0	4.9	24.3	23.8	-0.5	4.9	24.6	26.0	1.4	4.9	19.9	24.6	4.7	4.8	14.6	19.1	4.5
FCV with on-board ref	0.0	0	0	0	0	0	5	19.1	14.1	0.0	3.0	0.0	-3.0	0	0	0	0	0	0	0	0
hydrogen FCV	0.0	0	0	0	0	0	1.6	33.9	32.3	0.0	12.6	57.0	44.4	0	23.8	59.1	35.3	0	30.8	70.3	39.5
Electric Vehicles	0.0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0	0
TOTAL PCT	100.0	100	100	100	0	100	100	100	0	100	100	100	0	100	100	100	0	100	100	100	0
New Light-Duty Vehicle Shares by Detailed Size Class(pct)																					
SubComCar	15.1	12.7	12.8	13.2	0.4	11.4	11.6	18.5	6.9	10.7	11.0	21.1	10.1	10.4	10.7	23.8	13.1	10.2	10.5	26.9	16.4
CompacCar	17.6	15.7	15.6	15.2	-0.4	14.7	14.4	13.3	-1.1	14.0	13.8	14.4	0.6	13.7	13.4	15.5	2.1	13.4	13.1	16.7	3.6
MediumCar	20.2	20.9	20.9	21	0.1	20.9	20.9	18.8	-2.1	20.9	20.9	15.9	-5	21.2	21.3	13.6	-7.7	21.5	21.6	10.9	-10.7
XLargeCar	3.9	4.2	4.2	4.1	-0.1	4.3	4.2	2.3	-1.9	4.3	4.2	1.9	-2.3	4.4	4.3	1.6	-2.7	4.5	4.4	1.2	-3.2
Mini_Vans	11.2	11.5	11.5	11.5	0	11.5	11.5	11.5	0	11.5	11.5	11.5	0	11.5	11.5	11.5	0	11.5	11.5	11.5	0
RegulrSUV	10.3	11.2	11.5	11.7	0.2	12.1	12.8	14.5	1.7	12.6	13.5	14.8	1.3	12.5	13.6	14.9	1.3	12.4	13.7	14.9	1.2
Large_SUV	0.6	4.6	4.2	4	-0.2	5.7	5.1	1.7	-3.4	6.6	5.6	1.7	-3.9	6.8	5.7	1.7	-4	7.1	5.8	1.6	-4.2
PickupVan	21.1	19.3	19.3	19.3	0	19.4	19.4	19.3	-0.1	19.5	19.5	18.7	-0.8	19.5	19.5	17.4	-2.1	19.5	19.5	16.2	-3.3
TOTAL PCT	100.0	100	100	100	0	100	100	100	0	100	100	100	0	100	100	100	0	100	100	100	0
New Light-Duty Vehicles by Major Size Class (1000)																					
Small Car	5,669	5,339	5,136	5,066	-70	5,309	4,860	5,777	917	5,339	4,720	6,520	1,800	5,430	4,705	7,281	2,576	5,522	4,691	8,132	3,441
Large Car	4,177	4,712	4,533	4,471	-62	5,115	4,682	3,824	-858	5,441	4,810	3,270	-1,540	5,750	4,983	2,816	-2,167	6,072	5,158	2,260	-2,898
Mini-van	1,948	2,166	2,084	2,056	-28	2,346	2,147	2,091	-56	2,491	2,202	2,117	-85	2,592	2,246	2,134	-112	2,698	2,292	2,151	-141
SUV	1,905	2,955	2,843	2,804	-39	3,634	3,327	2,945	-382	4,130	3,651	3,033	-618	4,337	3,758	3,063	-695	4,555	3,869	3,094	-775
Cargo Veh	3,657	3,620	3,483	3,435	-48	3,948	3,614	3,501	-113	4,206	3,718	3,426	-292	4,378	3,793	3,219	-574	4,556	3,870	3,025	-845
TOTAL LDV Sales	17,355	18,794	18,080	17,833	-247	20,353	18,630	18,138	-492	21,607	19,101	18,366	-735	22,487	19,486	18,514	-972	23,403	19,879	18,662	-1,217
Fuel Consumption by Transportation Mode (excludes Specialized Petroleum Products such as Lubricants) - Quads																					
Total LDV Fuel Use	15.0	19.0	17.9	17.8	-0.1	20.8	15.4	13.6	-1.8	22.6	13.3	9.6	-3.7	24.0	12.2	7.7	-4.5	25.2	11.7	7.1	-4.6
Cm Truck Fuel	0.7	0.9	0.9	0.8	0.0	0.9	0.9	0.7	-0.2	1.0	0.9	0.5	-0.4	1.1	1.0	0.5	-0.5	1.3	1.0	0.6	-0.5
Freight Truck Fuel	4.3	6.2	6.2	5.8	-0.4	7.4	7.3	5.6	-1.7	8.1	7.5	4.5	-3.0	8.8	7.5	3.8	-3.7	9.7	7.8	3.9	-3.9
Jet_air Fuel	3.6	4.5	4.5	4.2	-0.4	5.3	5.2	4.5	-0.8	5.9	5.3	4.1	-1.2	6.1	4.9	3.4	-1.5	7.1	5.0	3.4	-1.6
RailTrn Fuel	0.6	0.7	0.7	0.7	0.0	0.8	0.8	0.8	0.0	0.9	0.9	0.8	0.0	0.9	0.8	0.8	0.0	0.9	0.8	0.8	0.0
MarineT Fuel	1.5	1.6	1.6	1.6	0.0	1.8	1.8	1.8	0.0	1.8	1.8	1.8	0.0	1.8	1.8	1.8	0.0	1.7	1.6	1.7	0.0
TOTAL Fuel Use	25.6	32.9	31.7	30.9	-0.8	37.2	31.4	27.0	-4.5	40.3	29.7	21.4	-8.3	42.8	28.2	18.0	-10.2	45.9	27.9	17.3	-10.6

Big Problems Ahead

	2000	2010				2020				2030				2040				2050			
		Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg
Macroeconomic Variables (bil 2000$)																					
Real Consumption	6,699	8,801	7,904	7,844	-60	11,719	10,152	9,940	-212	14,724	12,271	12,025	-246	18,478	15,076	14,786	-290	23,179	19,223	18,937	-286
Real Investment	1,898	2,751	2,680	2,707	27	4,305	4,161	4,296	135	5,769	5,609	5,719	110	7,749	7,502	7,617	115	10,414	10,095	10,183	88
Real Govt Purchases	1,684	2,084	2,084	2,087	3	2,439	2,439	2,459	20	2,846	2,846	2,879	33	3,320	3,320	3,357	37	3,872	3,872	3,908	36
Real Exports	1,213	2,291	2,282	2,282	0	4,945	4,705	4,686	-19	6,664	6,393	6,372	-21	8,478	8,184	8,161	-23	9,443	9,135	9,110	-25
Real Imports	1,620	2,733	2,545	2,551	6	5,704	5,372	5,400	29	7,396	7,010	7,038	28	9,160	9,016	9,059	44	10,056	10,052	10,114	62
Real GDP	9,873	13,194	12,405	12,370	-35	17,704	16,086	15,980	-106	22,608	20,109	19,957	-152	28,865	25,067	24,861	-206	36,852	32,272	32,025	-247
Program Spending (bil 2000$)																					
Deployment Programs	0.0	0.0	0.0	1.3	1.3	0.0	0.0	9.8	9.8	0.0	0.0	17.8	17.8	0.0	0.0	19.9	19.9	0.0	0.0	19.9	19.9
Technology R&D	0.0	0.0	0.0	1.9	1.9	0.0	0.0	6.3	6.3	0.0	0.0	7.6	7.6	0.0	0.0	7.8	7.8	0.0	0.0	7.8	7.8
Macroeconomic Investment Components (bil 2000$)																					
Aggregate Investment Totals																					
Electric Utility	4.3	18.0	15.4	11.1	-4.3	22.0	26.4	23.9	-2.5	27.2	35.8	37.8	2.0	40.7	35.6	36.3	0.7	47.1	33.0	29.8	-3.2
Infrastructure	0.0	22.9	22.0	5.1	-16.9	27.9	32.4	24.9	-7.5	29.8	56.7	27.8	-28.9	31.4	55.0	25.1	-29.9	33.6	72.9	9.5	-63.4
Efficient Equipment	212.8	249.0	257.8	282.4	24.6	335.2	345.6	409.9	64.3	373.7	385.4	454.0	68.6	450.4	462.2	542.4	80.2	538.4	558.8	652.5	93.7
Vehicle Purchases	383.6	453.4	450.7	455.1	4.4	506.7	500.7	578.7	78.0	539.5	508.0	547.7	39.7	562.5	511.5	532.1	20.6	586.5	518.7	531.1	12.4
Total Energy-Related I	600.7	743.3	745.8	753.6	7.8	891.8	905.1	1037.3	132.2	970.2	985.9	1067.4	81.5	1084.9	1064.3	1135.9	71.6	1205.6	1183.4	1222.9	39.5
Detailed Investment Totals																					
Electric Facilities - Fos	4.1	15.1	11.8	5.5	-6.3	16.2	19.2	12.5	-6.7	17.9	24.3	20.3	-4.0	30.4	22.8	17.0	-5.8	37.0	20.3	10.6	-9.7
Renewable Electricity	0.1	2.8	3.6	5.6	2.1	5.8	7.2	11.3	4.1	9.3	11.5	17.5	6.0	10.3	12.8	19.2	6.4	10.1	12.7	19.1	6.4
Distributed Generation	0.0	1.5	1.6	3.6	2.0	3.7	4.3	8.4	4.1	4.1	4.6	9.1	4.5	4.7	5.0	10.0	5.0	5.4	5.5	11.2	5.7
Hydrogen Infrastructur	0.0	0.0	0.0	8.1	8.1	0.0	6.7	40.7	34.0	0.0	29.8	50.6	20.8	0.0	26.7	54.1	27.4	0.0	42.5	55.5	13.0
Fuel Supply	0.0	21.5	20.4	20.0	-0.4	24.2	21.4	18.7	-2.7	25.7	22.4	18.6	-3.8	26.7	23.3	19.6	-3.7	28.3	24.8	21.1	-3.7
Sequestration Investm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1	3.1	0.0	0.0	14.5	14.5	0.0	0.0	27.4	27.4	0.0	0.0	36.3	36.3
Residential Efficient Ec	77.4	91.0	93.6	99.4	5.8	122.1	125.1	139.0	13.9	135.2	138.5	153.3	14.8	161.5	164.9	182.2	17.3	191.7	197.5	217.7	20.2
Commercial Efficient E	71.9	83.1	85.3	91.6	6.3	112.6	116.1	137.2	21.1	123.7	128.3	150.7	22.4	148.4	153.3	180.1	26.9	177.0	183.8	215.9	32.2
Industrial Efficient Equ	63.5	75.0	78.9	91.4	12.5	100.4	104.5	133.6	29.1	114.8	118.6	150.0	31.4	140.4	144.1	180.1	36.0	169.6	177.5	218.8	41.3
Freight & Air Efficiency	0.0	0.0	0.0	7.7	7.7	0.0	0.0	37.3	37.3	0.0	0.0	43.9	43.9	0.0	0.0	47.9	47.9	0.0	0.0	49.4	49.4
Business Light-Vehicle	172.6	204.0	202.8	201.3	-1.5	228.0	225.3	243.6	18.3	242.8	228.6	226.7	-1.9	253.1	230.2	217.9	-12.3	263.9	233.4	216.8	-16.6
Non-Energy Productio	0.0	0.0	0.0	-26.6	-26.6	0.0	0.0	-46.0	-46.0	0.0	0.0	-65.1	-65.1	0.0	0.0	-86.0	-86.0	0.0	0.0	-114.6	-114.6
Expenditures on Imported Oil and Gas (bil 2000$)																					
Crude Oil Imports	91.8	91.3	222.6	221.9	-0.7	98.7	171.0	145.5	-25.5	105.4	134.6	80.0	-54.6	111.3	123.9	43.0	-80.9	118.3	123.9	30.0	-93.9
Petroleum Product Imp	30.9	44.1	76.6	73.6	-3.0	65.2	28.7	24.9	-3.8	85.1	23.2	22.5	-0.7	103.1	22.3	21.0	-1.3	125.0	21.9	20.4	-1.5
Natural Gas Imports	10.4	15.3	22.3	22.9	0.6	21.1	21.0	21.3	0.3	39.7	29.6	26.3	-3.3	56.6	40.5	29.6	-10.9	69.6	68.9	43.6	-25.3
Light-Duty Vehicle Purchases (bil 2000$)																					
Household Vehicles	211.0	249.4	247.9	246.1	-1.8	278.7	275.4	297.7	22.3	296.7	279.4	277.1	-2.3	309.4	281.3	266.3	-15.0	322.6	285.3	264.9	-20.4
Business Light-Vehicle	172.6	204.0	202.8	201.3	-1.5	228.0	225.3	243.6	18.3	242.8	228.6	226.7	-1.9	253.1	230.2	217.9	-12.3	263.9	233.4	216.8	-16.6
Total Light-Vehicles	383.6	453.4	450.7	447.4	-3.3	506.7	500.7	541.3	40.6	539.5	508.0	503.9	-4.1	562.5	511.5	484.2	-27.3	586.5	518.7	481.7	-37.0
Avg Price per Vehicle	22103	24124	25302	25268.0	-34.0	24894.0	27833.0	31351.0	3518.0	24969.0	27959.0	29697.0	1738.0	25014.0	27870.0	28821.0	951.0	25059.0	27979.0	28962.0	983.0
Energy Expenditures by Major Sector (bil 2000$)																					
Residential	143.6	148.7	166.8	194.4	27.6	172.7	178.4	202.5	24.1	211.0	213.8	226.9	13.1	264.5	263.5	278.5	15.0	326.9	333.6	357.6	24.0
Commercial	117.8	116.1	131.3	155.5	24.2	140.1	145.0	157.5	12.5	171.1	174.7	167.9	-6.8	217.3	217.3	204.0	-13.3	267.7	272.5	259.9	-12.6
Industrial	183.3	200.3	226.9	257.3	30.4	222.8	234.2	249.7	15.5	263.6	256.6	245.4	-11.2	313.6	299.0	260.9	-38.1	370.0	358.8	298.9	-59.9
Transportation	264.5	339.2	537.6	539.6	2.0	381.5	477.5	430.3	-47.2	413.1	406.9	312.2	-94.7	438.9	374.2	253.1	-121.1	468.5	368.3	237.0	-131.3
Total Economy-wide	709.1	804.2	1062.7	1146.8	84.1	917.1	1035.2	1040.1	4.9	1058.9	1052.0	952.4	-99.6	1234.4	1154.0	996.7	-157.3	1433.1	1333.2	1153.3	-179.9
Average Primary Ener	$7.07	$6.97	$9.60	$10.56	$0.96	$7.10	$9.14	$10.66	$1.52	$7.59	$9.05	$10.13	$1.08	$8.41	$9.70	$10.17	$0.47	$9.10	$10.71	$10.92	$0.21
Energy Consumption (Quads)																					
Petroleum Products	38.1	46.0	42.7	42.2	-0.5	50.9	38.2	34.4	-3.9	55.2	34.0	25.3	-8.7	58.8	32.0	19.9	-12.1	63.1	31.2	17.4	-13.8
Natural Gas	23.4	29.4	27.2	27.4	0.2	36.1	29.2	29.3	0.1	42.6	31.9	30.8	-1.1	47.4	35.0	31.9	-3.1	50.6	41.6	35.8	-5.8
Coal	23.4	25.4	25.5	23.3	-2.2	27.4	29.0	15.9	-13.1	26.1	32.2	16.5	-15.7	23.8	33.1	21.1	-12.0	26.2	32.1	23.7	-8.4
Renewable Energy	6.9	7.2	7.3	7.7	0.4	8.1	9.0	10.4	1.5	9.7	11.1	14.3	3.2	11.4	12.9	18.4	5.5	12.9	14.4	22.4	8.0
Nuclear Power	8.1	7.2	7.7	7.7	0.0	6.3	7.6	7.3	-0.3	5.7	6.7	6.7	0.1	5.0	5.6	6.4	0.8	4.4	4.8	5.9	1.1
Other	0.4	0.4	0.4	0.4	0.0	0.4	0.4	0.4	0.0	0.4	0.4	0.4	0.0	0.4	0.4	0.4	0.0	0.4	0.4	0.4	0.0
Total Primary Energy	100.3	115.4	110.7	108.6	-2.1	129.1	113.3	97.6	-15.7	139.5	116.3	94.1	-22.2	146.8	119.0	98.0	-21.0	157.5	124.5	105.6	-18.9
TPE / GDP (kBtu / 200	10.16	8.75	8.92	8.78	-0.14	7.29	7.04	6.11	-0.93	6.17	5.78	4.71	-1.07	5.08	4.75	3.94	-0.81	4.27	3.86	3.30	-0.56
Carbon Emissions (MtC)																					
Transportation Carbon	511	656	611	604	-7	741	574	494	-80	803	513	344	-169	852	473	265	-208	914	458	245	-213
End Use Carbon	458	521	488	490	2	612	512	462	-50	678	547	464	-83	711	559	472	-87	775	600	503	-97
Central Station Carbor	589	695	683	626	-57	757	727	447	-280	765	779	439	-340	747	810	515	-295	782	821	565	-256
Captured & Sequester	0	0	0	0	0	0	0	-38	-38	0	0	-182	-182	0	0	-343	-343	0	0	-454	-454
Total Carbon Emissi	1,559	1,872	1,782	1,720	-62	2,110	1,813	1,365	-448	2,246	1,839	1,065	-774	2,310	1,842	909	-933	2,471	1,879	859	-1,020
Carbon-to-GDP Ratio (grams / 2000$)																					
Emissions per $ Outpu	158	142	144	139	-5	119	112	85	-27	99	91	53	-38	80	72	37	-35	67	57	27	-30

Appendix 2
Engines of Growth
Summary of Modeling Runs

Big Problems Ahead

	2000	2010				2020				2030				2040				2050			
		Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg
ENERGY PRICE AND SUPPLY TABLES																					
Carbon Charge (2000$)																					
Carbon Price ($/metric	0	0	0	146	146	0	0	211	211	0	0	234	234	0	0	258	258	0	0	285	285
Carbon Price in Gas ($	0.00	0.00	0.00	2.14	2.14	0.00	0.00	3.09	3.09	0.00	0.00	3.41	3.41	0.00	0.00	3.77	3.77	0.00	0.00	4.16	4.16
Carbon Price in Coal (	0.00	0.00	0.00	3.66	3.66	0.00	0.00	5.29	5.29	0.00	0.00	5.84	5.84	0.00	0.00	6.45	6.45	0.00	0.00	7.12	7.12
World Oil Price (2000$	27.72	23.39	58.62	58.56	-0.06	24.34	46.61	45.94	-0.67	25.18	42.93	41.49	-1.44	25.90	41.12	38.85	-2.27	26.74	40.46	37.76	-2.70
Crude Oil Price (2000$	4.66	3.93	9.86	9.85	-0.01	4.09	7.84	7.72	-0.12	4.23	7.22	6.98	-0.24	4.35	6.91	6.53	-0.38	4.49	6.80	6.35	-0.45
Petroleum Supply (Quads)																					
Domestic Crude Oil	15.0	14.8	14.4	14.3	0.0	15.4	13.8	13.4	-0.4	15.9	13.4	12.5	-0.9	16.4	13.3	11.9	-1.4	16.9	13.3	11.6	-1.7
Imports Crude Oil	19.7	23.2	22.6	22.5	-0.1	24.1	21.8	18.8	-3.0	24.9	18.7	11.5	-7.2	25.6	17.9	6.6	-11.3	26.3	18.2	4.7	-13.5
Imports Petroleum Pro	4.7	8.0	5.6	5.3	-0.2	11.4	2.6	2.3	-0.3	14.4	2.3	2.3	0.0	16.9	2.3	2.3	0.0	19.9	2.3	2.3	0.0
Natural Gas Supply (Quads)																					
Domestic Gas Product	19.6	23.7	21.5	21.7	0.2	28.7	22.9	23.0	0.1	32.3	24.2	23.5	-0.7	35.3	26.2	24.2	-2.0	37.3	30.3	26.7	-3.6
Imports of Gas	3.9	5.7	5.6	5.7	0.1	7.4	6.2	6.3	0.0	10.3	7.7	7.3	-0.4	12.1	8.9	7.7	-1.2	13.2	11.3	9.2	-2.1
Total Gas Demand	23.4	29.4	27.2	27.4	0.2	36.1	29.2	29.3	0.1	42.6	31.9	30.8	-1.1	47.4	35.0	31.9	-3.1	50.6	41.6	35.8	-5.8
Natural Gas Prices (2000$)																					
Wellhead Gas Price ($	2.76	2.75	4.04	4.10	0.06	2.93	3.46	3.49	0.03	3.95	3.93	3.68	-0.25	4.81	4.68	3.93	-0.75	5.38	6.25	4.87	-1.38
																					0.00
Industrial Gas Price ($	3.65	3.36	4.94	7.15	2.21	3.47	4.10	7.22	3.12	4.63	4.61	7.73	3.12	5.60	5.46	8.35	2.89	6.23	7.24	9.81	2.57
Commercial Gas Price	7.39	5.36	8.13	10.40	2.27	4.89	5.87	9.01	3.14	6.38	6.36	9.32	2.96	7.31	7.10	9.64	2.54	7.59	8.91	10.99	2.08
Residential Gas Price	8.51	6.48	9.25	11.52	2.27	6.01	6.99	10.13	3.14	7.50	7.48	10.44	2.96	8.43	8.22	10.76	2.54	8.71	10.03	12.11	2.08
Electric Utility Gas Price ($/MBtu)																					
Without Carbon Charg	3.19	3.18	4.66	4.73	0.07	3.38	3.99	4.03	0.04	4.55	4.54	4.24	-0.30	5.54	5.40	4.53	-0.87	6.21	7.21	5.62	-1.59
With Carbon Charge	3.19	3.18	4.66	6.87	2.21	3.38	3.99	7.12	3.13	4.55	4.54	7.65	3.11	5.54	5.40	8.30	2.90	6.21	7.21	9.78	2.57
Avg Electricity Price	67.0	60	63	74	11	61	69	84	15	62	73	88	15	70	82	98	16	79	91	109	18
Industrial Electricity Pr	45.0	44	46	58	12	44	51	67	16	45	57	71	14	53	65	81	16	61	73	91	18
Commercial Electricity	73.0	60	63	74	11	62	69	85	16	62	74	88	14	71	83	99	16	79	91	110	19
Residential Electricity I	81.0	75	78	89	11	76	83	99	16	76	88	102	14	85	97	113	16	94	106	125	19
TOTAL PRIMARY ENERGY BY FUEL AND SECTOR																					
Petroleum Products (Quads)																					
Transport Petroleum	25.7	32.9	30.7	30.3	-0.4	37.1	28.8	24.8	-4.0	40.2	25.7	17.2	-8.4	42.6	23.7	13.3	-10.4	45.7	22.8	12.2	-10.6
Other Petroleum	12.4	13.1	12.1	11.9	-0.2	13.8	9.5	9.6	0.1	15.0	8.4	8.1	-0.3	16.2	8.3	6.6	-1.7	17.4	8.3	5.2	-3.2
TOTAL PETROLE	38.1	46.0	42.7	42.2	-0.5	50.9	38.2	34.4	-3.9	55.2	34.0	25.3	-8.7	58.8	32.0	19.9	-12.1	63.1	31.2	17.4	-13.8
Natural Gas (Quads)																					
Central Station Natura	4.2	6.6	5.0	5.2	0.2	7.8	3.0	6.0	3.0	10.5	1.6	4.9	3.3	13.8	3.2	2.7	-0.5	13.2	6.2	1.9	-4.4
Sector Natural Gas	19.2	22.7	22.1	22.2	0.1	28.1	26.1	23.1	-2.9	31.9	30.2	25.6	-4.6	33.4	31.6	29.0	-2.7	37.1	35.0	33.7	-1.4
Transport Natural Gas	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.2	0.1	0.1	0.0	0.2	0.2	0.2	0.0	0.3	0.3	0.3	0.0
NGas reformed to hyd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL NATURAL	23.4	29.4	27.2	27.4	0.2	36.1	29.2	29.3	0.1	42.6	31.9	30.8	-1.1	47.4	35.0	31.9	-3.1	50.6	41.6	35.8	-5.8
Coal (Quads)																					
Coal Generation	20.8	22.9	23.0	20.8	-2.2	25.1	26.6	13.2	-13.4	23.9	29.0	11.4	-17.6	21.8	28.2	14.4	-13.8	24.3	25.8	17.1	-8.6
Other sector Coal	2.6	2.5	2.5	2.5	0.0	2.3	2.3	1.9	-0.4	2.2	2.2	1.5	-0.7	2.0	2.0	1.2	-0.9	1.9	1.9	0.8	-1.1
IGCC for hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.8	0.8	0.0	1.1	3.5	2.5	0.0	2.8	5.5	2.7	0.0	4.5	5.8	1.3
TOTAL COAL	23.4	25.4	25.5	23.3	-2.2	27.4	29.0	15.9	-13.1	26.1	32.2	16.5	-15.7	23.8	33.1	21.1	-12.0	26.2	32.1	23.7	-8.4
Renewable Energy (Quads)																					
Trans Renewable Ene	0.2	0.2	0.2	0.4	0.2	0.2	0.7	1.4	0.7	0.3	1.0	1.6	0.6	0.3	0.9	1.2	0.2	0.3	0.8	1.0	0.2
Electric Generation Re	3.8	3.7	3.9	4.0	0.2	4.3	4.7	5.3	0.6	5.3	6.1	7.8	1.8	6.5	7.5	11.2	3.7	7.3	8.6	13.7	5.2
Wind Power to produc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
On Site Renewable Er	2.9	3.2	3.2	3.2	0.0	3.6	3.6	3.7	0.1	4.1	4.1	4.7	0.6	4.7	4.5	6.0	1.5	5.3	5.0	7.7	2.7
TOTAL RENEWAB	6.9	7.2	7.3	7.7	0.4	8.1	9.0	10.4	1.5	9.7	11.1	14.3	3.2	11.4	12.9	18.4	5.5	12.9	14.4	22.4	8.0
Hydrogen Production (Quads)																					
Hydrogen fr Natural Ga	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydrogen fr Renewabl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydrogen fr Coal Gasi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.3	0.0	0.5	1.6	1.1	0.0	1.3	2.5	1.2	0.0	2.0	2.6	0.6
TOTAL HYDROGE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.0	0.5	1.8	1.4	0.0	1.3	2.5	1.2	0.0	2.0	2.6	0.6

Big Problems Ahead

	2000	2010				2020				2030				2040				2050			
		Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg
ELECTRICITY SUPPLY TABLES																					
1. Electricity Supply-Demand Balance (BkWh)																					
Electricity End-Use De	3,569	4,371	4,239	4,140	-99	5,078	4,682	4,055	-627	5,778	5,193	4,269	-924	6,575	5,904	4,835	-1,069	7,481	6,524	5,510	-1,014
large CHP	369	410	410	449	39	421	425	533	108	423	434	602	168	430	447	658	211	438	459	697	238
Dist Gen - excl Winc	2	26	34	83	49	104	129	277	148	228	271	551	280	350	394	796	402	482	509	1,035	526
Total large CHP and o	370	436	444	531	87	525	554	810	256	652	705	1,153	448	781	841	1,454	613	919	968	1,731	763
Amount for Own Use	187	231	235	282	47	280	296	432	136	352	381	623	242	421	454	785	331	496	523	935	412
Sales to grid	183	205	209	250	41	245	258	377	119	300	324	531	207	359	387	669	282	423	445	796	351
Electric Generators Lo	3,458	4,211	4,062	3,864	-198	4,824	4,373	3,442	-931	5,438	4,760	3,313	-1,447	6,152	5,375	3,605	-1,770	6,973	5,905	4,036	-1,869
Net Imports	35	35	35	35	0	35	35	35	0	35	35	35	0	35	35	35	0	35	35	35	0
Total to grid	3,676	4,451	4,305	4,149	-156	5,104	4,666	3,854	-812	5,772	5,120	3,879	-1,241	6,546	5,797	4,308	-1,489	7,431	6,385	4,867	-1,518
Sales from grid	3,382	4,140	4,004	3,858	-146	4,798	4,386	3,623	-763	5,426	4,812	3,646	-1,166	6,153	5,450	4,050	-1,400	6,985	6,002	4,575	-1,427
T&D Losses	294	312	301	290	-11	306	280	231	-49	346	307	233	-74	393	348	258	-90	446	383	292	-91
2. CHP and Other Distributed Generation (TWh)																					
Conventional CHP	356	419	423	504	81	473	465	643	178	520	488	728	240	554	507	785	278	576	521	823	302
Municiple Solid Waste	14	14	14	14	0	12	12	12	0	11	11	11	0	10	10	10	0	10	10	10	0
Fuel Cell CHP	0	0	4	9	5	18	60	118	58	48	151	293	142	70	215	415	200	81	247	478	231
Building Integrated PV	1	3	3	5	2	23	17	37	20	73	55	122	67	146	109	243	134	252	189	420	231
3. Electricity Generation, excl. CHP and other DG (TWh)																					
Coal	1,907	2,225	2,226	2,050	-176	2,540	2,741	1,359	-1,382	2,539	3,173	1,103	-2,070	2,544	3,333	1,370	-1,963	3,298	3,229	1,649	-1,580
Gas and Oil	533	878	690	650	-40	1,114	359	725	366	1,592	183	621	438	2,114	449	340	-109	2,034	937	262	-675
Biomass Gasification	0	0	0	0	0	0	0	1	1	14	16	22	6	55	63	85	22	139	160	214	54
Nuclear	752	737	771	771	0	702	790	790	0	677	738	738	0	652	688	688	0	627	638	638	0
Hydro	321	321	321	321	0	321	321	321	0	321	321	321	0	321	321	321	0	321	321	321	0
Wind	9	36	39	56	17	119	131	208	77	220	244	394	150	310	344	558	214	364	404	656	252
Geothermal	16	15	15	16	1	27	29	38	9	74	84	114	30	156	177	242	65	189	215	295	80
TOTAL Load	3,458	4,211	4,062	3,864	-198	4,824	4,373	3,442	-931	5,438	4,760	3,313	-1,447	6,152	5,375	3,605	-1,770	6,973	5,905	4,036	-1,869
4. Fuel Use, excl. CHP and other DG (Quads)																					
Coal	20.8	22.9	23.0	20.8	-2.2	25.1	26.7	14.0	-12.7	23.9	30.0	15.0	-15.1	21.8	31.1	19.9	-11.1	24.3	30.3	22.9	-7.3
Petroleum	1.2	0.6	1.0	0.9	-0.2	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas	4.2	6.6	5.0	5.2	0.2	7.8	3.0	6.0	3.0	10.5	1.6	4.9	3.3	13.8	3.2	2.7	-0.5	13.2	6.2	1.9	-4.4
Biomass Cofiring and (	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0
Net Imports Btu Equiva	0.4	0.3	0.4	0.4	0.0	0.3	0.3	0.3	0.0	0.3	0.3	0.3	0.0	0.3	0.3	0.3	0.0	0.3	0.3	0.3	0.1
Fossil HeatRate (Btu/k	10,729	9,711	9,968	9,947	-21	9,008	9,575	9,176	-399	8,348	9,029	9,109	80	7,642	8,174	9,283	1,109	7,036	7,565	9,232	1,667
5. Conventional Air Emissions																					
SO2 (thous tons)	12,767	10,366	6,376	6,455	79	8,618	3,673	1,629	-2,044	6,667	2,860	1,045	-1,815	4,187	1,727	1,050	-677	2,553	1,324	960	-364
NOx (thous tons)	5,905	4,622	2,741	2,892	151	4,088	2,222	1,376	-846	3,316	1,920	875	-1,045	2,269	1,385	708	-677	1,509	1,038	535	-503
Mercury (tons)	49	49	21	23	2	42	13	8	-5	33	11	5	-6	21	8	5	-4	13	6	4	-2
6. Investment Flows (mil 2000$)																					
Gas Facilities	4,124	7,987	2,820	2,355	-465	9,920	2,622	768	-1,854	11,619	2,611	985	-1,626	8,854	4,751	942	-3,809	6,051	9,366	909	-8,457
Coal Facilities	0	7,154	9,023	3,118	-5,905	6,322	16,585	11,765	-4,820	6,280	21,683	19,318	-2,365	21,498	18,050	16,081	-1,969	30,959	10,925	9,733	-1,192
Renewable Facilities	126	2,820	3,545	5,643	2,098	5,788	7,231	11,345	4,114	9,323	11,492	17,513	6,021	10,296	12,779	19,243	6,464	10,093	12,729	19,139	6,410
Total (non DG) Faciliti	4,251	17,961	15,389	11,117	-4,272	22,030	26,437	23,878	-2,559	27,222	35,786	37,815	2,029	40,648	35,580	36,266	686	47,103	33,020	29,782	-3,238
Total Distributed Gene	0	1,453	1,567	3,617	2,050	3,730	4,260	8,440	4,180	4,134	4,563	9,113	4,550	4,673	4,967	10,011	5,044	5,393	5,507	11,212	5,705
7. Operating & Maintenance (mil 2000$)																					
Coal Facilities	17,760	19,881	19,987	18,625	-1,362	20,652	22,244	12,194	-10,050	19,041	24,615	11,604	-13,011	17,100	25,691	14,554	-11,137	20,384	26,012	16,013	-9,999
Gas Facilities	1,141	2,806	2,153	1,907	-246	4,141	2,134	2,394	260	5,996	1,960	1,907	-53	7,678	2,275	1,452	-823	7,437	3,766	1,203	-2,563
Hydro Facilities	3,120	3,120	3,120	3,120	0	3,120	3,120	3,120	0	3,120	3,120	3,120	0	3,120	3,120	3,120	0	3,120	3,120	3,120	0
Renewable Facilities	391	593	675	860	185	1,553	1,889	2,830	941	3,500	4,277	6,439	2,162	6,311	7,690	11,384	3,694	8,466	10,409	15,242	4,833
Total O&M costs	22,412	26,400	25,934	24,512	-1,422	29,466	29,388	20,538	-8,850	31,658	33,972	23,070	-10,902	34,209	38,777	30,511	-8,266	39,407	43,307	35,578	-7,729
TRANSPORTATION AND ENERGY TABLE																					
Vehicle Miles Traveled (LDVs incl Light Commercial Trucks)																					
VMT (billions)	2,396	3,295	3,259	3,257	-2	3,715	3,498	3,438	-60	4,095	3,625	3,461	-164	4,367	3,687	3,432	-255	4,588	3,738	3,407	-331
New Vehicle On-Road Average Fuel-Economy Calculations																					
New Car Avg Fuel-Ecc	22.8	25.3	34.9	34.8	-0.1	25.6	43.5	61.8	18.3	25.6	49.4	69.0	19.6	25.6	53.7	71.5	17.8	25.5	56.1	74.3	18.2
New Light Truck Avg F	17.0	19.1	26.2	26.1	-0.1	19.3	32.4	42.4	10.0	19.3	37.9	52.2	14.3	19.2	41.4	55.7	14.3	19.2	43.5	62.7	19.2
Overall LDV On-Road	19.8	22.0	30.3	30.1	-0.2	22.1	37.5	50.8	13.3	22.0	43.2	60.0	16.8	21.9	47.3	63.3	16.0	21.9	49.7	68.6	18.9
New Light-Duty Vehicle Additions by Technology (1000)																					
Conventional Vehicle	17,256	17,988	13,751	13,880	129	19,239	6,795	0	-6,795	20,383	4,770	0	-4,770	21,175	4,134	0	-4,134	21,990	3,902	0	-3,902
Dedicated CNG Vehicl	48	76	72	72	0	122	143	138	-5	174	235	220	-15	221	320	293	-27	280	434	389	-45
Advanced Diesel & oth	0	0	2,670	2,452	-218	0	4,152	4,127	-25	0	4,324	2,876	-1,448	0	4,386	2,672	-1,714	0	4,377	1,662	-2,715
Hybrid Electric Vehicle	52	730	1,318	1,301	-17	991	5,077	4,952	-125	1,050	4,274	5,304	1,030	1,091	2,371	4,943	2,572	1,133	438	3,847	3,409
FCV with on-board refo	0	0	0	0	0	0	1,216	2,992	1,776	0	604	0	-604	0	0	0	0	0	0	0	0
hydrogen FCV	0	0	0	0	0	0	608	5,059	4,451	0	3,964	8,567	4,603	0	7,143	8,891	1,748	0	9,386	10,732	1,346
Electric Vehicles	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL LDV Sales	17,355	18,794	17,811	17,705	-106	20,353	17,990	17,267	-723	21,607	18,171	16,967	-1,204	22,487	18,353	16,798	-1,555	23,403	18,538	16,631	-1,907

Big Problems Ahead	2000	2010				2020				2030				2040				2050			
		Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg
Transportation Energy Consumption by Fuel Type (excluding pipeline natural gas use) - Quads																					
Motor Gasoline	15.8	19.9	18.6	18.9	0.3	21.8	14.3	12.4	-2.0	23.5	10.2	6.1	-4.2	24.9	7.6	3.7	-3.9	26.1	6.1	3.1	-3.0
Diesel Fuel	5.2	7.3	6.8	6.3	-0.5	8.7	8.7	7.1	-1.6	9.5	9.7	6.4	-3.3	10.2	10.5	5.5	-5.0	11.3	11.2	5.3	-5.9
Jet fuel	3.6	4.5	4.1	3.9	-0.2	5.3	4.5	4.0	-0.5	5.9	4.5	3.5	-1.0	6.1	4.3	2.8	-1.5	7.1	4.4	2.6	-1.8
Residual and other Pe	1.1	1.2	1.2	1.2	0.1	1.3	1.2	1.2	0.0	1.3	1.2	1.3	0.1	1.3	1.2	1.2	0.0	1.3	1.2	1.2	0.0
Petroleum Subtota	25.7	32.9	30.7	30.3	-0.4	37.1	28.8	24.8	-4.0	40.2	25.7	17.2	-8.4	42.6	23.7	13.3	-10.4	45.7	22.8	12.2	-10.6
Natural Gas Fuel	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.2	0.1	0.1	0.0	0.2	0.2	0.2	0.0	0.3	0.3	0.3	0.0
Biofuels replace gasoli	0.1	0.2	0.2	0.3	0.1	0.2	0.4	0.8	0.4	0.2	0.6	0.9	0.3	0.2	0.5	0.7	0.1	0.2	0.4	0.6	0.1
Bio-Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.2	0.1	0.0	0.1	0.2	0.0	0.0	0.1	0.2	0.0
Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.0	0.5	1.8	1.4	0.0	1.3	2.5	1.2	0.0	2.0	2.6	0.6
Electricity	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0
Total Delivered E	25.9	33.2	31.0	30.8	-0.2	37.5	29.4	26.3	-3.1	40.6	27.1	20.4	-6.7	43.1	25.9	16.9	-9.0	46.2	25.8	15.9	-9.9
New Light-Duty Vehicle Shares by Technology (pct)																					
Conventional Vehicle	99.4	95.7	77.2	78.4	1.2	94.5	37.8	0.0	-37.8	94.3	26.2	0.0	-26.2	94.2	22.5	0.0	-22.5	94.0	21.0	0.0	-21.0
Dedicated CNG Vehicl	0.3	0.4	0.4	0.4	0.0	0.6	0.8	0.8	0.0	0.8	1.3	1.3	0.0	1.0	1.7	1.7	0.0	1.2	2.3	2.3	0.0
Advanced Diesel & oth	0.0	0.0	15.0	13.8	-1.2	0.0	23.1	23.9	0.8	0.0	23.8	17.0	-6.8	0.0	23.9	15.9	-8.0	0.0	23.6	10.0	-13.6
Hybrid Electric Vehicle	0.3	3.9	7.4	7.3	-0.1	4.9	28.2	28.7	0.5	4.9	23.5	31.3	7.8	4.9	12.9	29.4	16.5	4.8	2.4	23.1	20.7
FCV with on-board refo	0.0	0.0	0.0	0.0	0.0	0.0	6.8	17.3	10.5	0.0	3.3	0.0	-3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
hydrogen FCV	0.0	0.0	0.0	0.0	0.0	0.0	3.4	29.3	25.9	0.0	21.8	50.5	28.7	0.0	38.9	52.9	14.0	0.0	50.6	64.5	13.9
Electric Vehicles	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL PCT	100.0	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0
New Light-Duty Vehicle Shares by Detailed Size Class(pct)																					
SubComCar	15.1	12.7	13.2	13.2	0.0	11.4	15.3	18.5	3.2	10.7	17.6	21.1	3.5	10.4	20.1	23.8	3.7	10.2	22.9	26.9	4.0
CompacCar	17.6	15.7	15.2	15.2	0.0	14.7	16.5	13.3	-3.2	14.0	17.9	14.4	-3.5	13.7	19.2	15.5	-3.7	13.4	20.7	16.7	-4.0
MediumCar	20.2	20.9	21.0	21.0	0.0	20.9	17.7	18.8	1.1	20.9	15.0	15.9	0.9	21.2	12.9	13.6	0.7	21.5	10.3	10.9	0.6
XLargeCar	3.9	4.2	4.1	4.1	0.0	4.3	3.4	2.3	-1.1	4.3	2.8	1.9	-0.9	4.4	2.3	1.6	-0.7	4.5	1.8	1.2	-0.6
Mini_Vans	11.2	11.5	11.5	11.5	0.0	11.5	11.5	11.5	0.0	11.5	11.5	11.5	0.0	11.5	11.5	11.5	0.0	11.5	11.5	11.5	0.0
RegulrSUV	10.3	11.2	11.7	11.7	0.0	12.1	12.3	14.5	2.2	12.6	12.6	14.8	2.2	12.5	12.7	14.9	2.2	12.4	12.8	14.9	2.1
Large_SUV	0.6	4.6	4.0	4.0	0.0	5.7	4.0	1.7	-2.3	6.6	3.9	1.7	-2.2	6.8	3.9	1.7	-2.2	7.1	3.8	1.6	-2.2
PickupVan	21.1	19.3	19.3	19.3	0.0	19.4	19.3	19.3	0.0	19.5	18.7	18.7	0.0	19.5	17.4	17.4	0.0	19.5	16.2	16.2	0.0
TOTAL PCT	100.0	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0
New Light-Duty Vehicles by Major Size Class (1000)																					
Small Car	5,669	5,339	5,060	5030	-30	5309	5730	5500	-230	5339	6450	6023	-427	5430	7218	6607	-611	5522	8077	7247	-830
Large Car	4,177	4,712	4,466	4439	-27	5115	3793	3641	-152	5441	3236	3021	-215	5750	2791	2555	-236	6072	2245	2014	-231
Mini-van	1,948	2,166	2,053	2041	-12	2346	2074	1990	-84	2491	2095	1956	-139	2592	2116	1936	-180	2698	2137	1917	-220
SUV	1,905	2,955	2,801	2784	-17	3634	2921	2803	-118	4130	3000	2802	-198	4337	3037	2779	-258	4555	3073	2757	-316
Cargo Veh	3,657	3,620	3,431	3411	-20	3948	3473	3333	-140	4206	3390	3165	-225	4378	3192	2921	-271	4556	3005	2696	-309
TOTAL LDV Sales	17,355	18,794	17,811	17705	-106	20353	17990	17267	-723	21607	18171	16967	-1204	22487	18353	16798	-1555	23403	18538	16631	-1907
Fuel Consumption by Transportation Mode (excludes Specialized Petroleum Products such as Lubricants) - Quads																					
Total LDV Fuel Use	15.0	19.0	17.8	17.8	0.0	20.8	14.8	13.5	-1.3	22.6	12.1	9.3	-2.8	24.0	10.5	7.3	-3.2	25.2	9.6	6.6	-3.0
Cm Truck Fuel	0.7	0.9	0.8	0.8	0.0	0.9	0.8	0.7	-0.2	1.0	0.8	0.5	-0.4	1.1	1.0	0.5	-0.5	1.3	1.1	0.5	-0.6
Freight Truck Fuel	4.3	6.2	5.7	5.6	-0.1	7.4	6.6	5.4	-1.2	8.1	6.9	4.2	-2.6	8.8	7.4	3.5	-3.8	9.7	8.0	3.5	-4.5
Jet_air Fuel	3.6	4.5	4.1	3.9	-0.2	5.3	4.5	4.0	-0.5	5.9	4.5	3.5	-1.0	6.1	4.3	2.8	-1.5	7.1	4.4	2.6	-1.8
RailTrn Fuel	0.6	0.7	0.7	0.7	0.0	0.8	0.8	0.8	0.0	0.9	0.8	0.8	0.0	0.9	0.8	0.8	-0.1	0.9	0.8	0.7	-0.1
MarineT Fuel	1.5	1.6	1.6	1.6	0.0	1.8	1.6	1.7	0.1	1.8	1.7	1.7	0.1	1.8	1.7	1.7	0.0	1.7	1.6	1.6	0.0
TOTAL Fuel Use	25.6	32.9	30.7	30.5	-0.2	37.2	29.1	26.0	-3.1	40.3	26.8	20.1	-6.7	42.8	25.6	16.6	-9.0	45.9	25.5	15.5	-9.9

Cheap Energy Reigns Supreme	2000	2010				2020				2030				2040				2050			
		Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg
Macroeconomic Variables (bil 2000$)																					
Real Consumption	6,699	8,801	9,149	9,034	-115	11,719	12,700	12,316	-384	14,724	16,148	15,699	-449	18,478	20,528	20,083	-445	23,179	25,621	25,190	-431
Real Investment	1,898	2,751	2,962	3,007	45	4,305	4,880	5,040	160	5,769	6,709	6,829	120	7,749	8,762	8,831	70	10,414	11,531	11,537	6
Real Govt Purchases	1,684	2,084	2,084	2,088	4	2,439	2,439	2,471	32	2,846	2,846	2,902	56	3,320	3,320	3,384	64	3,872	3,872	3,935	63
Real Exports	1,213	2,291	2,292	2,291	-1	4,945	4,977	4,945	-32	6,664	6,700	6,664	-36	8,478	8,516	8,477	-39	9,443	9,483	9,443	-40
Real Imports	1,620	2,733	2,766	2,756	-10	5,704	5,252	5,286	34	7,396	7,346	7,393	47	9,160	9,627	9,699	72	10,056	10,733	10,839	106
Real GDP	9,873	13,194	13,721	13,664	-57	17,704	19,744	19,485	-259	22,608	25,056	24,702	-354	28,865	31,499	31,076	-423	36,852	39,774	39,266	-508
Program Spending (bil 2000$)																					
Deployment Programs	0.0	0.0	0.0	1.5	1.5	0.0	0.0	16.1	16.1	0.0	0.0	30.1	30.1	0.0	0.0	34.0	34.0	0.0	0.0	34.0	34.0
Technology R&D	0.0	0.0	0.0	1.8	1.8	0.0	0.0	9.0	9.0	0.0	0.0	13.1	13.1	0.0	0.0	14.8	14.8	0.0	0.0	14.8	14.8
Macroeconomic Investment Components (bil 2000$)																					
Aggregate Investment	0.0	0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0	0.0	
Electric Utility	4.3	18.0	14.2	15.3	1.1	22.0	15.8	22.7	6.9	27.2	22.3	31.7	9.4	40.7	30.8	41.4	10.7	47.1	37.0	45.0	8.0
Infrastructure	0.0	22.9	24.3	-33.5	-57.8	27.9	28.8	-62.5	-91.3	29.8	31.3	-90.3	-121.6	31.4	33.6	-133.7	-167.3	33.6	35.9	-188.3	-224.2
Efficient Equipment	212.8	249.0	248.0	286.5	38.5	335.2	331.4	419.0	87.6	373.7	365.9	461.5	95.6	450.4	446.6	551.6	105.0	538.4	539.9	659.6	119.7
Vehicle Purchases	383.6	453.4	466.3	442.3	-24.0	506.7	548.6	613.1	64.5	539.5	612.6	600.2	-12.4	562.5	671.0	602.6	-68.4	586.5	735.2	619.5	-115.7
Total Energy-Related I	600.7	743.3	752.8	710.6	-42.2	891.8	924.5	992.3	67.8	970.2	1032.1	1003.0	-29.1	1084.9	1181.9	1061.9	-120.0	1205.6	1348.0	1135.8	-212.2
Detailed Investment Totals																					
Electric Facilities - Fos	4.1	15.1	12.8	5.8	-7.0	16.2	13.1	3.9	-9.2	17.9	18.0	4.1	-13.9	30.4	26.1	11.7	-14.4	37.0	32.4	15.6	-16.8
Renewable Electricity	0.1	2.8	1.4	9.6	8.3	5.8	2.7	18.8	16.1	9.3	4.2	27.5	23.3	10.3	4.7	29.6	24.9	10.1	4.6	29.5	24.9
Distributed Generation	0.0	1.5	2.6	3.7	1.1	3.7	3.9	7.5	3.6	4.1	4.1	8.6	4.5	4.7	4.3	10.1	5.8	5.4	4.5	12.2	7.7
Hydrogen Infrastructur	0.0	0.0	0.0	2.4	2.4	0.0	0.0	11.7	11.7	0.0	0.0	14.2	14.2	0.0	0.0	15.4	15.4	0.0	0.0	15.8	15.8
Fuel Supply	0.0	21.5	21.7	20.9	-0.8	24.2	24.8	20.7	-4.1	25.7	27.3	19.9	-7.4	26.7	29.3	19.9	-9.4	28.3	31.4	21.0	-10.4
Sequestration Investm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	2.3	0.0	0.0	15.0	15.0	0.0	0.0	16.7	16.7	0.0	0.0	23.6	23.6
Residential Efficient E	77.4	91.0	90.7	99.1	8.4	122.1	121.1	140.1	19.0	135.2	133.1	153.8	20.8	161.5	160.5	183.2	22.7	191.7	192.1	218.3	26.2
Commercial Efficient E	71.9	83.1	82.7	92.1	9.4	112.6	111.5	139.5	28.0	123.7	121.4	152.8	31.4	148.4	147.0	182.9	36.0	177.0	176.5	218.7	42.2
Industrial Efficient Equ	63.5	75.0	74.6	95.3	20.8	100.4	98.8	139.4	40.6	114.8	111.5	154.8	43.3	140.4	139.2	185.5	46.3	169.6	171.2	222.7	51.5
Freight & Air Efficiency	0.0	0.0	0.0	8.7	8.7	0.0	0.0	48.7	48.7	0.0	0.0	58.1	58.1	0.0	0.0	62.7	62.7	0.0	0.0	64.7	64.7
Business Light-Vehicle	172.6	204.0	209.8	195.1	-14.7	228.0	246.9	254.0	7.2	242.8	275.7	243.9	-31.8	253.1	301.9	242.9	-59.0	263.9	330.8	249.7	-81.1
Non-Energy Productio	0.0	0.0	0.0	-60.6	-60.6	0.0	0.0	-104.8	-104.8	0.0	0.0	-148.1	-148.1	0.0	0.0	-195.8	-195.8	0.0	0.0	-260.9	-260.9
Expenditures on Imported Oil and Gas (bil 2000$)																					
Crude Oil Imports	91.8	91.3	90.7	89.3	-1.4	98.7	95.9	80.1	-15.8	105.4	98.6	58.3	-40.3	111.3	100.2	38.2	-62.0	118.3	104.1	28.3	-75.8
Petroleum Product Imp	30.9	44.1	44.4	40.5	-3.9	65.2	65.7	21.8	-43.9	85.1	84.2	10.3	-73.9	103.1	100.3	9.0	-91.3	125.0	121.2	8.2	-113.0
Natural Gas Imports	10.4	15.3	15.4	16.5	1.1	21.1	20.9	15.5	-5.4	39.7	37.6	14.3	-23.3	56.6	72.0	17.2	-54.8	69.6	112.4	21.6	-90.8
Light-Duty Vehicle Purchases (bil 2000$)																					
Household Vehicles	211.0	249.4	256.5	238.5	-18.0	278.7	301.7	310.4	8.7	296.7	336.9	298.1	-38.8	309.4	369.0	296.9	-72.1	322.6	404.3	305.1	-99.2
Business Light-Vehicle	172.6	204.0	209.8	195.1	-14.7	228.0	246.9	254.0	7.2	242.8	275.7	243.9	-31.8	253.1	301.9	242.9	-59.0	263.9	330.8	249.7	-81.1
Total Light-Vehicles	383.6	453.4	466.3	433.6	-32.7	506.7	548.6	564.4	15.8	539.5	612.6	542.1	-70.5	562.5	671.0	539.9	-131.1	586.5	735.2	554.8	-180.4
Avg Price per Vehicle	22103.0	24124.0	24231.0	24201.0	-30.0	24894.0	25050.0	30568.0	5518.0	24969.0	25076.0	28707.0	3631.0	25014.0	25111.0	28166.0	3055.0	25059.0	25156.0	28513.0	3357.0
Energy Expenditures by Major Sector (bil 2000$)																					
Residential	143.6	148.7	147.3	191.8	44.5	172.7	167.3	219.5	52.2	211.0	199.7	240.0	40.3	264.5	269.6	295.4	25.8	326.9	345.3	370.2	24.9
Commercial	117.8	116.1	114.5	154.9	40.4	140.1	135.5	172.6	37.1	171.1	161.7	180.8	19.1	217.3	219.0	220.9	1.9	267.7	281.2	275.0	-6.2
Industrial	183.3	200.3	198.9	283.8	84.9	222.8	218.4	293.4	75.0	263.6	254.4	280.7	26.3	313.6	320.6	292.8	-27.8	370.0	390.1	320.0	-70.1
Transportation	264.5	339.2	336.2	359.7	23.5	381.5	381.0	427.6	46.6	413.1	420.2	317.2	-103.0	438.9	456.5	261.5	-195.0	468.5	498.6	250.7	-247.9
Total Economy-wide	709.1	804.2	796.9	990.2	193.3	917.1	902.2	1113.1	210.9	1058.9	1036.1	1018.7	-17.4	1234.4	1265.7	1070.7	-195.0	1433.1	1515.2	1215.8	-299.4
Average Primary Ener	$7.07	$6.97	$6.90	$8.87	$1.97	$7.10	$7.00	$10.71	$3.70	$7.59	$7.32	$10.49	$3.17	$8.41	$8.30	$10.96	$2.66	$9.10	$9.19	$11.44	$2.25
Energy Consumption (Quads)																					
Petroleum Products	38.1	46.0	46.1	45.2	-0.9	50.9	51.8	39.8	-12.0	55.2	57.4	32.2	-25.2	58.8	62.8	27.1	-35.8	63.1	69.2	24.9	-44.3
Natural Gas	23.4	29.4	30.5	31.0	0.6	36.1	40.0	37.3	-2.7	42.6	49.8	39.6	-10.2	47.4	60.2	41.1	-19.1	50.6	69.5	43.3	-26.2
Coal	23.4	25.4	24.7	20.3	-4.4	27.4	23.7	9.4	-14.3	26.1	21.6	4.0	-17.6	23.8	17.0	3.1	-13.9	26.2	14.0	6.0	-8.0
Renewable Energy	6.9	7.2	6.9	7.8	0.9	8.1	7.1	11.2	4.1	9.7	7.6	16.1	8.6	11.4	8.1	21.8	13.7	12.9	8.7	28.0	19.3
Nuclear Power	8.1	7.2	6.9	7.0	0.0	6.3	5.9	5.9	0.0	5.7	4.9	4.9	0.0	5.0	4.0	4.2	0.3	4.4	3.2	3.7	0.5
Other	0.4	0.4	0.4	0.4	0.0	0.4	0.4	0.4	0.0	0.4	0.4	0.4	0.0	0.4	0.4	0.4	0.0	0.4	0.4	0.4	0.0
Total Primary Energy	100.3	115.4	115.5	111.6	-3.9	129.1	128.8	103.9	-24.9	139.5	141.6	97.1	-44.4	146.8	152.5	97.7	-54.8	157.5	165.0	106.3	-58.7
TPE / GDP (kBtu / 200	10.16	8.75	8.42	8.17	-0.25	7.29	6.52	5.33	-1.19	6.17	5.65	3.93	-1.72	5.08	4.84	3.14	-1.70	4.27	4.15	2.71	-1.44
Carbon Emissions (MtC)																					
Transportation Carbon	511	656	658	635	-23	741	758	569	-189	803	846	448	-398	852	930	376	-554	914	1,035	362	-673
End Use Carbon	458	521	529	511	-18	612	622	512	-110	678	710	494	-216	711	767	484	-283	775	812	508	-304
Central Station Carbor	589	695	687	604	-83	757	718	381	-337	765	734	260	-474	747	720	236	-484	782	737	280	-457
Captured & Sequester	0	0	0	0	0	0	0	-23	-23	0	0	-150	-150	0	0	-167	-167	0	0	-236	-236
Total Carbon Emissior	1,559	1,872	1,875	1,750	-125	2,110	2,098	1,439	-659	2,246	2,290	1,053	-1,237	2,310	2,417	929	-1,488	2,471	2,584	914	-1,670
Carbon-to-GDP Ratio (grams / 2000$)																					
Emissions per $ Outpu	158	142	137	128	-9	119	106	74	-32	99	91	43	-48	80	77	30	-47	67	65	23	-42

Cheap Energy Reigns Supreme

	2000	2010				2020				2030				2040				2050			
		Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg
ENERGY PRICE AND SUPPLY TABLES																					
Carbon Charge (2000$)																					
Carbon Price ($/metric	0	0	0	204	204	0	0	295	295	0	0	325	325	0	0	359	359	0	0	397	397
Carbon Price in Gas ($	0.00	0.00	0.00	2.98	2.98	0.00	0.00	4.30	4.30	0.00	0.00	4.75	4.75	0.00	0.00	5.25	5.25	0.00	0.00	5.80	5.80
Carbon Price in Coal (:	0.00	0.00	0.00	5.10	5.10	0.00	0.00	7.36	7.36	0.00	0.00	8.13	8.13	0.00	0.00	8.98	8.98	0.00	0.00	9.93	9.93
World Oil Price (2000$	27.72	23.39	23.18	23.00	-0.18	24.34	23.52	21.40	-2.12	25.18	23.32	18.95	-4.37	25.90	22.93	16.70	-6.23	26.74	22.94	15.13	-7.81
Crude Oil Price (2000$	4.66	3.93	3.90	3.87	-0.03	4.09	3.95	3.60	-0.35	4.23	3.92	3.19	-0.73	4.35	3.85	2.81	-1.04	4.49	3.86	2.54	-1.32
Petroleum Supply (Quads)																					
Domestic Crude Oil	15.0	14.8	14.8	14.7	-0.1	15.4	15.5	14.2	-1.3	15.9	16.1	13.4	-2.8	16.4	16.7	12.8	-4.0	16.9	17.4	12.4	-4.9
Imports Crude Oil	19.7	23.2	23.3	23.1	-0.2	24.1	24.2	22.3	-2.0	24.9	25.2	18.3	-6.8	25.6	26.0	13.6	-12.4	26.3	27.0	11.1	-15.9
Imports Petroleum Pro	4.7	8.0	8.1	7.5	-0.7	11.4	11.9	4.3	-7.5	14.4	15.3	2.3	-13.0	16.9	18.6	2.3	-16.3	19.9	22.4	2.3	-20.1
Natural Gas Supply (Quads)																					
Domestic Gas Product	19.6	23.7	24.6	25.0	0.4	28.7	32.0	30.3	-1.8	32.3	38.3	31.9	-6.5	35.3	44.9	32.8	-12.0	37.3	50.8	34.2	-16.6
Imports of Gas	3.9	5.7	5.9	6.0	0.2	7.4	8.0	7.1	-0.9	10.3	11.5	7.7	-3.8	12.1	15.3	8.3	-7.0	13.2	18.8	9.1	-9.7
Total Gas Demand	23.4	29.4	30.5	31.0	0.6	36.1	40.0	37.3	-2.7	42.6	49.8	39.6	-10.2	47.4	60.2	41.1	-19.1	50.6	69.5	43.3	-26.2
Natural Gas Prices (2000$)																					
Wellhead Gas Price ($	2.76	2.75	2.68	2.80	0.12	2.93	2.69	2.25	-0.44	3.95	3.34	1.90	-1.44	4.81	4.81	2.12	-2.69	5.38	6.13	2.42	-3.71
Industrial Gas Price ($.	3.65	3.36	3.27	6.40	3.13	3.47	3.18	6.96	3.78	4.63	3.92	6.98	3.06	5.60	5.60	7.71	2.11	6.23	7.10	8.60	1.50
Commercial Gas Price	7.39	5.36	5.20	8.43	3.23	4.89	4.43	7.91	3.48	6.38	5.32	7.53	2.21	7.31	7.31	8.15	0.84	7.59	8.72	8.91	0.19
Residential Gas Price	8.51	6.48	6.32	9.55	3.23	6.01	5.55	9.03	3.48	7.50	6.44	8.65	2.21	8.43	8.43	9.27	0.84	8.71	9.84	10.03	0.19
Electric Utility Gas Price ($/MBtu)																					
Without Carbon Charg	3.19	3.18	3.09	3.23	0.14	3.38	3.10	2.59	-0.51	4.55	3.86	2.19	-1.67	5.54	5.55	2.44	-3.11	6.21	7.07	2.80	-4.27
With Carbon Charge	3.19	3.18	3.09	6.20	3.11	3.38	3.10	6.89	3.79	4.55	3.86	6.94	3.08	5.54	5.55	7.69	2.14	6.21	7.07	8.59	1.52
Avg Electricity Price	67	60	59	80	21	61	59	92	33	62	58	97	39	70	67	108	41	79	76	120	44
Industrial Electricity Pr	45	44	43	63	20	44	42	75	33	45	42	80	38	53	50	91	41	61	58	102	44
Commercial Electricity	73	60	59	80	21	62	60	93	33	62	59	97	38	71	67	109	42	79	76	120	44
Residential Electricity I	81	75	74	95	21	76	74	107	33	76	73	111	38	85	82	123	41	94	91	135	44
TOTAL PRIMARY ENERGY BY FUEL AND SECTOR																					
Petroleum Products (Quads)																					
Transport Petroleum	25.7	32.9	33.0	31.8	-1.2	37.1	38.0	28.6	-9.4	40.2	42.3	22.5	-19.9	42.6	46.5	18.8	-27.7	45.7	51.7	18.1	-33.5
Other Petroleum	12.4	13.1	13.1	13.3	0.2	13.8	13.8	11.3	-2.6	15.0	15.1	9.7	-5.4	16.2	16.3	8.2	-8.1	17.4	17.6	6.8	-10.8
TOTAL PETROLE	38.1	46.0	46.1	45.2	-0.9	50.9	51.8	39.8	-12.0	55.2	57.4	32.2	-25.2	58.8	62.8	27.1	-35.8	63.1	69.2	24.9	-44.3
Natural Gas (Quads)																					
Central Station Natura	4.2	6.6	7.2	9.0	1.8	7.8	11.1	12.1	1.0	10.5	15.7	12.9	-2.8	13.8	22.8	12.5	-10.4	13.2	29.7	10.3	-19.4
Sector Natural Gas	19.2	22.7	23.2	22.0	-1.2	28.1	28.8	25.0	-3.8	31.9	34.0	26.1	-7.9	33.4	37.1	27.6	-9.5	37.1	39.5	31.5	-8.0
Transport Natural Gas	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.2	0.2	0.1	-0.1	0.2	0.2	0.1	-0.1	0.3	0.3	0.2	-0.2
NGas reformed to hyd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.5	0.5	0.0	0.0	0.9	0.9	0.0	0.0	1.3	1.3
TOTAL NATURAL	23.4	29.4	30.5	31.0	0.6	36.1	40.0	37.3	-2.7	42.6	49.8	39.6	-10.2	47.4	60.2	41.1	-19.1	50.6	69.5	43.3	-26.2
Coal (Quads)																					
Coal Generation	20.8	22.9	22.3	17.8	-4.4	25.1	21.4	7.7	-13.7	23.9	19.4	2.7	-16.7	21.8	15.0	2.2	-12.8	24.3	12.1	5.5	-6.6
Other sector Coal	2.6	2.5	2.5	2.5	0.0	2.3	2.3	1.8	-0.6	2.2	2.2	1.3	-0.8	2.0	2.0	0.9	-1.1	1.9	1.9	0.5	-1.4
IGCC for hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL COAL	23.4	25.4	24.7	20.3	-4.4	27.4	23.7	9.4	-14.3	26.1	21.6	4.0	-17.6	23.8	17.0	3.1	-13.9	26.2	14.0	6.0	-8.0
Renewable Energy (Quads)																					
Trans Renewable Ene	0.2	0.2	0.2	0.3	0.1	0.2	0.2	0.7	0.5	0.3	0.2	1.0	0.8	0.3	0.2	0.8	0.5	0.3	0.3	0.7	0.4
Electric Generation Re	3.8	3.7	3.6	4.3	0.7	4.3	3.5	6.4	2.9	5.3	3.7	9.6	5.9	6.5	4.0	13.5	9.5	7.3	4.3	16.9	12.6
Wind Power to produc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.4	0.4	0.0	0.0	0.8	0.8	0.0	0.0	1.1	1.1
On Site Renewable Er	2.9	3.2	3.2	3.2	0.1	3.6	3.4	3.9	0.5	4.1	3.7	5.1	1.5	4.7	3.9	6.8	2.9	5.3	4.1	9.3	5.2
TOTAL RENEWAB	6.9	7.2	6.9	7.8	0.9	8.1	7.1	11.2	4.1	9.7	7.6	16.1	8.6	11.4	8.1	21.8	13.7	12.9	8.7	28.0	19.3
Hydrogen Production (Quads)																					
Hydrogen fr Natural G	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.4	0.4	0.0	0.0	0.7	0.7	0.0	0.0	1.0	1.0
Hydrogen fr Renewabl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.2	0.2	0.0	0.0	0.3	0.3
Hydrogen fr Coal Gasi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL HYDROGE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.5	0.5	0.0	0.0	1.0	1.0	0.0	0.0	1.4	1.4

Cheap Energy Reigns Supreme	2000	2010				2020				2030				2040				2050			
		Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg
ELECTRICITY SUPPLY TABLES																					
1. Electricity Supply-Demand Balance (BkWh)																					
Electricity End-Use De	3,569	4,371	4,405	4,236	-169	5,078	5,201	4,227	-974	5,778	5,931	4,526	-1,405	6,575	6,769	5,182	-1,587	7,481	7,717	5,948	-1,769
large CHP	369	410	435	443	8	421	495	496	1	423	543	519	-24	430	584	536	-48	438	613	547	-66
Dist Gen - excl Winc	2	26	65	76	11	104	160	243	83	228	257	502	245	350	329	781	452	482	388	1,118	730
Total large CHP and o	370	436	500	519	19	525	655	739	84	652	800	1,022	222	781	913	1,317	404	919	1,001	1,665	664
Amount for Own Use	187	231	265	275	10	280	350	395	45	352	432	552	120	421	493	711	218	496	541	899	358
Sales to grid	183	205	235	244	9	245	305	344	39	300	368	470	102	359	420	606	186	423	461	766	305
Electric Generators Lo	3,458	4,211	4,181	3,980	-201	4,824	4,821	3,698	-1,123	5,438	5,447	3,723	-1,724	6,152	6,222	4,116	-2,106	6,973	7,139	4,570	-2,569
Net Imports	35	35	35	35	0	35	35	35	0	35	35	35	0	35	35	35	0	35	35	35	0
Total to grid	3,676	4,451	4,451	4,259	-192	5,104	5,161	4,077	-1,084	5,772	5,850	4,228	-1,622	6,546	6,677	4,757	-1,920	7,431	7,635	5,371	-2,264
Sales from grid	3,382	4,140	4,140	3,961	-179	4,798	4,851	3,832	-1,019	5,426	5,499	3,975	-1,524	6,153	6,276	4,471	-1,805	6,985	7,176	5,049	-2,127
T&D Losses	294	312	312	298	-14	306	310	245	-65	346	351	254	-97	393	401	285	-116	446	458	322	-136
2. CHP and Other Distributed Generation (TWh)																					
Conventional CHP	356	419	485	484	-1	473	614	585	-29	520	708	629	-79	554	771	652	-119	576	811	665	-146
Municiple Solid Waste	14	14	14	14	0	12	12	12	0	11	11	11	0	10	10	10	0	10	10	10	0
Fuel Cell CHP	0	0	0	13	13	18	21	79	58	48	57	175	118	70	83	242	159	81	96	275	179
Building Integrated PV	1	3	1	8	7	23	8	63	55	73	24	207	183	146	49	413	364	252	84	715	631
3. Electricity Generation, excl. CHP and other DG (TWh)																					
Coal	1,907	2,225	2,156	1,771	-385	2,540	2,141	820	-1,321	2,539	1,990	291	-1,699	2,544	1,606	215	-1,391	3,298	1,434	533	-901
Gas and Oil	533	878	954	1,069	115	1,114	1,611	1,475	-136	1,592	2,395	1,650	-745	2,114	3,541	1,665	-1,876	2,034	4,633	1,475	-3,158
Biomass Gasification	0	0	0	0	0	0	0	1	1	14	5	27	22	55	21	103	82	139	53	261	208
Nuclear	752	737	714	714	0	702	677	677	0	677	607	607	0	652	537	537	0	627	467	467	0
Hydro	321	321	321	321	0	321	321	321	0	321	321	321	0	321	321	321	0	321	321	321	0
Wind	9	36	23	88	65	119	56	358	302	220	97	687	590	310	135	976	841	364	157	1,149	992
Geothermal	16	15	13	17	4	27	14	45	31	74	31	140	109	156	62	299	237	189	74	364	290
TOTAL Load	3,458	4,211	4,181	3,980	-201	4,824	4,821	3,698	-1,123	5,438	5,447	3,723	-1,724	6,152	6,222	4,116	-2,106	6,973	7,139	4,570	-2,569
4. Fuel Use, excl. CHP and other DG (Quads)																					
Coal	20.8	22.9	22.3	17.8	-4.4	25.1	21.4	7.7	-13.7	23.9	19.4	2.7	-16.7	21.8	15.0	2.2	-12.8	24.3	12.1	5.5	-6.6
Petroleum	1.2	0.6	0.6	0.8	0.2	0.0	0.0	0.2	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas	4.2	6.6	7.2	9.0	1.8	7.8	11.1	12.1	1.0	10.5	15.7	12.9	-2.8	13.8	22.8	12.5	-10.4	13.2	29.7	10.3	-19.4
Biomass Cofiring and (	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0
Net Imports Btu Equiva	0.4	0.3	0.3	0.3	0.0	0.3	0.3	0.3	0.0	0.3	0.3	0.3	0.0	0.3	0.3	0.3	0.0	0.3	0.2	0.3	0.0
Fossil HeatRate (Btu/k	10,729	9,711	9,657	9,721	64	9,008	8,680	8,676	-4	8,348	8,002	8,054	52	7,642	7,360	7,820	460	7,036	6,894	7,899	1,005
5. Conventional Air Emissions																					
SO_2 (thous tons)	12,767	10,366	6,434	6,160	-274	8,618	3,516	1,299	-2,217	6,667	2,382	367	-2,015	4,187	957	114	-843	2,553	502	225	-277
NO_x (thous tons)	5,905	4,622	2,838	2,699	-139	4,088	2,222	1,185	-1,037	3,316	1,808	590	-1,218	2,269	1,218	386	-832	1,509	856	265	-591
Mercury (tons)	49	49	24	22	-2.3	42	15	6	-9.6	33	12	2	-9.8	21	7	0	-6.4	13	4	1	-3.1
6. Investment Flows (mil 2000$)																					
Gas Facilities	4,124	7,987	10,801	5,678	-5,123	9,920	11,200	3,280	-7,920	11,619	16,081	2,207	-13,874	8,854	19,439	5,106	-14,333	6,051	22,793	5,989	-16,804
Coal Facilities	0	7,154	2,038	84	-1,954	6,322	1,847	643	-1,204	6,280	1,940	1,940	0	21,498	6,640	6,640	0	30,959	9,562	9,562	0
Renewable Facilities	126	2,820	1,353	9,566	8,213	5,788	2,728	18,776	16,048	9,323	4,240	27,509	23,269	10,296	4,665	29,613	24,948	10,093	4,633	29,452	24,819
Total (non DG) Faciliti	4,251	17,961	14,192	15,328	1,136	22,030	15,775	22,700	6,925	27,222	22,261	31,655	9,394	40,648	30,743	41,359	10,616	47,103	36,988	45,003	8,015
Total Distributed Gene	0	1,453	2,559	3,719	1,160	3,730	3,943	7,457	3,514	4,134	4,078	8,600	4,522	4,673	4,257	10,128	5,871	5,393	4,497	12,169	7,672
7. Operating & Maintenance (mil 2000$)																					
Coal Facilities	17,760	19,881	19,425	17,118	-2,307	20,652	17,931	8,628	-9,303	19,041	15,539	4,207	-11,332	17,100	11,528	2,943	-8,585	20,384	9,863	3,779	-6,084
Gas Facilities	1,141	2,806	3,037	2,542	-495	4,141	5,794	4,220	-1,574	5,996	8,561	4,679	-3,882	7,678	12,134	4,766	-7,368	7,437	15,557	4,854	-10,703
Hydro Facilities	3,120	3,120	3,120	3,120	0	3,120	3,120	3,120	0	3,120	3,120	3,120	0	3,120	3,120	3,120	0	3,120	3,120	3,120	0
Renewable Facilities	391	593	478	1,205	727	1,553	841	4,497	3,656	3,500	1,638	9,977	8,339	6,311	2,811	16,957	14,146	8,466	3,737	22,216	18,479
Total O&M costs	22,412	26,400	26,060	23,985	-2,075	29,466	27,686	20,466	-7,220	31,658	28,859	21,984	-6,875	34,209	29,593	27,786	-1,807	39,407	32,278	33,968	1,690
TRANSPORTATION AND ENERGY TABLE																					
Vehicle Miles Traveled (LDVs incl Light Commercial Trucks)																					
VMT (billions)	2,396	3,295	3,311	3,265	-46	3,715	3,840	3,528	-312	4,095	4,417	3,702	-715	4,367	4,935	3,803	-1,132	4,588	5,436	3,879	-1,557
New Vehicle On-Road Average Fuel-Economy Calculations																					
New Car Avg Fuel-Ecc	22.8	25.3	25.2	26.5	1.3	25.6	25.5	54.5	29.0	25.6	25.6	61.4	35.8	25.6	25.6	64.1	38.5	25.5	25.5	67.4	41.9
New Light Truck Avg F	17.0	19.1	19.1	19.9	0.8	19.3	19.2	39.3	20.1	19.3	19.3	45.6	26.3	19.2	19.2	51.1	31.9	19.2	19.2	59.9	40.7
Overall LDV On-Road	19.8	22.0	21.9	23.0	1.1	22.1	22.0	46.1	24.1	22.0	22.0	52.9	30.9	21.9	21.9	57.5	35.6	21.9	21.9	63.9	42.0
New Light-Duty Vehicle Additions by Technology (1000)																					
Conventional Vehicle	17,256	17,988	18,419	17,319	-1,100	19,239	20,700	0	-20,700	20,383	23,045	0	-23,045	21,175	25,161	0	-25,161	21,990	27,459	0	-27,459
Dedicated CNG Vehicl	48	76	78	73	-5	122	131	111	-20	174	197	152	-45	221	262	188	-74	280	350	233	-117
Advanced Diesel & oth	0	0	0	0	0	0	0	4,847	4,847	0	0	3,498	3,498	0	0	3,083	3,083	0	0	1,990	1,990
Hybrid Electric Vehicle	52	730	748	527	-221	991	1,067	9,279	8,212	1,050	1,187	12,392	11,205	1,091	1,296	11,412	10,116	1,133	1,415	9,108	7,693
FCV with on-board refc	0	0	0	0	0	0	0	2,815	2,815	0	0	0	0	0	0	0	0	0	0	0	0
hydrogen FCV	0	0	0	0	0	0	0	1,411	1,411	0	0	2,840	2,840	0	0	4,485	4,485	0	0	8,127	8,127
Electric Vehicles	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL LDV Sales	17,355	18,794	19,245	17,918	-1,327	20,353	21,898	18,463	-3,435	21,607	24,430	18,883	-5,547	22,487	26,719	19,168	-7,551	23,403	29,224	19,457	-9,767
Cheap Energy Reigns Supreme	2000	2010				2020				2030				2040				2050			

		Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg	Official Future	Base	Challenge	Chg
Transportation Energy Consumption by Fuel Type (excluding pipeline natural gas use) - Quads																					
Motor Gasoline	15.8	19.9	20.0	20.0	0.0	21.8	22.6	15.6	-6.9	23.5	25.4	9.8	-15.7	24.9	28.2	7.1	-21.0	26.1	30.9	6.2	-24.7
Diesel Fuel	5.2	7.3	7.3	6.5	-0.8	8.7	8.7	7.1	-1.6	9.5	9.5	7.0	-2.5	10.2	10.2	6.4	-3.8	11.3	11.3	6.3	-4.9
Jet fuel	3.6	4.5	4.5	4.2	-0.4	5.3	5.4	4.6	-0.8	5.9	6.1	4.4	-1.7	6.1	6.8	4.0	-2.8	7.1	8.3	4.4	-3.9
Residual and other Pe	1.1	1.2	1.2	1.2	0.0	1.3	1.3	1.3	0.0	1.3	1.3	1.3	0.0	1.3	1.3	1.3	0.0	1.3	1.3	1.2	-0.1
Petroleum Subtota	25.7	32.9	33.0	31.8	-1.2	37.1	38.0	28.6	-9.4	40.2	42.3	22.5	-19.9	42.6	46.5	18.8	-27.7	45.7	51.7	18.1	-33.5
Natural Gas Fuel	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.2	0.2	0.1	-0.1	0.2	0.2	0.1	-0.1	0.3	0.3	0.2	-0.2
Biofuels replace gasoli	0.1	0.2	0.1	0.2	0.1	0.2	0.1	0.5	0.3	0.2	0.2	0.6	0.5	0.2	0.2	0.5	0.3	0.2	0.2	0.4	0.2
Bio-Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.1
Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.5	0.5	0.0	0.0	1.0	1.0	0.0	0.0	1.4	1.4
Electricity	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0
Total Delivered E	25.9	33.2	33.3	32.2	-1.1	37.5	38.3	29.4	-8.9	40.6	42.7	23.9	-18.9	43.1	47.0	20.6	-26.4	46.2	52.3	20.3	-32.0
New Light-Duty Vehicle Shares by Technology (pct)																					
Conventional Vehicle	99.4	95.7	95.7	96.7	1.0	94.5	94.5	0.0	-94.5	94.3	94.3	0.0	-94.3	94.2	94.2	0.0	-94.2	94.0	94.0	0.0	-94.0
Dedicated CNG Vehicl	0.3	0.4	0.4	0.4	0.0	0.6	0.6	0.6	0.0	0.8	0.8	0.8	0.0	1.0	1.0	1.0	0.0	1.2	1.2	1.2	0.0
Advanced Diesel & oth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.3	26.3	0.0	0.0	18.5	18.5	0.0	0.0	16.1	16.1	0.0	0.0	10.2	10.2
Hybrid Electric Vehicle	0.3	3.9	3.9	2.9	-1.0	4.9	4.9	50.3	45.4	4.9	4.9	65.6	60.7	4.9	4.9	59.5	54.6	4.8	4.8	46.8	42.0
FCV with on-board ref	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.2	15.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
hydrogen FCV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.6	7.6	0.0	0.0	15.0	15.0	0.0	0.0	23.4	23.4	0.0	0.0	41.8	41.8
Electric Vehicles	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL PCT	100.0	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0
New Light-Duty Vehicle Shares by Detailed Size Class(pct)																					
SubComCar	15.1	12.7	12.7	13.2	0.5	11.4	11.4	18.5	7.1	10.7	10.7	21.1	10.4	10.4	10.4	23.8	13.4	10.2	10.2	26.9	16.7
CompacCar	17.6	15.7	15.7	15.2	-0.5	14.7	14.7	13.3	-1.4	14.0	14.0	14.4	0.4	13.7	13.7	15.5	1.8	13.4	13.4	16.7	3.3
MediumCar	20.2	20.9	20.9	21.0	0.1	20.9	20.9	18.8	-2.1	20.9	20.9	15.9	-5.0	21.2	21.2	13.6	-7.6	21.5	21.5	10.9	-10.6
XLargeCar	3.9	4.2	4.2	4.1	-0.1	4.3	4.3	2.3	-2.0	4.3	4.3	1.9	-2.4	4.4	4.4	1.6	-2.8	4.5	4.5	1.2	-3.3
Mini_Vans	11.2	11.5	11.5	11.5	0.0	11.5	11.5	11.5	0.0	11.5	11.5	11.5	0.0	11.5	11.5	11.5	0.0	11.5	11.5	11.5	0.0
RegulrSUV	10.3	11.2	11.2	11.7	0.5	12.1	12.1	14.5	2.4	12.6	12.6	14.8	2.2	12.5	12.5	14.9	2.4	12.4	12.4	14.9	2.5
Large_SUV	0.6	4.6	4.6	4.0	-0.6	5.7	5.7	1.7	-4.0	6.6	6.6	1.7	-4.9	6.8	6.8	1.7	-5.1	7.1	7.1	1.6	-5.5
PickupVan	21.1	19.3	19.3	19.3	0.0	19.4	19.4	19.3	-0.1	19.5	19.5	18.7	-0.8	19.5	19.5	17.4	-2.1	19.5	19.5	16.2	-3.3
TOTAL PCT	100.0	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0
New Light-Duty Vehicles by Major Size Class (1000)																					
Small Car	5,669	5,339	5,468	5,091	-377	5,309	5,712	5,881	169	5,339	6,036	6,703	667	5,430	6,452	7,539	1,087	5,522	6,896	8,478	1,582
Large Car	4,177	4,712	4,826	4,493	-333	5,115	5,503	3,893	-1,610	5,441	6,152	3,362	-2,790	5,750	6,832	2,915	-3,917	6,072	7,582	2,356	-5,226
Mini-van	1,948	2,166	2,218	2,065	-153	2,346	2,524	2,128	-396	2,491	2,816	2,177	-639	2,592	3,080	2,210	-870	2,698	3,369	2,243	-1,126
SUV	1,905	2,955	3,026	2,818	-208	3,634	3,910	2,997	-913	4,130	4,670	3,118	-1,552	4,337	5,154	3,171	-1,983	4,555	5,688	3,226	-2,462
Cargo Veh	3,657	3,620	3,707	3,452	-255	3,948	4,248	3,564	-684	4,206	4,756	3,523	-1,233	4,378	5,202	3,333	-1,869	4,556	5,689	3,154	-2,535
TOTAL LDV Sales	17,355	18,794	19,245	17,918	-1,327	20,353	21,898	18,463	-3,435	21,607	24,430	18,883	-5,547	22,487	26,719	19,168	-7,551	23,403	29,224	19,457	-9,767
Fuel Consumption by Transportation Mode (excludes Specialized Petroleum Products such as Lubricants) - Quads																					
Total LDV Fuel Use	15.0	19.0	19.1	18.8	-0.3	20.8	21.6	15.6	-6.0	22.6	24.5	11.3	-13.2	24.0	27.3	9.1	-18.2	25.2	30.0	8.3	-21.7
Cm Truck Fuel	0.7	0.9	0.9	0.8	0.0	0.9	0.9	0.7	-0.2	1.0	1.0	0.5	-0.5	1.1	1.1	0.5	-0.6	1.3	1.3	0.5	-0.8
Freight Truck Fuel	4.3	6.2	6.2	5.8	-0.4	7.4	7.4	5.7	-1.8	8.1	8.1	4.7	-3.5	8.8	8.8	4.0	-4.7	9.7	9.7	4.2	-5.6
Jet_air Fuel	3.6	4.5	4.5	4.2	-0.4	5.3	5.4	4.6	-0.8	5.9	6.1	4.4	-1.7	6.1	6.8	4.0	-2.8	7.1	8.3	4.4	-3.9
RailTrn Fuel	0.6	0.7	0.7	0.7	0.0	0.8	0.8	0.8	0.0	0.9	0.9	0.8	-0.1	0.9	0.9	0.8	-0.1	0.9	0.9	0.8	-0.1
MarineT Fuel	1.5	1.6	1.6	1.6	0.0	1.8	1.8	1.8	0.0	1.8	1.8	1.8	0.0	1.8	1.8	1.8	0.0	1.7	1.7	1.7	-0.1
TOTAL Fuel Use	25.6	32.9	33.0	31.9	-1.1	37.2	38.0	29.1	-8.9	40.3	42.4	23.6	-18.9	42.8	46.7	20.3	-26.4	45.9	51.9	19.9	-32.0