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73–334PS
2002

ENERGY REALITIES: RATES OF CONSUMPTION,
ENERGY RESERVES, AND FUTURE OPTIONS

HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY
COMMITTEE ON SCIENCE
HOUSE OF REPRESENTATIVES

ONE HUNDRED SEVENTH CONGRESS

FIRST SESSION

MAY 3, 2001

Serial No. 107–35

Printed for the use of the Committee on Science

Available via the World Wide Web: http://www.house.gov/science

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Appendix 2: Additional Material for the Record

ENERGY REALITIES: RATES OF CONSUMPTION, ENERGY RESERVES, AND FUTURE OPTIONS

THURSDAY, MAY 3, 2001

House of Representatives,

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Subcommittee on Energy,

Committee on Science,

Washington, DC.

The Subcommittee met, pursuant to call, at 10:05 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Roscoe G. Bartlett [Chairman of the Subcommittee] presiding.

Committee on Science

Subcommittee on Energy

U.S. House of Representatives

Hearing on

Energy Realities: Rates of Consumption, Energy Reserves, and Future Options

Thursday, May 3, 2001

10:00 A.M. TO 1:00 P.M.

2318 RAYBURN HOUSE OFFICE BUILDING

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Mr. Henry A. Courtright

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HEARING CHARTER

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Energy Realities: Rates of Consumption,

Energy Reserves, and Future Options

1. Purpose of the Hearing

On Thursday, May 3, 2001, the Subcommittee on Energy will hold a hearing on *Energy Realities: Rates of Consumption, Energy Reserves, and Future Options.* The purpose of the hearing is to examine what advanced technology options may be available to provide energy in the future since energy demand growth is outstripping current production and the nation faces the increasing risk of energy shortages in the future. The witness panel will include (1) Dr. Albert A. Bartlett, Professor Emeritus of Physics, University of Colorado at Boulder; (2) Dr. Suzanne D. Weedman, Program Coordinator, Energy Resources Programs, U. S. Geological Survey; (3) Dr. W. David Montgomery, Vice President, Charles River Associates; (4) Mr. Howard S. Geller, Executive Director Emeritus, American Council for an Energy Efficient Economy; (5) Mr. Henry A. Courtright, Vice President, Power Generation and Distributed Resources, Electric Power Research Institute; and, (6) Dr. Alexandra von Meier, Director, Environmental Technology Center, Sonoma State University.

2. Overview

As in most the world, the U.S. relies on fossil fuels—petroleum, coal, and natural gas—for most of its energy needs. Petroleum, or oil, is primarily used in the production of transportation fuel. Petroleum is used to produce home heating oil and as a feedstock for a huge array of petrochemicals from plastics to fertilizer (for example, oil comprises over 75 percent of materials by volume of tires).

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All fossil fuels are used to produce electricity, however, as a result of the 1973 Organization of Petroleum Exporting Countries (OPEC) oil embargo most oil-fired electricity production plants have been converted to coal- and natural gas-fired plants.

These fossil fuel sources provide energy for all of our daily activities from transportation and shipping to electricity for our homes and offices. Over the past decade, most new electricity production capacity has been natural gas but with the recent increases in natural gas prices, due to increasing demand and limited distribution capacity, orders for new coal-fired electricity generating capacity are accelerating.

The old and new economies depend on abundant and inexpensive energy to continue our impressive economic growth. Shortages cause increased prices for the manufacturing sector and electricity generators. These costs cascade through the economy causing increased prices (inflation) or reduced operating margins leading to layoffs and perhaps recession. Although the U.S. is known to have huge coal, oil, natural gas and uranium reserves—in addition to state-of-the-art renewable energy technologies—many of the energy shortage problems we are experiencing today stem from increasingly stringent environmental permitting regulations, energy distribution infrastructure constraints, poorly conceived and poorly implemented electricity deregulation (such as in California) causing market dislocations, and OPEC monopoly pricing power. However, we are headed in to an era when shortages of readily available fossil fuels will likely contribute to shortages in energy supply. We also have to consider the emissions profile of different forms of energy, as or Americans demand ever cleaner air and water and regulators push emissions down to near zero.

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The rates of consumption and demand growth are critical to determine the extent of our energy reserves. Technological innovation, conservation and efficiency have allowed us to decrease the energy intensity of our economic activity—in other words, we can make more for less. Energy efficient building and transportation technologies continue to reduce the rate of growth of demand for energy. Conservation efforts have also helped. Yet we still face increasing demand and a finite fossil fuel resource.

Clearly, this country and the world need to understand the reality of our energy supply and demand. Part of the solution is to extend our fossil reserves as much as possible. This can be partially achieved through efficiency and conservation. We can also improve extraction technologies to extend reserves and provide environmentally safe and responsible access to currently untapped reserves. We may also need to expand the use of clean coal technology and nuclear energy. Finally, we should continue to explore the potential of renewable forms of energy wherever practical.

2.1 Growing Imports of Oil from Politically Unstable Regions of the World

U.S. oil imports are at an all time high approaching 67 percent of total U.S. supply, growing from 54 percent in 1999. A growing regulatory burden has greatly increased the industry's costs (total environmental compliance investments exceeded $90 billion over the past decade) and expanded its product mix, reducing product fungibility—creating stranded markets and "product islands." This has reduced the industry's flexibility to respond to unusual market developments and discouraged investment in new facilities to increase production capacity. Increased regulation has also contributed to consolidation and downsizing within the industry. The U.S. has only half the refineries it had less than 20 years ago. Government actions have also placed America's best prospects for new oil and gas production off-limits to development, which has forced increased reliance on foreign crude oil supplies, driven jobs overseas, and deprived markets of additional petroleum that would tend to push prices downwards.

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A recent study by the Center for Strategic and International Studies concludes that the Middle East's Gulf states will remain the key supplier of oil to the world market and that U.S. dependence on imported oil from this region will continue to grow despite U.S. efforts to promote oil production in the states of the former Soviet Union. In other words, we are more dependent on imported oil today than we were at the time of the 1973 Oil Embargo. Additionally, China's demand for energy is expected to double over the next twenty years with most of their oil imports coming from the Middle East, competing with U.S. demand. Increased demand from the rest of the developing world will exacerbate these trends.

The same study predicts that military conflict will remain a threat in this oil-producing region and will be compounded by internal instability and domestic unrest. On the other hand, energy analysts have concluded that OPEC has become a sophisticated cartel over the past several decades, learning how to "tweak" production to achieve desired revenue flow. We are experiencing OPEC's market manipulations now with substantial price increases at the gasoline pump, in home heating fuels, and with fuel surcharges on airline tickets.

2.2 Growing "Electrification" of the United States

Since the 1973 OPEC oil embargo, the U.S. population has soared from 211 million to more than 281 million, and our economy has grown about 50 percent. Yet our use of energy has grown only 10 percent. The U.S. has learned to use energy much more efficiently. However, U.S. demand for electricity continues to grow. We have a growing population, an expanding economy, and technologies that require more and more electricity. E-commerce and the Internet are driving the current increase in electricity demand. At a recent seminar sponsored by the Brookings Institute, an expert panel concluded that the Internet and E-commerce are driving a major increase in U.S. electricity demand. A recent Scripps Howard News Article (see footnote 1) reported that a study produced by The Center for Energy and Climate Solutions estimates that by 2010, the energy savings from reduced construction (avoided via E-commerce) will be the equivalent of 175 power plants. That, in turn, is the equivalent of saving 300 million metric tons of carbon dioxide from being loaded into the atmosphere. The Internet is environmentally friendly because people are able to shop and work from home, therefore, not expending resources (except electricity) otherwise necessary for commerce infrastructure and transportation. The study concluded that environmental impacts from transportation of goods, shoppers and workers to and from stores and offices, and construction of new stores and offices are expected to decrease.

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Further increases in electricity demand can be expected as electric vehicles are deployed across the country. Electric powered vehicles reduce mobile source greenhouse gas emissions and our dependence on imported oil for gasoline and diesel fuel. However, recharging the batteries will result in significant additional demand for electricity.

2.3 U.S. Energy Supply and Consumption

The first chart below depicts each energy resources contribution to U.S. energy supply. This demand includes transportation demand. The second chart depicts each energy resources contribution to U.S. electricity demand. Since oil and gas are predominately used in transportation and industry applications, each energy resources share of the pie is larger, except for oil and gas.

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The United States spends over one-half trillion dollars annually for energy and our economic well being depends on reliable, affordable supplies of clean energy. Energy is also a global commodity. Growing populations and rising living standards, economies in transition to market-based systems, and increasing globalization of energy markets are expected to only increase the global demand for energy—by as much as 50 percent in the next twenty years in some regions of the world.

The two charts(see footnote 2) in this section show recent and projected U.S. fuel use and energy consumption by sector. America's energy resources are extensive and diverse. Coal, oil, natural gas, and uranium are abundant, and a variety of renewable resources are available in large untapped quantities. The United States produces almost twice as much energy as any other nation, and nearly as much as Russia and

China combined. Although our Nation uses most of this energy domestically, it exports considerable amounts of coal, refined petroleum products, and enriched uranium.

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In the chart above, the Energy Information Administration (EIA) has projected that nuclear energy's contribution to energy supply will decline over the next twenty years. This assumption was based on the fact that no new nuclear plant has been ordered in the U.S. during the last few decades. The EIA assumed that the operating licenses of some plants would not be renewed or that some plants may even be shut down early. This assumption may already have been proven wrong since the market demand for nuclear generating capacity is on an upswing and many utilities have applied to the Nuclear Regulatory Commission for license extensions.

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Energy is consumed in the four basic demand sectors of our economy: transportation, industry, residential, and commercial. Petroleum currently accounts for nearly 97 percent of fuels consumed in the transportation sector. Electricity and natural gas are the dominant fuels used in the residential and commercial sectors, while a wide variety of fuels are used in the industrial sector. Over 35 percent of primary energy consumed in the U.S. is used to generate electricity. In the U.S., demand for energy. and particularly electricity, is expected to continue to grow despite more efficient use of all energy sources. As an example, even with a tripling of renewable energy it only keeps pace with its current share of the energy mix.

2.4 Oil Price Volatility

Over the past few years, consumers have paid an average of about $1.20 per gallon for gasoline and have more recently risen to a range between $1.65 and $1.75 with even higher prices in California. Excise taxes comprised a large proportion of that price, averaging about 43.1 cents per gallon. In contrast, oil industry profits accounted for an estimated 7.3 cents per gallon of the pump price. The price refiners pay for crude oil is determined in the international marketplace by the forces of supply and demand. The price consumers pay at the pump also reflects these market forces. It is for this reason that changes in the retail price of gasoline closely track changes in the price of crude oil. The peaks and troughs of oil company profits reflect world crude price fluctuations. Not only do oil companies contend with greater volatility in their profit rates, but throughout most of the 1980s and 1990s they have also had to face a return on investment that has averaged less than the all-industry average.

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3. Energy, Reserves and Resources

3.1 Fossil Energy Reserves

3.1.1 Oil Reserves

U.S. crude oil, in the amount of 68.7 billion barrels, could be made available from various sources through 2015. Natural gas in oil and gas accumulations could also total 474 trillion cubic feet. These estimates are based on (1) economic quantities of undiscovered conventional and unconventional oil and gas evaluated at $30 per barrel of oil and at $3.34 per MCF of gas; (2) proven reserves on record as of January 1994; and (3) projections of field growth (inferred reserves in the assessment) from 1994 through 2015 for pre-1992 discoveries. Field growth accounts for 44 percent of the projected reserves of oil and 30 percent of the total reserves of natural gas. Based on World Resources Institute data, a 1995 survey of resource estimates revealed that world estimated reserves are conservatively set at 1.7 trillion barrels.

However, finding reserves is not sufficient to assure supply. Infrastructure constraints and environmental regulations may make it difficult or impossible to transport petroleum to the refinery. Even then, there may not be enough refinery capacity to absorb increased domestic production. Building a new refinery would be a formidable undertaking. The permitting process is very difficult and time consuming. Companies and other investors are reluctant to invest in a new refinery because the potential returns aren't too enticing. The nation's newest major refinery was constructed nearly 25 years ago.

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*3.1.2 Coal Reserves**(see footnote 3)*

Coal accounts for a major portion of U.S. energy at present and in projected future energy supply. The U. S. Geological Survey (USGS), Department of Interior has published reserve base estimated at nearly 475 billion short tons which USGS states "suggests that the United States has enough coal to meet projected energy needs for almost 200 years, based on current consumption rates. However, the traditional procedures used for estimating the demonstrated reserve base do not account for many environmental and technological restrictions placed on coal mining."

A better appreciation of the net amount of coal, considering restrictions imposed by technology, geology, and societal, environmental, and economic factors, is needed. As an example, a pilot study was conducted in cooperation with Dr. James C. Cobb, Assistant State Geologist, and his colleagues at the Kentucky Geological. Pertinent geologic, mining, land-use, and technological data were collected and their model was applied to data to eliminate coal reserves affected by land-use or technological restrictions. Neither recover restrictions nor economic factors were considered in the model. Results indicate that of the original 986.5 million short tons of coal in the study, 13 percent had been mined and 25 percent were restricted, leaving 62 percent of the original or about 612 million short tons of coal available for mining. However, only 44 percent of this available coal, or about 266 million short tons, was determined to comply with environmental constraints without further scrubbing technologies.

3.1.3 Natural Gas Reserves

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Forecasts(see footnote 4) for annual U.S. natural gas production indicate natural gas supply will grow from 21 trillion cubic feet (Tcf) in 2001 to around 27 Tcf by 2015. Demand is projected to exceed 30 Tcf by 2015. Whereas most of the historical U.S. natural gas has come from associated, high-permeability, and shallow offshore sources, around 50 percent of the produced natural gas in 2015 is forecast to come from deepwater, subsalt, and unconventional sources such as tight gas, shale gas, and coalbed methane sources. Coalbed methane represents a tremendous potential energy resource for the U.S. The in-place coalbed methane resources of the United States are estimated to be more than 700 Tcf, but less than 100 Tcf may be economically recoverable.

3.2 Uranium Reserves(see footnote 5)

Light water reactors consume relatively small amounts of fuel, and known global reserves of uranium are widespread. Yet, at current rates of use of about 70,000 tons per year in world nuclear reactors, known world resources of 4.24 million tons amount to only 55 years of supply. However, this energy resource is abundant in the U.S. Estimates have shown that the U.S. has enough reserves to power its own reactors for 500 years. Worldwide, if 12.13 million tons of additional speculative (geological evidence but not characterized) resources are included, some 200 years of resource can be identified. However, light water reactors use only 2 percent of the energy available from natural uranium contained in fuel. Most of the energy remains unused in the used nuclear fuel removed from reactors. Reprocessing the used nuclear fuel could extend the energy extracted from natural uranium to 75 percent or higher. The reserves of uranium could be extended using breeder reactor technology.

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Uranium is distributed throughout the world in reserves having various costs of exploitation. The above figures for known resources include those of less dean $60 per pound (the first quarter of 2001 spot price for uranium is around $7.50 per pound and has been below $15 per pound for a decade). Even though large amounts of uranium may be available beyond known or speculative reserves, this does not mean that the potential supply of energy from nuclear power is simply proportional to whatever quantities can be identified. For example, seawater is often cited as a source of natural uranium without reference to the cost of extracting it. Uranium dispersed throughout the earth's crust or in seawater may be a large energy resource, but is not necessarily an economic energy source in comparison with other options.

A qualification to the notion of finite energy resources is given by the example of fossil fuel reserves. Fossil fuels have seemingly always been in danger of depletion 30 years from the moment any estimate is made. This has to do with the state of knowledge at any point, as driven by commercial interest, prospecting technology and activity in fossil fuel extraction. Economic reserves of fossil fuel have consistently risen over the years even as the rate of consumption has increased.

Nuclear fuel reserves are assumed to follow the same pattern. They could be expected to grow as demand and uranium price increased. Unlike fossil fuels, uranium accounts for a relatively small proportion of final electricity cost, so large price increases could be tolerated in the cost of finding and extracting uranium before this had a significant impact on final electricity production costs. This places less of a sharp edge on reserve estimates and depletion rates for natural uranium.

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3.3 Renewable Reserves

It is difficult to quantify renewable reserves since they are natural phenomena and technology constrained. They cannot easily be included in the electricity baseload because of their natural variability and their distance froze market (in the case of wind, hydro, geothermal and perhaps solar). Renewable resources, when exploited on a large scale, also can generate protest for anti-environmental consequences—hydro dams are being breached where they restrict salmon spawning, some people think wind turbines are noisy and contribute to "visual pollution." Solar panels are space intensive and require toxic chemicals in the production process. Geothermal energy requires drilling into the earth sometimes in pristine wilderness areas, with many of the same concerns as oil drilling can produce. Many of these renewable resources are either expensive on a kWh basis, or capital intensive, prompting many energy providers to shy away from them at this time. However, even with the constraints imposed by costs, technological hurdles, environmental concerns, and variability of supply, renewable reserves will be an important part of our future energy portfolio in many parts of this country.

3.4 Efficiency and Conservation Reserves-Equivalent (off-setting)

The Alliance to Save Energy has estimated the contribution of energy efficiency to our energy supply. Improvements in the efficiency of energy use (e.g., increases in mpg of automobiles) substitute capital for fuel and serve as an energy source.

The energy saved on a national scale from energy efficiency improvements was first estimated by the Department of Energy's Office of Policy in a series of reports, the last of which was released in April 1995. That report, *Energy Conservation Trends*, estimated the saved energy each year for the years 1973 to 1991. The report also took into account reductions in energy use from structural shifts in the economy—a greater proportion of the GDP accounted for by the less-energy-intensive service sector—to avoid counting such changes as energy efficiency. The DOE estimates of energy efficiency and structural shift were made based on detailed analyses of energy efficiency changes in equipment and buildings and in structural changes in the economy.

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Because the 1995 DOE report was the last such report published, the Alliance to Save Energy has made its own estimates of the savings in energy from energy efficiency and the reduction in energy use from structural shifts since the last DOE report using similar linear regression analysis. From 1973 through 1999, the cumulative energy use of oil was 920 quads; natural gas, 542 quads; coal, 467 quads; nuclear, 124 quads; hydro, 81 quads; geothermal and other, 7 quads. Energy efficiency saved 404 quads, or 16 percent of what the energy use would have been without the efficiency improvements. In other words, energy efficiency "supplied" almost one-sixth of our nation's energy needs since 1973, making energy efficiency the fourth major "fuel" source over the last two and one-half decades.

Since the U.S. has imported 408 quads of oil from 1973 through 1999, energy efficiency "supplied" as much energy as we imported. Assuming (a) there had been no energy efficiency improvements since 1973 and (b) we had consumed that much oil instead, we would have imported 812 quads of oil, which would have resulted in oil consumption of 1,324 quads and imports accounting for 61 percent of our oil consumption.

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The chart above shows cumulative actual energy use—bottom wedge or blue area—since 1973 is 2,141 quads. Cumulative savings from structural shifts—middle wedge or yellow area—is 278 quads. Cumulative savings from energy efficiency—top wedge or green area—is 404 quads. In 1999, actual energy use—bottom or blue wedge—is 94 quads (not counting some renewable sources). Estimated energy reduction due to structural shift—middle or yellow wedge—is 20 quads. Estimated energy reduction due to energy efficiency gains—top or green wedge—is 27 quads.

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As the chant above depicts, in 1999, oil consumption was 38 quads; natural gas, 22 quads; coal, 22 quads; nuclear, 8 quads; and other, 4 quads. Thus, energy efficiency, 27 quads, accounted for 22 percent of what otherwise would have been our energy consumption, 121 quads—assuming no efficiency improvements from 1973 efficiencies. In 1999, energy production in the U.S. was 22 quads of coal, 19 quads of natural gas, 15 quads of oil, and 12 quads of nuclear and other. Thus, the energy savings in 1999 from energy efficiency, 27 quads, provided more energy "supply" than any domestic energy source.

4. Future Options

Most energy outlook studies that predict energy demand increases conclude that natural gas will "fill the gap" as nuclear energy, coal and oil decrease. Typically, these studies predict a 3-fold increase in renewable energy resources; however, renewable energy only keeps its current share of the energy pie with no real percentage increase in contribution. The shortfall is expected to be met by natural gas, but that would mean, according to the Center for Strategic and International Studies and DOE's Energy Information Administration, that demand for natural gas will increase at *twice* the rate of any other major category of energy. It is doubtful that gas infrastructure can readily be expanded to meet this demand and, in the short term, demand for gas turbines is so great that production is backed logged by over a year. Questions exist whether natural gas will be able to completely meet our growing energy and electricity demand.

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4.1 Oil

Clearly, oil is a mature, limited and declining resource. As with other fossil reserves, many potential areas of exploration and drilling have been set off limits, further accelerating the decline in supply. In the meantime, worldwide demand for oil is increasing rapidly, as mentioned earlier. New field discoveries, such as the potential of up to 200 billion barrels in Kazahkstan extend the life of the reserves significantly but many of these new fields are in economically or politically unstable areas of the world, calling into question the reliability of this supply to Western consumers.

New drilling technologies will also extend well life and may make previously uneconomic wells productive once again. Deep-water drilling technologies will improve, making previously inaccessible supplies viable. However, world production is still expected to peak in the early part of this century and begin to decline.

4.2 Coal(see footnote 6)

Coalbed methane can be used as an energy source that can partly replace coal as a fossil energy source, and it sometimes occurs where other conventional resources of oil and gas are not present. Coalbed methane accumulations are widespread, commonly basin-wide, and are characterized by large in-place heterogeneous reserves. The in-place coalbed methane resources of the United States are estimated to be more than 700 trillion cubic feet (Tcf), but less than 100 Tcf may be economically recoverable. Basin-wide studies are needed to determine controls of the occurrence, availability, and recoverability of coalbed methane in the United States and other countries that need clean energy resources. Underground coal-mining areas, such as the Appalachian basin, should be emphasized because of the need to reduce atmospheric methane emissions. Most previous exploration and research efforts have been in the San Juan basin and the Black Warrior basin. However, since each coal-bearing basin has unique attributes, coalbed methane issues need to be studied separately in each basin.

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The coalification process, whereby plant material is progressively converted to coal, generates barge quantities of methane-rich gas, which are stored within the coal. The presence of this gas has been long recognized due to explosions and outbursts associated with underground coal mining. Only recently has coal been recognized as a reservoir rock as well as a source rock, thus representing an enormous undeveloped "unconventional" energy resource. But production of coalbed methane is accompanied by significant environmental challenges, including prevention of unintended loss of methane to the atmosphere during underground mining, and disposal of large quantities of water, sometimes saline, that are unavoidably produced with the gas.

Most gas in coal is stored on the internal surfaces of organic matter. Because of its large internal surface area, coal stores 6 to 7 times more gas than the equivalent rock volume of a conventional gas reservoir. Gas content generally increases with coal rank, with depth of burial of the coalbed, and with reservoir pressure. Fractures, or cleats, that permeate coalbeds are usually filled with water; the deeper the coalbed, the less water is present, but the more saline it becomes. In order for gas to be released from the coal, its partial pressure must be reduced, and this is accomplished by removing water from the coalbed. Large amounts of water, sometimes saline, are produced from coalbed methane wells, especially in the early stages of production. While economic quantities of methane can be produced, water disposal options that are environmentally acceptable and yet economically feasible, is a concern. Water may be discharged on the surface if it is relatively fresh, but often it is injected into rock at a depth where the quality of the injected water is less than that of the host rock. Another alternative, not yet attempted, is to evaporate the water and collect the potentially saleable solid residues; this scheme might be feasible in regions having high evaporation rates.

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4.3 Nuclear Energy's Role

4.3.1 Breeder Reactors

The key to long term energy supply from nuclear power is not uranium ore reserves, or even reserves of fertile materials like thorium. It is new, as yet non-commercial, nuclear technology that could allow nuclear power to be sustained over a very long period. Today the first step appears to be the use of breeder reactors.

Thermal reactors use only 2 percent of the energy available from natural uranium. Most of the energy remains unused in depleted uranium. Breeder reactors could overcome this deficiency in two ways: by recycling plutonium produced in thermal reactors, and by converting fertile uranium (U–238), normally concentrated in depleted uranium, into fissile plutonium. A breeding fuel cycle based on thorium uranium is also possible. Together these improvements could increase the energy extracted from natural uranium to 75 percent or higher. The reserves of uranium mentioned above could thus be extended by 40 times. Eight thousand years does indeed sound sustainable.

4.3.2 Nuclear Energy and Greenhouse Gas Emissions

When fossil fuels—coal, oil, and natural gas—are burned to generate electricity or used for transportation (gasoline and diesel fuel derived from oil), a variety of gases and particulates are formed as a result of combustion. Although most of these gases and particulates are captured by a variety of pollution control equipment, some small fraction of these "products of combustion" is released into the atmosphere. Among the gases emitted during the burning of fossil fuels are sulfur dioxide (SO), nitrogen oxides (NO**X**), and carbon dioxide (CO). Because a nuclear energy plant does not "burn" fossil fuel to produce electricity there are no products of combustion and, therefore, nuclear energy does not produce any greenhouse gases.

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It is estimated that in the U.S. nuclear generated electricity avoided 3.9 million tons of sulfur dioxide and 582,000 tons of nitrogen oxides in 1999. Through the use of nuclear energy 163.8 million metric tons of carbon in the atmosphere were avoided 1998.(see footnote 7) This figure is equal to the amount of reductions needed to achieve the 1990 levels agreed to in the United Nations Climate Change Treaty signed in Rio de Janeiro in 1992. Without the emission avoidance from nuclear generation, required reductions would increase by more than 50 percent to achieve targets under the Kyoto Protocol. As reported in the June 20, 2000, issue of *Energy Daily*, a prestigious panel in the United Kingdom has concluded that nuclear power and renewable energy are the only ways to meet that region's targets for greenhouse gas emissions reductions.

4.4 Efficiency's Role

Conservation measures and energy efficiency improvements have made an important contribution to our energy economy: lowering and stabilizing demand during the 70's and 80's, kept prices stable and extended our reserves of oil and gas, which otherwise might have been nearly depleted by now.

The potential exists to not only continue to increase our energy productivity (reduce energy intensity), but to lower per capita energy use substantially—if this trend were encouraged it would enable the eventual achievement of a truly sustainable energy economy, where energy needs can be met mainly by renewable sources.

4.4.1 Industrial Sector Efficiency

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Industry uses more than one-third of all the energy used in the United States. Most of the energy industry uses is supplied from natural gas and petroleum, with electricity coming in a distant third, followed closely by coal. Certain industries, for instance steel and paper production, require a large amount of energy per unit of product, and are the best candidates on which to focus energy-efficiency efforts.

The industrial sector of the U.S. economy has made tremendous improvements in the efficient used of energy in the face of increased competition and raising energy costs. For example, the on-site production of electricity is particularly attractive to industries that can also make use of the waste heat. Such combined heat and power systems—also called cogeneration systems—achieve higher thermal efficiencies than stand-alone power plants. Motor-driven equipment accounts for 64 percent of the electricity consumed by U.S. industries. Energy-efficient motors can cut this energy use by at least 12 percent. Over 45 percent of all the fuel burned by U.S. manufacturers is consumed to raise steam. A typical industrial facility can realize steam savings of 20 percent by improving its steam system. Simple approaches to improving energy performance include insulating steam and condensate return lines, stopping any steam leaks, and maintaining steam traps. Condensate return to the boiler is essential for energy efficiency. Optimization of compressed air systems can provide energy-efficiency improvements of 20 to 50 percent. Many industries use compressed air systems as power sources for tools and equipment used for pressurizing, atomizing, agitating, and mixing applications. Compressors using variable-speed drives are saving energy, while simple measures like detecting and fixing air leaks remain all-important.

4.4.2 Efficiency in Power Production

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In the power industry, energy efficiency involves getting the most usable energy out of the fuels that supply the power plants. At its best, energy efficiency in the power industry can lead to postponing—or altogether avoiding—the construction of new power plants. The efficient generation of power is only one way a power plant can pursue energy efficiency. New technologies applied to the storage of energy and the transmission of energy contribute to energy efficiency. For instance, the copper wires used in typical transmission lines lose a percentage of the electricity passing through them because of resistance, which causes the wires to heat up. But "superconducting" materials have no resistance, and if they are used to transmit electricity, in the future, very little of the electricity will be lost. Energy storage can also make an electric utility system operate more efficiently. The most familiar way to store electricity is using batteries, but many other technologies have been developed, ranging from pumping water uphill to trapping electrical current in superconducting loops of wire.

The inability to store excess electricity during periods of low demand can force utilities to operate power plants at less than full power, which is usually less efficient. Energy storage allows excess electricity to be stored during slack times and used during periods of high demand. Energy storage can also help electric utilities to make the best use intermittent energy sources, like wind and solar power. Another way for utilities to meet these changing energy demands is to locate smaller power sources close to the customers that need the power. This concept, called "distributed generation," helps take the load off of transmission lines and, because the electricity travels only short distance before it is used, there is little or no energy lost in the transmission of the electricity.

Demand side management encourages utility customers to take action on their side of the meter, changing the quantity or timing of the energy flow. These programs can be run by a state agency, by an independent agency operating with state funds, by private firms known as energy service companies, or by individual utilities. Utility companies also can structure rate schedules to encourage energy efficiency by charging more for peak electricity, which shifts demand to off-peak periods. Consumers who respond to these programs by shifting the timing of their energy use or by employing energy-efficient lighting and appliances may ultimately reduce the need for more power plants.

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4.4.3 Commercial and Residential Efficiency

In buildings, energy efficiency means using less energy for heating, cooling, and lighting. It also means buying energy-saving appliances and equipment for use in a building. An important concept for energy efficiency in buildings is the building envelope, which is everything that separates the interior of the building from the outdoor environment: the doors, windows, walls, foundation, roof, and insulation. All the components of the building envelope need to work together to keep a building warm in the winter and cool in the summer. Your home's insulation, for instance, will be less effective if the roof, walls, and ceiling allow air to leak in or allow moisture to collect in the insulation. There are ways to determine how energy efficient a building really is and, if needed, what improvements can be made. Homeowners can conduct simple energy audits on their homes or have professional audits done. Professional energy audits are also available for commercial buildings.

Various approaches can help improve the building envelope. Stone windows and doors can reduce heat loss when temperatures drop. In warns regions, windows with special glazing can let in daylight without heat gain. Even some simple weatherization techniques, such as weather-stripping doors and windows, can significantly improve a building's energy efficiency. Heating and cooling systems typically use the most energy in a building. In homes, the addition of efficient controls, like a programmable thermostat, can significantly reduce the energy use of these systems. Some homes can also use zone heating and cooling systems, which reduce heating and cooling in the unused areas of a home. In commercial buildings, integrated space and water heating systems can provide the best approach to energy-efficient heating. The energy used to heat water can be reduced by both heating water more efficiently and by reducing hot water use. A wide variety of fixtures, such as low-flow showerheads and faucet aerators, can reduce hot water use. In a home, an older water heater can be replaced with a newer, more energy-efficient one, and the water heater and hot water pipes can be insulated to minimize heat loss. Today, most common appliances and electronic devices are available in energy-efficient models—from clothes washers and refrigerators to copiers and computers. Several energy-efficient lighting options, such as compact fluorescent light bulbs, are also available. Lastly, proper operation and maintenance is critical to efficient energy use.

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4.4.4 Transportation Sector Efficiency

In the transportation sector there are many components and technologies that make up alternative fuel and advanced vehicles. Although these vehicles are making their way into the market place, research continues through government and industry partnerships to optimize the components for various vehicle configurations and applications. Components can be categorized into advanced engines, electric drive components, natural gas vehicle components, fuel cell components, and emission control components.

Advanced engine technologies include Compression Ignition Direct Injection Engines (CIDI). These engines are designed for direct injection of fuel into the combustion chamber of an engine yielding improvements in thermal efficiency and overall fuel efficiency. Engines that ignite the fuel solely by compressing it—known as "compression ignition" or diesel engines—have a high energy efficiency, and the application of direct-injection technologies can further boost the fuel efficiency of these engines.

Turbocharged direct Injection (TDI) diesel engines are a turbocharged version of the CIDI, and are very popular in Europe, and are now available in automobiles sold in the United States. Spark Ignition Direct Injection (SIDI) Engines designed with a standard gasoline engine use a spark to ignite the fuel. Like CIDI engines, SIDI engines inject fuel directly into the combustion chamber. SIDI engines have the advantage of burning gasoline and many alternative fuels. Gas Turbine Engines run efficiently on a wide variety of fuels. Because of their loss of efficiency at low power and their slow response time, they are best suited for hybrid electric vehicle applications. Lastly, Stirling engines use a heat source external to the engine's cylinders to expand gases within the cylinders and driving pistons, which provide the drive power. These "heat engines" are truly external combustion engines, and may be applicable to hybrid electric vehicles.

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Electric Drive Components including motors, power electronics, and controllers are essential components of electric drive systems, whether used in purely electric vehicles or in hybrid electric vehicles.

Regenerative braking generates electricity to recharge the electric drive's batteries while braking, essentially converting the momentum of the vehicle into electricity. High-power and high-energy batteries are essential components of electric drive systems.

Natural gas vehicle components produce a lean-burning natural .gas engines produce low emissions with high thermal efficiency. Natural gas must be stored under pressure or in liquid form. Advanced materials are needed to achieve strong storage tanks with the necessary capacity. Still under development, fuel cells generally convert hydrogen and oxygen into water, producing electricity. Because they produce only water vapor as emissions, fuel cells are ideal power sources for transportation, providing power for an electric drive motor. Fuel cells generally convert hydrogen and oxygen into water, producing electricity. Most current concepts take advantage of existing fuel infrastructures by relying on a fuel reformer to convert liquid fuels into hydrogen. The reformer can be on-board or installed in a fueling station.

Emission control technologies such as catalytic converters treat exhaust gases to remove nitrous oxides. Such after-treatment technologies are less effective for advanced lean-burning engines. Oxygen sensors measure the air to fuel ratio and are critical to fuel economy and emissions. Cost-effective, highly sensitive sensors that are quick to respond are needed. Filters and ceramic traps may help remove particulates from diesel engine emissions.

4.5 Renewable Energy's Role

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4.5.1 Renewable Energy R&D

Even with a twenty-year history of heavy investment in renewable energy renewable energy contributes less than 4 percent (excluding hydroelectricity) to U.S. energy supply. The installed base is growing, and the potential for technological breakthroughs is significant in renewables. Breakthroughs could either drive down the capital cost reducing the entry price, or significantly increase efficiency, perhaps driving down the cost per kWh and reducing the footprint. While even the most optimistic projections see renewable holding their current share of the energy portfolio, it is conceivable that massive increases in energy efficiency may create a situation where renewables provide a much more significant portion of our nation's energy supply. This scenario relies on the continuation of the growth trend in renewables and major breakthroughs in energy efficiency.

Renewable energy technologies, like solid state electronics are experiencing steadily declining costs as they evolve and volume of production increases to meet resulting increased demand. This process can be expected to accelerate as the technologies mature and stable markets emerge. Renewables today are poised for rapid growth with the potential to become significant contributors if growth rates can be maintained at even a fraction of current rates (40 percent per year for wind turbines and solar photovoltaic production).

Chairman **BARTLETT.** Let me momentarily call our subcommittee hearing to order. You heard the two bells go off. This means that we have a vote on. It is a mischievous vote to adjourn. I don't know if there will be another mischievous vote following that. But we will adjourn our subcommittee hearing so that we can go vote. We will return immediately after the vote or votes are completed. Let me reconvene our subcommittee hearing. This will be a difficult day for attendance of members. We have a mark-up on the Education Committee and several of our members are on that, including our ranking member who will be from time to time called from here because of a vote on the mark-up in the Education Committee.

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Today we will examine the extent of U.S. and world energy reserves and resources, our rates of consumption of energy and alternative forms of energy and energy use that provide options for the future. I believe this is a critical time in our nation's history. Not only do we face finite supplies of fossil energy, we also have limited financial resources available to invest in future energy technologies and infrastructure. With growing worldwide demand competing for those same limited resources, there is scant time for us to establish policies to make the transition to a truly sustainable energy economy.

Our witnesses will discuss the extent of our fossil fuels and how quickly they will be consumed at present and future rates of consumption. Of course, rates of consumption in the future are subject to much speculation, as is the extent of the planet's remaining fossil energy. So I expect to hear a wide range of answers to these questions.

We will hear from Dr. Albert Bartlett, Professor Emeritus of Physics, University of Colorado at Boulder. Dr. Suzanne Weedman, Program Coordinator, Energy Resources Programs, U.S. Geological Survey. Dr. David Montgomery, Vice President, Charles River Associates. Mr. Howard Geller, Executive Director Emeritus, American Council for an Energy Efficient Economy. Mr. Henry Courtright, Vice President, Power Generation and Distributed Resources, Electric Power Research Institute. And Dr. Alexandra von Meier, Director, Environmental Technology Center, Sonoma State University. Thank you all very much for coming.

This hearing comes at a crucial time because many Americans are experiencing their first energy crisis, while for others the fuel crisis of '73 and '79 are a dim and distant memory. This summer will be a shock to many Americans. It is safe to assume that many of us will experience not only record high gas prices, but some of us will feel the effects of rolling blackouts and other inconveniences related to short energy supplies.

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I believe that it is important to discuss all sources of energy as well as all uses of energy in today's discussion. We derive energy from fossil fuels; hydroelectric; renewable sources, such as solar, wind and geothermal; and nuclear power. We use energy to drive our cars, fly our airplanes, drive our trucks, light our homes, and power the information age. Truly, both our old economy and our emerging new economy would not exist without abundant inexpensive sources of energy.

The correlation between economic prosperity and readily available energy is well documented. And there are several trends that we must be aware of as well. We use more energy than ever before, but we are less energy intensive. Technology, innovation, efficiency and conservation have brought us to the point where we can be more productive while using less energy. This is an encouraging trend.

Unfortunately, we are also reaching a point where the easy and inexpensive fossil fuels are being consumed and we will have to transition toward more difficult to extract and costly fossil fuels. We Americans are also demanding cleaner air, so some sources of fossil fuels, such as coal, that are abundant and cheap, are shunned in favor of cleaner burning, more expensive natural gas. All of these trends make the future of fossil fuels problematic. Clearly, there needs to be another way.

The good news is that there are many promising technologies that may allow us to transition from today's fossil fuel economy to a more sustainable energy future. Certainly, nuclear energy must play an increasing role in our energy portfolio. We must also learn how to economically deliver wind, solar and other renewable resources. Hydrogen fuel cells, although not yet cost effective, provide the option for clean energy in our daily lives, both for transportation and for electricity delivery. We must examine the use of bio-based fuels, getting beyond corn ethanol to the use cellulosic and other types of biomass, not only for fuels such as ethanol and bio-diesel, but for bio-refineries to produce feedstock substitutes for the petrochemical industry. This list does not include all the potential sources of renewable resources that may be available in the future. It is meant to provide a glimpse of the possibilities.

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We must take advantage of this window of opportunity to prepare ourselves for the day when there are no more readily available fossil fuels, whether that is 20 years from now or 200 years from now. I look forward to hearing today's testimony pursuing these subjects in greater detail.

Before we get started, however, I would like to remind the members of the subcommittees that—and our witnesses that this hearing is being broadcast live on the Internet. So please keep that in mind during today's proceedings. I would also like to ask for unanimous consent that all members who wish might have their opening statements entered into the record without objection. So ordered.

[The prepared statement of Roscoe G. Bartlett follows:]

PREPARED STATEMENT OF CHAIRMAN ROSCOE BARTLETT

Today we will examine the extent of U.S. energy reserves and resources, our rates of consumption of energy, and alternative forms of energy and energy use that provide options for the future. I believe this is a critical time in our nation's history—not only do we face finite supplies of fossil energy, we also have limited financial resources available to invest in future energy technologies and infrastructure. With growing worldwide demand competing for those same limited resources, there is scant time for us to establish policies to make the transition to a truly sustainable energy economy.

Our witnesses will discuss the extent of our fossil fuels and how quickly they will be consumed—at present and future rates of consumption. Of course rates of consumption in the future are subject to much speculation, as is the extent of the planet's remaining fossil energy, so I expect to hear a whole range of answers to these questions.

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We will hear from:

1. Dr. Albert Bartlett, Professor Emeritus of Physics, University of Colorado at Boulder;

2. Dr. Suzanne D. Weedman, Program Coordinator, Energy Resources Programs, U.S. Geological Survey;

3. Dr. W. David Montgomery, Vice President, Charles River Associates;

4. Mr. Howard S. Geller, Executive Director Emeritus, American Council for an Energy Efficient Economy;

5. Mr. Henry A. Courtright, Vice President, Power Generation and Distributed Resources, Electric Power Research Institute; and,

6. Dr. Alexandra von Meier, Director, Environmental Technology Center, Sonoma State University.

This hearing comes at a crucial time because many Americans are experiencing their first "energy crisis," while for others, the fuel crises of 1973 and 1979 are a dim and distant memory. This summer will be a shock to many Americans. It is safe to assume that many of us will experience not only record high gas prices, but some of us will feel the effects of rolling blackouts and other inconveniences related to short energy supplies.

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I believe that it is important to discuss all sources of energy as well as all uses of energy in today's discussion. We derive energy from fossil fuels; hydroelectric; renewable sources, such as solar, wind and geothermal; and nuclear power. We use energy to drive our cars, fly our airplanes, drive our trucks, light our homes, and power the information age. Truly, both our "old" economy and our emerging "new" economy would not exist without abundant, inexpensive sources of energy.

The correlation between economic prosperity and readily available energy is well documented. And, there are several trends that we must be aware of as well. We use more energy than ever before, but we are less energy intensive. Technology, innovation, efficiency and conservation have brought us to the point where we can be more productive while using less energy. That is an excellent trend.

Unfortunately, we are also reaching a point where the "easy" and inexpensive fossil fuels are being consumed and we will have to transition towards more difficult to extract and costly fossil fuels. We Americans are also demanding cleaner air, so some sources of fossil fuels, such as coal, that are abundant and cheap are shunned in favor of cleaner burning, more expensive natural gas. All of these trends make the future of fossil fuels problematic. Clearly there needs to be another way.

The good news is that there are many promising technologies that may allow us to transition away from today's fossil fuel economy to a more sustainable energy future. Certainly nuclear energy must play an increasing role in our energy portfolio. We must also learn how to economically deliver wind, solar and other renewable resources. Hydrogen fuel cells—although not yet cost-effective—provide the option for clean energy in our daily lives, both for transportation and for electricity delivery. We must examine the use of bio-based fuels—getting beyond corn ethanol to the use of cellulosic and other types of biomass, not only for fuels such as ethanol and bio-diesel, but for "bio-refineries" to produce feedstock substitutes for the petrochemical industry. This list does not include all the potential sources of renewable resources that may be available in the future. It is meant to provide a glimpse of the possibilities.

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We must take advantage of this window of opportunity to prepare ourselves for the day when there are no more, readily available fossil fuels—whether that's 20 years from now, or 200 years.

Chairman **BARTLETT.** I now would like to recognize my distinguished ranking member, Miss Woolsey, for her opening remarks.

STATEMENT OF THE HONORABLE LYNN C. WOOLSEY, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF CALIFORNIA

Mrs. **WOOLSEY.** Thank you, Mr. Chairman and thank you for holding today's hearing. Like you, I believe it is crucial that we have an accurate picture of how much energy we have used and how much energy remains. You have put together a distinguished panel. I am anxious to hear what they have to say. And I also want to know everything they know that they can tell us in 5 minutes.

I am especially pleased that you have invited Dr. Alexandra von Meier of Sonoma State University in my district. Dr. von Meier is a very bright woman. She is full of accomplishments. And I am proud to day that she lives in Sonoma County, where I live also. Dr. von Meier is an assistant professor in the Environ—Department of Environmental Studies and Planning at Sonoma State University, where she directs the Energy Management and Design Program. She is also the Director of Sonoma State's Environmental Technology Center, which is due to be completed this summer. And when it is completed I want you out there to tour it. The Environmental Technology Center is a campus building that teaches. Because of the building materials, because of its passive solar heating and cooling, daylighting and smart building management system it uses 80 percent less energy than most new buildings. And the energy it uses comes from solar photovaltaic cells built into its roof shingles. Most exciting, the center is expected to be a net energy producer on the grid.

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Over the past district work period I held an energy summit at SSU, and more than 200 of my constituents attended to discuss the future of energy supplies. Dr. von Meier participated on a panel that highlighted local sustainable energy projects, where she discussed energy efficient buildings. Dr. von Meier is certainly representative of the melding of good science, environmental awareness and personal commitment that makes my district a very special place.

Like my constituents, Mr. Chairman, and like you and like me, we all share a common concern about the limits of the availability of conventional energy. Unfortunately, we are finding out how misunderstood these limits are, even by public officials charged with the development and implementation of national energy policy. There is much we need to learn about the complex subject and the role that the Federal Government can play in ensuring a smooth transition to an energy economy that relies less on oil, less on natural gas and coal, and more on renewables.

In California we have already reached the limits of electric power availability. People throughout California are beginning to go through a very sober reassessment of how they use electricity and other forms of energy, and how they can save it as well. They are looking for answers about our energy future and I hope that we will find some of those answers in the testimony we hear today.

On a separate note, I am mindful of the limitations of one of our panelists, Dr. Montgomery, who has asked that he be excluded from any discussion of the California power situation. His employer, Charles River Associates, is involved with one or more of the numerous parties in the California situation. Dr. Montgomery, we certainly will honor your request to avoid sensitive issues. But you are probably going to have to tell us when we hit that point because we may not know.

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With that, Mr. Chairman, I yield back the balance of my time.

Chairman **BARTLETT.** Thank you very much. In a former life I was a home builder and I built a number of passive solar homes. I look forward to visiting Sonoma and your technology building there.

I have been very much concerned for a number of years now that with our relatively small percentage of the world's reserves in oil that we faced an uncertain energy future. When you have only about 2 percent of the known reserves of oil in the world when you are using 25 percent of the world's oil, that obviously should be pause for concern. We were concerned that we did not have a national energy policy. It just seemed fool-hardy to me that a country that has only 2 percent of the known reserves of oil and uses 25 percent of the world's oil ought to have a national energy policy. And this subcommittee hearing is a very important step in developing a base of knowledge for developing that national energy policy.

What we hope to determine at today's hearing is the best counsel of those who know as to how much of the world's energy and fossil fuels has been found and used, and how much of it remains. So I look forward with great anticipation to today's hearing.

Without objection, the full written testimony of all the witnesses will be entered into the record. We have asked that you try to condense your testimony to 5 minutes. Let me assure you that there will be more than ample time to expand on anything you wish during the question and answer period. And listen intently please to the testimony of the other witnesses because near the end of today's hearing I will invite you to comment on and question each other's testimony. What we want on the record today is the best information that we can have.

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Let me now recognize my namesake. I guess I am his namesake since he may be a year or two older, maybe not, Dr. Albert Bartlett from the University of Colorado. Let me say that at 1:30, if we are not interrupted by mischievous votes and we go beyond that at 1:30, Dr. Bartlett will be giving a 1-hour lecture. I would encourage you to stay if you are a witness, to stay if you are simply in the room here. This is the most interesting 1-hour lecture I have ever heard. And I taught for 24 years and that includes all the lectures I have given, too. It is the most interesting 1-hour lecture I have ever heard. And you will be all the wiser for having stayed to go through that 1-hour lecture. It is very interesting. You will think that only 10 minutes has past and you will look at your watch and the hour has gone. Please stay for that hearing if you can. Dr. Bartlett.

STATEMENT OF DR. ALBERT A. BARTLETT, PROFESSOR EMERITUS OF PHYSICS, UNIVERSITY OF COLORADO AT BOULDER

Dr. **BARTLETT.** Yes. Mr. Chairman, thank you very much for your kind words. And, members of the Committee, I am very honored to be here.

The national energy situation is a mess. For years we have seen recommendations from the U.S. Department of Energy that suggest the leaders of the Department have little scientific understanding of the problems of energy.

We have seen the President of the United States sending his Secretary of Energy on bended knee to plead with OPEC leaders, asking them please to increase petroleum production so as to keep our gasoline prices from rising. For a country that boasts that it is the world's only superpower, this profoundly humiliating. Gasoline prices are rising. California currently has an electrical energy crisis, which is likely to spread, and natural gas prices are rising rapidly. This poses a real economic hardship for millions of homeowners who depend on natural gas to heat their homes. The only energy proposals we see are for short-term fixes, sometimes spread over a few years. But they seem to ignore the real world realities of resource of availability and consumer costs.

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For years, scientists have warned that fossil fuel resources are finite. The long-range energy plans should be made. These plans must recognize the growing rates of consumption of fossil fuels will lead, predictably, to serious shortages, which are now starting to appear. For years I have heard learned opinions, generally from non-scientists, that resources are effectively infinite; that more of a resource that we consume the greater are the remaining reserves of that resource; that the human intellect is our greatest resource because human mind can harness science and technology to solve all our shortages.

There seem to be two cultures, science and non-science, which are isolated from each other. Each has its own Ph.D. experts and its own think tanks. Each has its own lobbyists arguing vigorously that their path is the proper one to follow to achieve long-term sustainability. So let us compare these two paths.

The centerpiece of the scientific path is conservation. Hence, it is appropriate to call this path the conservative path. On this path, the Federal Government is called on to provide leadership, plus strong, reliable, long-term support toward the achievement of the following goals. The U.S. should have an energy planning horizon that addresses the problems of sustainability through several future decades.

We should have a program for the continual and dramatic improvement of the efficiency with which we use energy in all parts of our society. Improved energy efficiency is our lowest cost energy resource. We should move toward the rapid development and deployment of all manner of renewable energies throughout our entire society. We should embark on a program of continual reduction of the annual total consumption of non-renewable energy in the United States. We should recognize that moving quickly to consume the remaining U.S. fossil fuel resources will only speed and enlarge the present, serious dependence on fossil fuel resources of other nations. And this will leave our children vitally vulnerable to supply disruptions, which they won't be able to control.

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And finally and most important, we should recognize that population growth in the U.S. is a major factor that is driving up the demand for energy. This calls for recognizing the conclusion of President Nixon's Rockefeller Commission Report that concluded that it could find no benefit to the United States from any further U.S. population growth.

Now in contrast is the non-scientific path, which suggests that resources are effectively infinite, that we can be as liberal as we wish in their use and consumption. Hence, this path is properly called the Liberal Path. The proponents of other Liberal Path recommend that the U.S. should makes plans only to meet immediate crises, because the crises are all temporary. We should have governments—not have governments promote improvements in energy efficiency because the market place will provide these improvements. We should not have government programs develop renewable energy resources because again, the market can be counted on to take care of all of our needs. We should let fossil fuel consumption rates continue to increase because to do otherwise might hurt the economy. And we should drill and dig and consume our remaining fossil fuels as fast as possible because we need them. We don't have to worry about our children, they can count on having advanced technologies that they will need to solve the problems that we are creating for them.

And finally, the non-scientific path people claim that population growth is a benefit rather than a problem because more people equals more brains. We should not be confused by the conflicting expertise that supports each of these two paths because of a very fundamental law. For every Ph.D. there is an equal and opposite Ph.D.

In our energy polices we as a nation must choose between the liberal and the conservative paths. Now the two paths are exact opposites of each other. Each is advocated by credentialed experts. On what basis can we make an intelligent choice.

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Well, fortunately, there is a rational way to make the choice between the two paths. We must recognize that if the path we choose turns out to be the correct path, then there is no problem. The problems arise in case we choose the wrong path. So what we must do is to choose the path that leaves us in the less precarious position in case we choose the wrong path.

So there are two possible wrong choices that we have to compare. If we choose the conservative path of finite resources and our children later find the recourses are really infinite, then no great long-term harm has been done.

But if we choose the Liberal Path, which assumes that resources are effectively infinite, and later are children find that resources are actually finite, then we will have left our descendants in deep trouble.

I think there can be no question the conservative path in the prudent path to follow. However, the Liberal Path is what we seem to be on so eagerly today. If resources turn out to be infinite, then this liberal path will be okay. But if the resources turn out to be finite, then we are on the wrong path. And if we continue on this liberal path our children will have to bear the terrible consequences of the conscious choice that we made of the wrong path.

And I elaborate on these points in the written testimony I have submitted. And I thank you very much for this opportunity to share my views.

[The prepared statement of Dr. Albert Bartlett follows:]

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ELABORATION OF ORAL STATEMENT OF ALBERT A. BARTLETT

The text given here elaborates an the points that were presented in the brief oral presentation. The comments here are arranged in the same set of section headings as was used in the oral presentation.

I) INTRODUCTION

Here is an example of a statement from the Department of Energy that reveals a lack of understanding of the physical reality of energy production.

U.S. Energy Secretary Federico Pena has issued his comprehensive' national energy strategy, a set of general policy goals that include halting the slide in U.S. oil production by 2005. (1)

The physical reality is that U.S. oil production peaked in 1970, had a small subsidiary peak in the mid-1980s when production peaked in Alaska. Since then production has continued downward. This downward trend was predicted by Dr. M. King Hubbert in the 1950s. (2)

The pattern of production of a non-renewable resource was shown by Hubbert to start at zero, to rise to one or more maxima, and then to return to zero. This standard pattern can be approximated by what is called a "Hubbert Curve." My own published analysis (3), using the Hubbert Curve suggests that we have already consumed about 75% of the recoverable petroleum that was ever in the ground in the U.S. and that we are now coasting downhill on the last 25% of this once enormous resource.

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An article from the Reuters News Agency (February 17, 1999) carried the headline "U.S. Lower 48-State January Oil Output Hits 50-Year Low."

U.S. crude oil production in the lower 48 states during January [1999] sank to 4.8 million barrels per day, the lowest level in more than 50 years, and down 6 percent from a year ago, the American Petroleum Institute said Wednesday.

In its monthly energy statistical report the API said January oil production in Alaska, which accounted for one-fifth of total U.S. production was down 15 percent from last year to just 1.1 million barrels per day.

As predicted by Hubbert, after the peak, the permanent trend in U.S. oil production is downhill. We can put bumps on the declining side of the Hubbert Curve, but we can't reverse the downward trend.

Hence, the Secretary's goal of "halting the slide in U.S. oil production" is unscientific wishful thinking.

In a letter of February 26, 1998 to the Secretary, I gave detailed criticisms of the Department's "Comprehensive National Energy Strategy." (4)

II) WHAT'S HAPPENING?

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III) WHAT'S BEING PROPOSED?

The proposal for rapid drilling in the Arctic National Wildlife Refuge (ANWR) and offshore in the lower 48 states, appears to be a short-term energy fix that seems to ignore the real-world reality of resource availability.

The proposal to drill in the ANWR seems to be driven by urgency, without any long-term evaluation of the small effect on our national strategic energy situation that could be expected to result from the amount of petroleum that may be found in these areas. The number 3.2 billion barrels of oil has been offered as an estimate of what may be found in the ANWR. The U.S. is currently consuming over 6 billion barrels of oil each year, so the amount of oil that may be found in the ANWR is likely going to be less than one year's consumption in the U.S.

What follows is an examination of the real-world realities of resource availability.

Let's look at U.S. coal. This is especially urgent because of this sentence:

At current rates of output and recovery, these [American] coal reserves can be expected to last more than 500 years. (5)

This "500 years" figure has become part of American energy folklore, and it is widely interpreted to mean that we have nothing to worry about for centuries.

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Simple analysis shows that this 500 year figure is correct only if two highly improbable things happen simultaneously. First, we have to have 500 years of zero growth of coal production (This follows from the opening phrase, "At current rates. . .); and second, one has to find ways to recover and use 100% of the coal that is in the ground.

The Department of Energy has estimated that one can use about 50% of the coal that is in the ground. Other reports give recoverability estimates as low as 20%. From 1971 to 1991 the average rate of growth of U.S. coal production was 2.86% per year. If coal production could continue to grow at this rate, the 50% recovery figure would give a life expectancy of U.S. coal of about 72 years. The large number of coal-fired electricity generating plants currently being proposed would certainly raise the rate of growth above the 2.86% per year, with a corresponding reduction of the life-expectancy of U.S. coal.

A new report addresses coal mining in Virginia and the neighboring states (6).

Our purpose in this report is to provide data showing that Virginia's coal production life cycle has entered maturity, is past peak production, and is now entering the initial stages of a depletion-driven decline.

About half of Virginia's coal production is estimated to be sold in metallurgical markets. About 40 percent is exported, chiefly for metallurgical markets; of the coal sold in the United States, about one-third is for metallurgical markets. Much of the remainder is shipped to coal-fired [electric] power plants in Virginia and neighboring states.

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A related news story appeared in the *Richmond Times-Dispatch*, May 14, 1999.

Discussing his study yesterday at the Virginia Coal Council conference in Abingdon, geologist Jim Truman said all "proven and probable" coal reserves worth mining will be depleted by 2026, and efforts to find more coal in central Appalachia will probably prove fruitless.

Mining companies in the central Appalachian areas of Southwest Virginia, southern West Virginia, eastern Kentucky, and northeast Tennessee have long known the coal is running out, but perhaps not with as much exactitude as Truman.

Assuming a 1.5 percent growth in production every year—created by increased demand and better mechanization—Truman determined that the coal worth mining will last 27 years.

How much of the electricity consumed in Washington, D.C. and surrounding areas is generated by the combustion of this declining coal supply from Virginia?

The U.S. Department of Energy, in a publication for Energy Awareness Month, October 1994, tells us that:

Some 85% of the energy used in the U.S. today comes from fossil fuels, and it has been estimated there is over a 400-year supply of coal under U.S. soil.

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This is incredible! Even the people in the Department of Energy are victims of the 500 year (or 400 year) myth which is discussed above, and they are actively propagating this myth. This most recent quote does not even include the qualifying statement, ("At present rates of consumption. . .!").

The question of consumer costs seems to be almost universally ignored as people advance proposals to alleviate the shortages of electricity.

A report on National Public Radio (April 30, 2001) told of a serious proposal to build 2000 new electric power plants in the U.S. in the next 20 years. This is an average of 100 plants per year.

The reports cited above suggest that we may not have the coal needed to operate these plants throughout their expected lifetimes.

Now let's look at the costs to the consumers of this proposed construction. We have to look at the cost to the consumers because consumers are the only source of funds to pay for the construction of new power plants.

It costs approximately $1000 per kilowatt to purchase a new coal-fired electric generating plant. Natural gas plants cost less, nuclear plants cost more. So let's use the $1000 per kilowatt as an average cost of purchasing the hardware that is used to generate electricity.

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This does not include the costs of operating the plant or the costs of distribution of the electricity the plant produces.

Let's assume that these are "mid-size" electric plants each with a generating capacity of 3 hundred thousand kilowatts (300 megawatts), and so each generating plant costs $300 million to purchase. Each year's program of constructing 100 such plants will then cost a total of $30 billion.

The population of the U.S. is approximately 280 million.

So the cost of each year of this proposal to construct electric generating plants in the U.S. is over $100 per person for every man, woman, and child in the U.S.! Twenty years of such construction would cost every man, woman, and child in the U.S. a total of about $2000!

The operating and distribution costs are in addition to these costs.

Does anyone run such simple cost estimates before they advance these proposals to construct all sorts of new electric generating capacity in the U.S.?

The amounts of money involved here are about the same size as the President's proposed tax cut!

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The national U.S. electric consumption per person is the equivalent of about 1.5 kilowatts consumed continuously 24 hours a day.

The recent census indicated that the population of the U.S. increased by 37.2 million people in the 1990s. To purchase 1.5 kilowatts of generating capacity for all these new people would cost about $56 billion. If this cost is spread equally over the 280 million people in the U.S., the per person cost is about $2O per year for each of the ten years, for a total cost of $200 for every man, woman, and child in the country. This is just to provide the increased electrical generating capacity needed for the people added to the U.S. population in the decade of the 1990s.

These costs are so high that we should not wonder that construction of new electric generating plants has not even kept up with population growth, let alone with the much higher growth in total demand for electricity.

Let's look at these costs from a more local point of view. These figures mean that for each new person added to the population of the service area of an electric utility, the rate-payers of the utility must purchase about 1.5 kilowatts of generating capacity, which costs about $1500.

It follows then that if any period of time (whether it be a week or a decade) the population of the service area of an electric utility increases by 1%, then in that period, every man, woman, and child in the service area must pay about 1% of $1500, or about $15, for the purchase of the electric generating capacity made necessary by that population growth. That's $60 for a family of four!

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In a state such as Colorado whose population growth rate is something like 2.3% per year, the annual per person cost to purchase new electricity generating hardware to accommodate each year's population growth is about $34!

The examples just cited are concrete illustrations of the role of population growth in the electrical generating capacity crises in the U.S. I will write more about this later.

What is the energy content of the remaining conventional fossil fuels in the U.S.?

The size of the reserves of petroleum, natural gas, and coal in the U.S. have been addressed in the context of suggestions that natural gas could be used as a major fuel for motor vehicles. The data from the Department of Energy give no room for unbounded optimism. (7)

Using the estimate of energy reserves in the U.S. one calculates that the energy content of the remaining oil and the remaining natural gas are approximately the same.

If 50% of the coal can be used, the energy in the remaining coat is about ten times the energy in the remaining oil or in the remaining natural gas. If only 20% of the coal can be recovered and used, then the energy in the recoverable coal is only about four times that in the remaining oil or natural gas.

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IV) WARNINGS GALORE

The most prominent of the scientists who started sounding the alarm about the finite nature of fossil fuels was Dr. M. King Hubbert who was alerting people to the petroleum situation as early as 1956. Reference (2) above is a comprehensive presentation of the problems. He prepared this presentation for the Congress.

There was a brief period of national concern about energy back during the OPEC oil crises. As a result of that crisis, significant progress was made in improving energy efficiency, but energy consumption continues to grow. We still use energy as though we think energy supplies are infinite in extent.

Many other geological studies have reinforced and strengthened the concepts that Dr. Hubbert pioneered. In *Scientific American* for March of 1998 is a major article by the global petroleum geologists, Colin Campbell of England and Jean Laherrere of France. They concluded that world oil production will reach its peak before 2010. I have confirmed this in a completely independent study in reference (3) above. My Colorado colleague John D. Edwards, another global petroleum geologist, has estimated that the world petroleum production peak will be reached between 2020 and 2030. My study (3) shows that for every billion barrels of oil that is added to the world's estimated total resource of oil, the peak of production is delayed by 5.5 days!

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We have to ask ourselves,

What's going to happen when world oil production reaches its peak and then starts its inevitable decline toward zero, and we have a growing world population and a growing per capita demand for oil?

If the marketplace is working, prices of petroleum will rise rapidly. These price increases will impact every aspect of our national and personal lives. As one example, please think about the definition of modern agriculture:

Modern agriculture is the use of land
To convert petroleum into food.

The situation with natural gas supplies is fragile. In *Business Week* for September 18, 2000, Pg. 149, we read the article: "There Is Not Enough [Natural] Gas Around."

In this article about the growing demand for natural gas, we read:

But the biggest new demand is coming from [electric] power plants. To generate enough electricity for air conditioning, and for America's exploding population of high-tech gadgets, electric utilities are building gas-fired power plants like there's no tomorrow.

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Today, gas provides a tad more than 20% of U.S. energy needs. Forecasts call for a jump to nearly 30% by 2015. With supplies already tight, this surge seems guaranteed to lock in high prices—with the possibility of drastic price spikes. . .

The article quotes Robert L. Christensen, Jr., senior energy analyst. . .

"There is not enough gas around," he says, to serve the twin masters of current demand, plus storage for higher winter consumption by homes.

We import something like 15% of our natural gas from Canada but:

Longer term, the U.S. can't count on further increases from north of the border because, "Canada has been struggling with tight supplies too," notes Ronald Gist. . .

But with Canada's surplus rapidly vanishing, future options are getting murky.

The Energy Department's Energy Information Administration (EIA) estimates natural gas demand is growing 4.3% this year, while production is increasing by a mere 1%. Next year will be nearly as bad: 3.2% vs. 1%. So gas prices, which have doubled this year, seem destined to keep on climbing.

Growth in annual production [of gas] has gone from flat to minus numbers since 1994. Today, gas extraction from old U.S. wells is declining by about 24% per year. . .

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The gas industry wants to be able to drill in areas that are now off limits:

Otherwise, says Raymond Plank, CEO of Apache, "at the rate we're going, I don't think supply will ever catch up with demand." If Plank is right, the supply glut that depressed prices for years is as good as gone. In that case high prices are here to stay.

V) NON-WARNINGS

In a free country, we treasure diversity of opinions.

But it is important that we not fall into the trap of believing that facts can be changed by majority opinion. Facts are facts, and they are not subject to the voting of democracy or to the pronouncements of prominent people.

Here are some examples of the type of reassuring statements that come from academically credentialed individuals whose message is that resources are, for all intents and purposes, infinite, so there is no need to worry about running out of energy.

Citing a recent puzzling observation in an oil well in the Gulf of Mexico, Steve Forbes writes (*Forbes*, June 14, 1999, Pg. 32)

We're not even close to running out of oil.

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In the last 20 years, estimates of global oil reserves have climbed more than 70% despite record consumption.

The earth may have sufficient oil to supply our needs for centuries to come.

The scientific analysis that was done by the global petroleum geologists, Campbell and Laherrere (that was cited above) predicted that world petroleum production would peak before the year 2010. Commenting on this scientific analysis, M.A. Adleman, Emeritus Professor of Economics at M.I.T., said: (*Fortune*, November 22, 1999, Pg. 194)

This analysis is a piece of foolishness. The world will never run out of oil, not in 10,000 years.

Writing on "The Increasing Sustainability of Conventional Energy," Robert J. Bradley (Cato Policy Analysis No. 341, Cato Institute, April 22, 1999) writes:

Fossil-fuels are growing more abundant, not scarcer, a trend that is likely to continue in the foreseeable future.

He quotes Joseph Stanislaw of Cambridge Research Associates who suggests that the 21st Century will operate under "two essential assumptions, the first of which is:

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Oil, gas, and coal are virtually unlimited resources, to be used in any combination.

Bradley then observes:

America's reliance upon imported oil should not be of major foreign policy or economic concern.

. . .the intellectual tide has turned against doom and gloom on the energy front. Indeed, resource economists are almost uniformly of the opinion that fossil fuels will remain affordable in any reasonably foreseeable future.

Human ingenuity and financial wherewithal, two key ingredients in the supply brew, are not finite, but expansive.

There is no reason to believe that energy *per se* (as opposed to particular energy sources) will grow less abundant (more expensive) in our lifetimes or for future generations.

A leader among those who have been issuing non-warnings (anti-warnings) about resources was the late Dr. Julian Simon who is identified as a Professor of Economics and Business Administration at the University of Illinois and later at the University of Maryland. He was also an adjunct scholar at the Cato Institute in Washington, D.C. Writing on "The State of Humanity: Steadily Improving," a Cato Policy Report (Vol. 17, (5), Pg. 131, September/October 1995) Simon assures us that:

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Technology exists now to produce in virtually inexhaustible quantities just about all the products made by nature—foodstuffs, oil, even pearls and diamonds. . .

We have in our hands now—actually in our libraries—the technology to feed, clothe, and supply energy to an ever-growing population for the next 7 billion years.

Even if no new knowledge were ever gained. . .we would be able to go on increasing our population forever. . .

These assertions have been examined quantitatively and have been found to be scientifically untenable. (8)

VI) THE TWO CULTURES

Long-term sustainability should be our national goal. Community groups throughout the country are talking and working to achieve sustainability. But to be successful, we need to know the Laws of Sustainability. These are given in a published paper (9). The First Law of Sustainability is:

Population growth and/or growth in the rates of consumption of resources cannot be sustained.

This Law is not an opinion; rather, it is a mathematical consequence of arithmetic and of the finite nature of resources.

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In order to sustain our nation, we must preserve democracy. Isaac Asimov has observed (10) that:

Democracy cannot survive overpopulation.
Human dignity cannot survive overpopulation.
Convenience and decency cannot survive overpopulation. . .

A simple example will suffice to demonstrate the loss of democracy at the national level in the U.S. When the first Congress met over 200 years ago, there were approximately 30,000 constituents per member of the House of Representatives. Today there are well over 600,000 constituents per member of the House. Thus, in the approximately 200 year history of our nation, democracy at the national level has been diluted by about a factor of 20!

The population of the U.S. increased in the decade of the 1990s by a total of about 13%, while the membership of the House of Representatives remained unchanged at 435. Thus in the last decade, democracy at the national level declined on the average by about 13%. (11)

In states with large population growth rates, the decline in democracy was more rapid than the decline in states with smaller growth rates. The redistribution of each state's number of seats in the House is not done to give fast growing states more power at the expense of the slower growing states. The redistribution is designed to even up the losses.

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Fred Charles Ikle published a very perceptive article about the problems created by population growth in the U.S. in areas other than energy. (*National Review*, March 7, 1994, Pg. 44) In this article he writes:

Rapid population growth is the paramount, the most elemental anti-conservative force. It creates irresistible pressures for farflung, and usually irreversible, government interventions, allegedly to cope with all of the social changes that rapid population growth has unleashed. It thus helps the radical Left to garner political support for its social-engineering schemes. It dilutes the influence of religious institutions that seek to preserve society's moral fiber. It empowers the unprincipled and the rootless to tear down vastly more civilizing traditions and riches of culture than they will ever create.

VII) COMPARISON OF THE TWO RECOMMENDED PATHS

VIII) THE SCIENTIFIC (CONSERVATIVE) PATH

Population growth is the major factor in driving up the demand for energy and in particular for electricity. Data supporting this assertion have been provided above, but here are further data.

Here are three growth rates for the U.S. for the decade of the 1990s:

Table 1

From these figures one can see that about 60% of the growth in demand for electricity in the decade can be attributed to population growth in the U.S.

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Electricity consumption has been growing almost three times as fast as electric generating capacity.

Here in a nutshell, is the genesis of the electricity crisis in California. These figures suggest that this electricity crisis could easily spread to other parts of the country.

Why has this disparity between capacity and demand been allowed to develop? One can guess that the high cost of constructing electric generating plants is a significant factor. These high costs have to be paid by the rate payers. There is no one else to pay them. The companies and the Public Utility Commissions of the states are reluctant to be up front about the high cost of purchasing new electric generating capacity.

As important as it is to notice the differences in the growth rates of new plant construction, population, and consumption, it is troubling to note that population growth is almost never mentioned in news as being the major cause of the developing shortages of electricity.

Whenever there is a disparity between supply and demand, we almost always call it a shortage of supply. We never call it a "longage" of demand.

Fossil fuel energy resources are probably not available in sufficient quantities in the U.S. to allow us to continue for long in the historical path of always increasing supply to meet demand. If we are to have any hope of success in reducing shortages, we must take bold steps to reduce demand.

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IX) THE NON-SCIENTIFIC (LIBERAL) PATH

This seems to be the path of choice for most American political and industrial leaders.

X) REFLECTIONS ON THE CHOICE OF PATHS

We can no longer afford to be ambiguous, as was the case in the story attributed to Yogi Bera:

When you come to a fork in the road, take it.

The U.S. is at a fork in the road in regard to energy policy. We have to make a major long-term policy choice between the Liberal and the Conservative energy paths.

XI) THE FOOLPROOF WAY TO MAKE THE CHOICE

XII) THE TWO POSSIBLE CHOICES OF THE WRONG PATH

It often amazes people to learn of this simple decision-making process by which we can make a wise choice between two competing paths, when academically credentialed people recommend each path, and the paths are in absolute conflict with each other.

XIII) CONCLUSION: ARE WE ON THE RIGHT PATH?

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All the evidence I have seen leads me to conclude that we are on the Liberal Path when we should be on the Conservative Path.

There is no better time than the present to adopt the Conservative Path, and make conservation a central theme of our national energy policy.

It is clear that, in the long run, the society that survives will be the society that is in equilibrium with nature.

Easter Island is an example of a technologically sophisticated society (they carved the monolithic monuments for which the Island is known) that destroyed the resources on which the society had been based (large trees), and after the destruction of the trees was complete, the survivors lapsed into an extremely primitive condition and succeeding generations quickly lost their memory of the earlier civilization.

Advocates of the Liberal Path call my message "Malthusian," and then claim that science and technology has proven Malthus to be wrong.

I recently read Malthus for the third time.

Malthus was very right! Malthus understood that the power of the potentially exponential increase in population could quickly overwhelm any societal support systems, such as food and energy. Malthus' timetable was off, but his conclusions, based on simple arithmetic, are as valid today as when he wrote them 200 years ago.

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The message of Malthus was translated into more modern terms by the late great economist, Kenneth Boulding, who proposed three theorems.

The Dismal Theorem: If the only ultimate check on the growth of population is misery, then the population will grow until it is miserable enough to stop its growth.

The Utterly Dismal Theorem: Any technical improvement can only relieve misery for a while, for so long as misery is the only check on population, the [technical] improvement will enable population to grow, and will soon enable more people to live in misery than before. The final result of [technical] improvements, therefore, is to increase the equilibrium population, which is to increase the total sum of human misery.

The Moderately Cheerful Form of the Dismal Theorem: If something else, other than misery and starvation can be found which will keep a prosperous population in check, the population does not have to grow until it is miserable and starves, and it can be stably prosperous.

THANKS

I thank the Committee for this opportunity to share with you my thoughts on our national energy future.

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Several of these papers by A.A. Bartlett may be viewed on the website: *http://csf.colorado.edu/authors/Bartlett.Albert*

PREPARED STATEMENT OF ALBERT A. BARTLETT

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My name is Albert A. Bartlett. I am a Professor Emeritus of Physics at the University of Colorado at Boulder.

I) Introduction

Our National Energy Situation Is a Mess!

For years we have seen recommendations from the U.S. Department of Energy that suggest that the leaders of the Department have little scientific understanding of the problems of energy.

We have seen the President of the United States sending his Secretary of Energy on bended knee to plead with OPEC leaders, asking them to increase petroleum production so as to keep our gasoline prices from rising.

For a country that boasts that it is the world's only superpower, this is profoundly humiliating.

II) What's Happening?

Gasoline prices are rising.

California currently has an electrical energy crisis which is likely to spread.

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Natural gas prices are rising rapidly.

This poses real economic hardship for millions of home owners who depend on natural gas to heat their homes.

III) What's Being Proposed?

The only energy proposals we see are for short-term fixes sometimes spread over a few years that seem to ignore the real-world realities of resource availability and consumer costs.

IV) Warnings Galore!

For years, scientists have warned that fossil fuels resources are finite, and that long-range energy plans should be made.

These plans must recognize that growing rates of consumption of fossil fuels will lead, predictably, to serious shortages, which are now starting to appear.

V) Non-Warnings (Anti-Warnings)

For years we have heard learned opinions, generally from non-scientists, that resources are effectively infinite; that the more of a resource that we consume, the greater are the reserves of that resource; that the human intellect is our greatest resource because the human mind can harness science and technology to solve all of our shortages.

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VI) The Two Cultures

There seem to be two cultures, science and non-science, which are isolated from each other.

Each has it's own Ph.D. "experts" and think tanks.

Each has its own lobbyists arguing vigorously that their path is the proper one to follow in order to achieve long-term sustainability.

VII) Comparison of the Two Recommended Paths

Let's compare these two paths.

VIII) The Scientific (Conservative) Path

The centerpiece of the scientific path is conservation; hence it is appropriate to call this path the "conservative" path.

On this path the Federal Government is called on to provide leadership plus strong and reliable long-term support toward the achievement of the following goals.

The U.S. should:

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A) Have an energy planning horizon that addresses the problems of sustainability through several future decades.

B) Have a program for the continual and dramatic improvement of the efficiency with which we use energy in all parts of our society.

Improved energy efficiency is our lowest cost energy resource.

C) Move toward the rapid development and deployment of all manner of renewable energies throughout our entire society.

D) Embark on a program of continual reduction of the annual total consumption of non-renewable energy in the U.S.

E) Recognize that moving quickly to consume the remaining U.S. fossil fuel resources will only speed and enlarge our present serious dependence on the fossil fuel resources of other nations.

This will leave our children vitally vulnerable to supply disruptions which they won't be able to control.

F) Recognize that population growth in the U.S. is a major factor in driving up demand for energy.

This calls for recognizing the conclusion of President Nixon's Rockefeller Commission Report.

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("Commission on Population Growth and the American Future")

The Commission concluded that it could find no benefit to the U.S. from further U.S. population growth.

IX) The Non-Scientific (Liberal) Path

In contrast, the non-scientific path suggests that resources are effectively infinite, so that we can be as liberal as we please in their use and consumption. Hence this path is properly called the "liberal" path. The proponents of the liberal path recommend that the U.S. should:

A) Make plans only to meet immediate crises;

B) Not have government promote improvements in energy efficiency; because the market place will provide these needed improvements.

C) Not have government programs to develop renewable energies because, again, the market can be counted on to take care of all of our needs.

D) Let fossil fuel consumption rates continue to increase, because to do otherwise might hurt the economy.

E) Dig, dig, dig, and drill, drill, drill. Consume our remaining fossil fuels as fast as possible because we "need" them.

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Don't worry about our children. They can count on having the advanced technologies they will need to solve the problems that we are creating for them.

F) Claim that population growth is a benefit rather than a problem, because more people equals more brains.

X) Reflections on the Choice of Paths

We should not be confused by the conflicting expertise that supports each of these two paths, because for every Ph.D., there's an equal and opposite Ph.D.

In our energy policies, as a nation must choose between the liberal and conservative paths.

XI) The Foolproof Way to Make the Choice

The two paths are exact opposites of each other.

Each is advocated by credentialed experts.

On what basis can we make an intelligent choice?

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Fortunately there is a rational way to make the choice between the two paths.

We must recognize that:

1) If the path we choose turns out to be the correct path, then there's no problem.

2) The problems arise in case we chose the wrong path.

3) So what we must do is to choose the path that leaves us in the less precarious position in case the path we choose is the wrong one.

XII) The Two Possible Choices of the Wrong Path

There are then two possible wrong choices to compare.

1) If we choose the conservative path of finite resources and our children later find that resources are really infinite, then no great long-term harm has been done.

2) If we choose the liberal path, which assumes that resources are effectively infinite, and then later our children find that resources are actually finite, then we will have left our descendants in deep trouble.

XIII) Conclusion: Are We on the Right Path?

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There can be no question. The conservative path is the prudent path to follow.

However it is the liberal path that we are following so eagerly today.

If resources turn out to be infinite, then all will be well.

If resources turn out to be finite, then we are on the wrong path, and if we continue on this liberal path our children will have to bear the terrible consequences of our conscious choice of the wrong path.

XIV) Closing

I elaborate on these points in the written testimony I have submitted.

I thank you for this opportunity to share my views with you.

BIOGRAPHY FOR ALBERT ALLEN BARTLETT

PRESENT POSITION

Professor Emeritus, Department of Physics; (Retired, January 1, 1988) University of Colorado, Boulder, Colorado, 80309–0390; Phone: (303) 492–7016 or 492–6952; FAX: (303) 492–3352; E-Mail: Albert.Bartlett@Colorado.EDU

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HOME: 2935 19th Street, Boulder, Colorado 80304–2719; Phone: (303) 443–0595

BORN: March 21, 1923, Shanghai, China; of American Parents

EDUCATION

Westerville High School, Westerville, Ohio: Graduated: May 1940

Otterbein College, Westerville, Ohio: 1940–1941

Colgate University, Hamilton, New York: B.A., (Physics) 1944

Harvard University, Cambridge, Massachusetts; M.A., (Physics) 1948: Ph.D., (Nuclear Physics) 1951

PROFESSIONAL EMPLOYMENT

Scientific Staff, Los Alamos Scientific Laboratory, 1944–1946

Faculty of the Department of Physics, University of Colorado at Boulder, September 1950 to the present

Faculty: Harvard University Summer School; 1952, 1953, 1955, 1956

Scientific Staff: Nobel Institute of Physics, Stockholm, Sweden; Academic Year 1963–1964

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PROFESSIONAL MEMBERSHIPS

American Physical Society, (1948–); Fellow, 1984

American Association of Physics Teachers, (1950–)

Scientific Society of Sigma Xi, (1950–)

American Association for the Advancement of Science: Fellow, 1984

American Association of University Professors

OFFICES HELD

Elected Chair for two terms of the four-campus Faculty Council of the University of Colorado: 1969–1970 and 1970–1971

National President: American Association of Physics Teachers, 1978

HONORS-AWARDS

Phi Beta Kappa: Colgate University, 1944

Scientific Society of Sigma Xi: Harvard University, 1950

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Distinguished Service Citation: American Association of Physics Teachers, 1970

Thomas Jefferson Award: Faculty of the University of Colorado, 1972

Robert L. Stearns Award: Associated Alumni of the University of Colorado, 1974

University of Colorado Gold Medal: Regents of the University of Colorado, 1978

University of Colorado Award for Teaching, 1981

Robert A. Millikan Award: American Association of Physics Teachers, 1981

Melba Newell Phillips Award: American Association of Physics Teachers, 1990

PUBLIC SERVICE

City of Boulder Parks and Recreation Advisory Board, 1967–1972; Vice-Chair, 1969 and 1970; Chair, 1971

Founding Member of PLAN-Boulder County: An Environmental Organization for the City and County of Boulder

Lectures nationwide on "Arithmetic, Population, and Energy," (1969–)

Lecture on "Arithmetic, Population, and Energy"

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This tally was first given on September 19, 1969 to a group of students at the University of Colorado in Boulder. As of April 30, 2001 this one-hour tally has been given 1410 times in 49 states, a dozen or so times in Canada, and a couple of times overseas. During this time the talk has evolved, but the message remains unchanged:

The greatest shortcoming of the human race
is our inability to understand the exponential function.

The tally identifies the exponential function as the function that describes steady growth, and then shows how steady growth gives enormous numbers in modest periods of time. Yet steady growth is the centerpiece of the entire national and global economies. The economic growth is based on the easy availability of fossil fuels, particularly petroleum. The talk examines the dramatic reduction of the life expectancy of a finite non-renewable resource when the rate of consumption of the resource is growing steadily. These results are applied to petroleum and coal production. The resulting life-expectancies are very much shorter than those that are quoted by experts, journalists and scientists. Charts in the talk illustrate the probable future trend in petroleum production in the U.S. and globally. These charts are taken from my published paper (Mathematical Geology, January 2000, Pg. 1). Numerous examples are given of public statements by prominent people that demonstrate a complete lack of understanding of even the simplest fundamentals of resource arithmetic. The talk closes with a discussion of the importance of educating all of our people to the arithmetic and consequences of growth, especially terms of populations and in terms of the earth's finite resources.

The talk has given to groups ranging from junior high school students to university graduate students. After one of the talks to junior high science students, two of the students spoke to me, saying, "We can understand this. Why can't grown-ups understand it?" The talk has been given as a keynote address at all manner of science and non-science, professional and educational, national and regional conventions. On several occasions the tally has been given in Washington for staff members of the House and Senate. The tally was given 44 times in the year 2000.

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Videotapes of this talk are available from the Information Technology Services of the University of Colorado at Boulder, Phone (303) 492–1857.

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Chairman **BARTLETT.** Thank you very much for your testimony. Dr. Weedman.

STATEMENT OF DR. SUZANNE D. WEEDMAN, PROGRAM COORDINATOR, ENERGY RESOURCES PROGRAMS, U.S. GEOLOGICAL SURVEY

Dr. **WEEDMAN.** Good morning Mr. Chairman and Members of the Subcommittee, thank you for this opportunity to appear here today to present results of our U.S. Geological Survey Energy Resource Assessments.

Within the Federal Government, the USGS has the responsibility of assessing the undiscovered oil and gas resources of the onshore and state offshore waters of the nation, the nation's coal resources, and the oil and gas resources of the world. In 1995 the USGS released their national assessment of the United States Oil and as resources. We reported that in the U.S. onshore and state waters there remained about 112 billion barrels of technically recoverable oil, and about 1,074 trillion cubic feet of natural gas. Now these volumes include known reserves, reserve growth, and undiscovered resources. Basically, everything we think that remains now after the amount that we have already used.

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In the fall of last year the President signed the Energy Act of 2000. Section 604 of this new law charges the Secretary of the Interior to conduct an inventory of energy resources on Federal lands, and of the restrictions and impediments to their development. The USGS will work with the BLM, with the Forest Service, and with DOE to produce this digital inventory, which we will deliver to Congress in November of 2002.

The Minerals Management Service has recently updated their 1995 assessment of the outer Continental Shelf. Their assessment reports that 75 billion barrels of oil and 362 trillion cubic feet of natural gas are yet to be discovered in the outer Continental Shelf offshore. In the year 2000, last year, the USGS released its world petroleum assessment 2000. We report that there are 649 billion barrels and 4,669 trillion cubic feet of gas yet to be discovered in the world outside the U.S. In this new assessment we report a 20 percent more oil and 14 percent less gas than our previous world assessment back in 1994. This new oil is primarily we think in offshore basins.

The USGS is releasing its National Coal Resource Assessment this year. Two regions are complete. The Colorado Plateau and the northern Rocky Mountains and Great Plains. The Illinois Basin, the Appalachian Basin and the Gulf Coast assessments will be released later this year. There are nearly 4 trillion tons of coal in the United States. But not all of this coal is available for mining, nor is it economically recoverable. For example, in the Appalachian and the Illinois Basins about 50 to 60 percent of the coal is available for mining after land use and technological restrictions are applied. And only 8 to 38 percent of this resource is economically recoverable.

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About 30 percent of the nation's coal production comes from Federal lands. Most of the high quality coal reserves in Wyoming, Utah, Montana, Colorado and New Mexico occur on federally managed lands, or are managed by the Federal Government below land surface that is in state or private ownership. Our assessment shows that more than 360 billion short tons of Federal coal exist in Utah, Colorado and New Mexico, the Colorado Plateau, and more than 520 billion short tons of Federal coal exist in Wyoming, Montana and North Dakota.

Finally, I would like to summarize the current status of geothermal and uranium resources in this country. We have not done much work in the area at the USGS in the last decade. Today the U.S. has an installed capacity of 2,860 megawatts of electric power from geothermal plants in the states of California, Hawaii, Nevada and Utah. This constitutes .4 percent of our total electricity generation. The last geothermal resource assessment by the USGS was published in 1978. That assessment concluded that 9 states in the west have the potential to produce at least 100 megawatts of electricity from known geothermal systems. Those states are Alaska, Arizona, California, Hawaii, Idaho, Nevada, New Mexico, Oregon and Utah. Of these 9 states with this potential, only California has realized a significant fraction, that is 22 percent, of its potential geothermal electricity generating capacity.

And finally, uranium, the fuel for nuclear power generation, the first and only uranium assessment was the National Uranium Resource Evaluation, the NURE Program, completed by the Department of Energy in 1980. Today 22 percent of our electricity comes from nuclear generating plants. The U.S. imports most of its uranium, 76 percent of its uranium, now from Canada, from Australia, Russian, South Africa, Uzbekistan and Ukraine.

But since 1980 new resource areas have been identified. New types of uranium deposits have been discovered. And there are new mining methods that have become available. Because of these new discoveries, the original assessment is really very much out of date.

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Mr. Chairman, this concludes my remarks. I would be happy to respond to questions that you or members of your subcommittee may have.

[The prepared statement of Dr. Suzanne D. Weedman follows:]

PREPARED STATEMENT OF DR. SUZANNE D. WEEDMAN

Mr. Chairman and Members of the Subcommittee, thank you for this opportunity to present this statement regarding U.S. Geological Survey assessments of national and global energy resources.

Background

Within the Federal Government, the U.S. Geological Survey (USGS) is responsible for assessing undiscovered oil and gas resources of all onshore and State offshore areas of the Nation as well as coal and coal bed methane resources. The Geothermal Energy Research, Development and Demonstration Act of 1974 assigned responsibility for the evaluation and assessment of geothermal resources to the USGS through the U.S. Department of the Interior (DOI). The Minerals Management Service (MMS) is responsible for estimating the undiscovered oil and natural gas resources of the Outer Continental Shelf (OCS).

Because the Subcommittee requested a comprehensive overview of the U.S. Energy picture, we will also include a brief overview of U.S. uranium resources.

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Oil and Natural Gas Resources

The USGS 1995 National Oil and Gas Assessment. In February 1995, the USGS released the *National Assessment of United States Oil and Gas Resources.* Currently, we are updating that assessment in selected regions thought to have high potential for undiscovered natural gas, including coalbed methane. This update will be completed in 2004, with interim products available in early 2002. The updated assessment will include allocations of undiscovered oil and gas resources to Federal lands.

The 1995 USGS assessment of the Nation's onshore undiscovered oil and gas was published in digital format on a CD-ROM (USGS Digital Data Series-30) and in a non-technical summary, as USGS Circular 1118. The Assessment was conducted in collaboration with State Geological Surveys, MMS, and industry geologists working under the auspices of the American Association of Petroleum Geologists. Additional cooperation with the Bureau of Land Management, National Park Service, U.S. Forest Service, and Bureau of Indian Affairs was essential for USGS to generate information regarding oil and gas resources on Federal lands. The current update of the 1995 assessment involves many of the same partners.

Assuming existing technology, there are approximately 112 billion barrels of technically recoverable oil onshore and in State waters, according to USGS's most recent assessment. This volume includes both conventional and unconventional resources. Technically recoverable resources are those that may be recoverable using current technology without regard to economic feasibility. This includes measured (proved) reserves, future additions to reserves in existing fields (reserve growth), and undiscovered conventional resources.

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The technically recoverable conventional resources of natural gas in measured (proved) reserves, future additions to reserves in existing fields (reserve growth), and undiscovered conventional accumulations equal approximately 716 trillion cubic feet of gas. In addition to conventional gas resources, USGS has assessed technically recoverable resources in continuous-type (largely unconventional) accumulations. We estimate about 308 TCFG (trillion cubic feet of gas) of technically recoverable natural gas in continuous-type deposits in sandstones, shales, and chalks, and almost 50 TCFG of technically recoverable gas in coal beds. The total technically recoverable oil and gas resource base onshore and in State waters of the United States is displayed in Table 1.

Table 2

The estimates presented in this statement reflect USGS understanding as of January 1, 1994. They are intended to capture the range of uncertainty, to provide indicators of the relative potential of various petroleum provinces, and to provide a useful guide in considering possible effects of future oil- and gas-related activities within the United States.

The geographic information system (GIS) coverages contained in this assessment and related databases provide the capability to estimate oil and gas resource potential on specific tracts of land, including those managed by the Federal Government. This process is called allocation, based on expert opinion, and is accomplished using a methodology that takes into consideration all geologic information available about a particular basin.

1995 National Oil and Gas Assessment and Onshore Federal Lands (1998). In January 1998, USGS published an Open-File Report (OFR 95–0075–N) that reported estimates of volumes of undiscovered oil and gas on Federal lands. Estimates of oil in undiscovered conventional fields range from 4.4 to 12.8 billion barrels (BBO), with a mean value of 7.5 BBO. Estimates of technically recoverable gas in undiscovered conventional fields range from 34.0 to 96.8 trillion cubic feet (TCF), with a mean value of 57.9 TCF. Almost 85 percent of the assessed natural gas in undiscovered conventional accumulations was non-associated gas, that is, gas in gas fields rather than gas in oil fields. Estimates of technically recoverable resources in unconventional (continuous type) accumulations for oil are from 0.2 to 0.6 BBO, with a mean value of 0.3 BBO, and for gas, from 72.3 to 202.4 TCF, with a mean value of 127.1 TCF. These ranges of estimates correspond to 95-percent probability (19 in 20 chance) and 5-percent probability (1 in 20 chance) respectively, of a least those amounts occurring.

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An economic evaluation was applied to these technically recoverable estimates. Our study concluded that at $30 per barrel for oil and $3.34 per thousand cubic feet of gas, 3.3 BBO oil and 13.6 TCF in undiscovered conventional fields could be found, developed, and produced. In addition, at these estimated prices, 0.2 BBO oil and 11.4 TCF in continuous-type accumulations and 11.8 TCF of coalbed gas can be developed.

Estimated volumes of undiscovered oil, gas, and natural gas liquids in onshore Federal lands, as of January 1994 are displayed in Table 2.

Table 3

* Includes cost of finding, developing, and producing the resource. Based on mean values of technically recoverable estimate.

** BBO = billion barrels oil; TCF = trillion cubic feet; BBL = billion barrels liquid; bbl = barrel; mcf = thousand cubic feet.

The results of the USGS National Oil and Gas Resource Assessment have been used by the Energy Information Administration (EIA) for its *Annual Energy Outlook*, by the California Energy Commission and Canadian Energy Board to model inter-regional natural gas supply and demand and the resulting economic impacts, and by numerous petroleum companies as a basis for evaluating risk associated with exploration and development of domestic oil and gas resources.

Many Federal agencies use the information in the USGS National Oil and Gas Assessment for land-use planning, energy policy formulation, and economic forecasting. Customers include the Department of the Interior, Bureau of Land Management, National Park Service, U.S. Forest Service, Bureau of Indian Affairs, Energy Information Administration, and the Department of Energy (DOE), among others. In addition, most State Geological Surveys and/or State Divisions of Oil and Gas use the USGS assessment for regional and local resource evaluation and lease planning purposes. Many private sector organizations also use the digital oil and gas assessment results, including environmental protection advocacy groups, petroleum exploration companies, and utility companies (including natural gas and electricity utilities).

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Sec. 604 Energy Act of 2000. The Secretary of the Interior is charged with conducting an inventory of energy resources and the restrictions and impediments to their development on Federal Lands in Section 604 of the Energy Act of 2000, signed into law on November 9, 2000.

It is our understanding that the role of USGS will be to assess the oil and gas resources of oil- and gas-bearing basins that have federally managed lands, consistent with the USGS assessment and allocation methodology. Then, USGS geologists will allocate resource estimates to those specific land parcels managed by the Federal government. The USGS resource estimates will be combined with reserve volumes from the Energy Information Administration (EIA) of the Department of Energy (DOE), and will be incorporated into a geographic information system (GIS) to show the spatial distribution of those potential resources and known reserves. The resource and reserve information will be integrated with information on restrictions and impediments provided by the Bureau of Land Management (BLM) and the Forest Service.

The USGS will use resource estimates from the 1995 National Oil and Gas Assessment for areas where there are no significant new data and will update resource estimates for the gas-prone areas of the country where new data are available.

The Minerals Management Service's 2000 OCS Resource Assessment. As background, MMS's mission consists of two major programs: Offshore Minerals Management and Minerals Revenue Management. The leasing and oversight of mineral operations on the Outer Continental Shelf (OCS) and all mineral revenue management functions for Federal (onshore and offshore) and American Indian lands are centralized within the bureau. In 2000, OCS oil and natural gas production accounted for roughly 25 and 26 percent, respectively, of our nation's domestic energy production—oil production was over 500 million barrels and natural gas production was over 5 trillion cubic feet. The amount of oil and natural gas production in 2000 was the most ever produced on the OCS. In addition, in fiscal year 2000, MMS collected and distributed about $7.8 billion in mineral leasing revenues from Federal and American Indian lands.

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In its role as manager of the Nation's OCS energy and non-energy mineral resources, MMS is responsible for assessing those resources; determining if they can be developed in an environmentally sound manner; and if leased, regulating activities to ensure safety and environmental protection. An integral element in that mission is to identify the most promising areas of the OCS for the occurrence of crude oil and natural gas accumulations and to quantify the amounts of oil and natural gas that may exist in these areas.

Since its creation in 1982, MMS has completed four systematic assessments of Federal OCS undiscovered oil and natural gas resources, including its most recent assessment. The 2000 resource assessment was done to support staff work and analysis needed in formulating the next 5-Year Oil and Gas Leasing Program covering the timeframe 2002–2007. It should be noted that the methodology for the 2000 assessment has not changed significantly from that used in the previous 1995 assessment.

The 2000 assessment presents the updated assessment results since the 1995 assessment for the Alaska, Atlantic, and Gulf of Mexico OCS Regions. In the Alaska Region only the Beaufort and Chukchi Seas, Hope Basin, and Cook Inlet areas were updated, as there were no new data or other changes since the last assessment. The Pacific OCS Region was not updated for the same reasons. The Atlantic OCS Region was re-evaluated to reflect recent exploration results offshore Nova Scotia, current exploration and production technologies, and to make the water depth divisions compatible with the ones now being used in the Gulf of Mexico.

The MMS has recently made public the 2000 assessment, and I have included a copy of the assessment with my written statement for the hearing record. MMS estimates that the total mean undiscovered, conventionally recoverable resources for the United States OCS are 75.0 billion barrels of oil and 362.2 trillion cubic feet of natural gas. Within that total, MMS determined that the undiscovered conventionally recoverable resources foregone by the 1998 moratoria (i.e., the President's June 1998 OCS decision) would be approximately 16 billion barrels of oil and 62 trillion cubic feet of gas.

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The total mean undiscovered economically recoverable resources for the United States OCS are 26.6 billion barrels of oil and 116.8 trillion cubic feet of gas at prices of $18 per barrel and $2.11 per thousand cubic feet, respectively, and 46.7 billion barrels of oil and 168.1 trillion cubic feet of gas at prices of $30 barrel and $3.52 per thousand cubic feet, respectively.

USGS 2000 World Petroleum Assessment. In March 2000,USGS released the *World Petroleum Assessment 2000.* This assessment is a five-year project that was extensively reviewed by members of the World Energy Consortium. The project assessed recoverable undiscovered conventional oil and gas resources of the world, exclusive of the United States, for a 30-year time frame (1995–2025). This is a geologically based assessment and resources were allocated to individual countries, allocated to onshore and offshore, and allocated to OPEC, OECD, and other countries not part of OPEC or OECD. For the first time, our world assessment contains an estimate of the amount of reserve growth expected in the next 30 years. All the products are digital and available on CD–ROM and via the Web.

The assessment provides estimates of the quantities of conventional oil, gas, and natural gas liquids that have the potential to be added to global reserves in the next 30 years. The mean (expected) volumes of undiscovered resources are 649 billion barrels of oil (BBO), 4,669 trillion cubic feet of gas (TCFG), and 207 billion barrels of natural gas liquids (BBNGL). The estimated mean additions to reserves from discovered fields (potential reserve growth) are 612 BBO, 3,305 TCFG, and 42 BBNGL.

The potential additions to reserves from reserve growth are nearly as large as the estimated undiscovered resource volumes. These estimates imply that 75 percent of the world's grown conventional oil endowment (see Table 3 for explanation of grown endowment) and 66 percent of the world's grown conventional gas endowment have already been discovered in the areas assessed (exclusive of the U.S.). Additionally, for these areas, 20 percent of the world's grown conventional oil endowment and 7 percent of the world's grown conventional gas endowment had been produced as of the end of 1995.

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This assessment is based on extensive geologic studies rather than a statistical projection. The petroleum assessed occurs in fields exceeding a stated minimum size, which varies between 1 and 20 million barrels of oil equivalent in different areas, and in accumulation categories judged to be viable in a 30-year forecast span.

Compared to the last USGS world petroleum assessment (Masters and others, 1994, 1997), undiscovered volumes from this world assessment are 20 percent greater for oil, 14 percent smaller for gas, and 130 percent greater for natural gas liquids. The large estimated volumes of oil, gas, and natural gas liquids from reserve growth in this assessment represent a resource category not quantitatively assessed previously for the world by the USGS.

The volume of undiscovered oil estimated in this assessment is larger than that of the 1994 assessment, due in part to larger estimates for the Middle East and Atlantic offshore portions of South America and Africa. However, in some areas the estimated volumes of undiscovered oil were smaller, particularly for Mexico and China.

The volume of undiscovered gas estimated in this assessment is smaller than that of the previous world assessment mainly because of smaller estimates for arctic areas of the Former Soviet Union, some basins in China, and the Alberta Basin of Canada. The volume of undiscovered NGL estimated in this assessment is much larger than that of the previous assessment because of more detailed analysis, coupled with the incorporation of co-product ratios into the assessment calculations.

Areas assessed in the World Petroleum Assessment 2000 that contain the greatest volumes of undiscovered conventional oil include the Middle East, northeast Greenland Shelf, the West Siberian and Caspian areas of the Former Soviet Union, and the Niger and Congo delta areas of Africa. Significant new undiscovered oil resource potential was identified in a number of areas with no significant production history, such as northeast Greenland and offshore Suriname.

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Areas that contain the greatest volumes of undiscovered conventional gas include the West Siberia Basin, Barents and Kara Seas shelves of the Former Soviet Union, the Middle East, and offshore Norwegian Sea. A number of areas were identified that may contain significant additional undiscovered gas resources where large discoveries have been made but remain undeveloped. Examples include East Siberia and the Northwest Shelf of Australia.

Table 4

Mean values are the average or expected values

Grown Petroleum Endowment is the sum of the known petroleum volume (cumulative production plus remaining reserves), the mean of the undiscovered volume, and additions to reserves by reserve growth

1B = Data from USGS World Petroleum Assessment, 2000

• = Data from Petroconsultants, 1996, and NRG Associates, 1995

= Data from USGS National Oil and Gas Assessment, 1995, and from Minerals Management Service, 1996

= Mean U.S. Oil amounts include natural gas liquids

Coal Resources

The USGS is completing a National Coal Resource Assessment (NCRA) during 2001. To date, two coal resource assessments have been released, the Colorado Plateau and the Northern Rocky Mountains and Great Plains. Coal resource assessments of the Appalachian and Illinois Basins, and Gulf Coast Region will be available later in 2001. The USGS coal assessments also identify volumes of coal under federally owned lands, and of federally owned coal under privately owned lands, where present.

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The NCRA is a multi-year effort by the USGS to identify, characterize, and assess the coal resources that are expected to supply a major part of the Nation's energy needs during the 21st century. Products from NCRA include publicly available stratigraphic, geochemical, and GIS databases to answer a variety of questions of importance to government, industry and public decision makers and interpretive geologic and geochemical information for the primary coal resources of the Nation. Five priority regions were assessed: the Appalachian Basin, Illinois Basin, Gulf Coast, Colorado Plateau, and Northern Rocky Mountains and Great Plains. The NCRA is a cooperative effort between the USGS and a number of State geological surveys in these coal-bearing regions. Volumes of coal resources on Federal lands were also identified.

The results of the USGS National Coal Resource Assessment are important because they provide an impartial assessment of the Nation's coal resources. The USGS NCRA provides information that can be used to: (1) evaluate and minimize environmental impacts related to extraction, production, and use of energy resources; (2) manage resources on Federal lands; (3) address issues of energy and environmental policy and strategy; (4) determine the potential for coalbed gas resources and development of the United States; (5) determine the availability and recoverability of coal resources throughout the U.S; (6) determine potential areas of future coal development; and (7) assess the potential of coal to act as a storage site to sequester carbon dioxide.

The reported coal resource estimates for the five regions refer to coal resources in the ground and are quite large and should not be confused with available or minable and recoverable coal (often referred to as 'reserves') in these regions. There are trillions of tons of coal in the United States. However, total resources are also important because they are still potential resources, should technologic, societal, political, or economic needs change resulting in presently unminable coal becoming usable. For example, results from the two finalized assessment regions estimate resources of approximately 550 billion short tons of remaining coal in the Colorado Plateau and 660 billion short tons of coal in the Northern Rocky Mountains and Great Plains region. Not all of this coal is available for mining or economically recoverable. Studies in the Appalachian and Illinois Basins indicate that only 50 to 60 percent of the coal is usually available for mining after land use and technological restrictions are applied to the data, and only 11 to 38 percent is economically recoverable. Furthermore, coal quality affects coal usage greatly. Current Clean Air Act regulations limit the amount of sulfur dioxide that power plants may emit. These regulations limit the amount of sulfur in the coal that may be burned, unless the power plants install certain smoke stack equipment.

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In addition to the resources assessed in the five priority regions, a resource assessment of coal on Federal land was also conducted. The Federal Government manages vast amounts of coal resources. The U.S. Government held 91.7 billion short tons of coal in reserve in 1998–1999. Approximately one-third of the Nation's coal production comes from coal on Federal lands; in 1997, approximately 1.1 billion short tons of coal were produced in the United States and approximately 330 million tons of that coal originated from Federal lands. More than a quarter of a billion dollars in royalties are generated annually from production of coal on Federal lands, of which about half is disbursed to the States from which the coal was mined.

Federal coal and land ownership is a much more important issue in the western United States where many coal fields occur on Federally managed lands. The majority of relatively high quality coal reserves in Wyoming, Utah, Montana, Colorado and New Mexico occur on federally managed lands. Approximately 50 percent of the coal in the Colorado Plateau assessment region underlies land that is administered by Federal agencies including the Bureau of Land Management, the National Park Service, and the U.S. Forest Service; the Colorado Plateau also contains coal underlying Tribal, State, and private lands. Approximately 32 percent of the coal.in the Northern Rocky Mountains and Great Plains assessment region occurs beneath land surface managed by Federal agencies, however, Federal coal resources underlie approximately 80 percent of this area.

An important issue in Federal land management is the interrelationship between surface ownership and coal ownership. Often ownership of the coal and ownership of the surface land is not the same. This is strikingly illustrated when comparing land ownership versus federal coal ownership in the assessed units of the Colorado Plateau and the Northern Rocky Mountains and Great Plains. In the Powder River Basin, Wyoming and Montana, where more than a third of the country's coal is produced, almost all of the coal is Federally managed, yet most of the surface rights are privately held. In the Colorado Plateau, the majority of the coal is also federally managed, yet the majority of surface ownership is nonfederal (either State, Tribal, or private).

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Because federally managed coal plays a major role in the energy supply of the United States, National Coal Resource Assessment developed digital databases of information on Federal coal resources. These databases identify areas where surface ownership is different from mineral ownership and can help policy makers, land-use planners, land managers, and mineral developers make informed decisions regarding Federal land use while maintaining a healthy domestic energy industry. At this time, these databases only contain information for the conterminous United States, because digital information on coal ownership in Alaska is not presently available.

This work represents the first time that resource estimates have been calculated for Federal coal. More than 360 billion short tons of Federal coal exists in Utah, Colorado, and New Mexico and more than 520 billion short tons of Federal coal exists in Wyoming, Montana, and North Dakota.

Geothermal Resources

Assessment efforts initiated under the Geothermal Energy Research, Development, and Demonstration Act of 1974 led to the publication of USGS Circular 726, *Assessment of Geothermal Resources of the United States—1975 and* USGS Circular 790, *Assessment of Geothermal Resources of the United States—1978.* These reports established the methodology for geothermal resource assessments and provided estimates of potential electric power generation that have guided geothermal energy research and development for the past 22 years.

Today, the United States has an installed capacity of approximately 2,860 Megawatts (MW) of electrical power production from geothermal plants located in California, Hawaii, Nevada, and Utah. This constitutes 0.4% of our total electricity generation capacity. Geothermal energy is derived from the earth's internal heat and can be manifested as volcanoes, hot springs, and other thermal features. Large portions of the western U. S. are characterized by abnormally high heat flow as a result of active faulting and volcanism and all of the existing geothermal power plants fall within these regions.

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Geothermal reservoirs are classified according to their temperature and whether the reservoir fluid occurs as liquid water or as steam. Geothermal power is obtained from steam produced directly from the ground, from steam flashed and separated from hot water, or from binary systems involving closed-loop heat exchange between hot water and organic fluids with low boiling temperatures.

High temperature geothermal systems have temperatures greater than 150C (302F) with the reservoir fluid comprising hot water and/or steam. These systems are typically the best candidates for electricity generation and power plants exploiting these systems typically flash the hot water to drive steam turbines.

Intermediate temperature systems have temperatures between 90 and 150C (194 and 302F) and generally require the use of binary power plants with closed-loop heat exchange technology that allows transfer of the heat in the geothermal fluid to a second fluid that vaporizes at lower temperature.

Low temperature systems are those with temperatures less than 90C (194F) and are generally considered appropriate for direct use applications (space heating, agricultural process heat, spas). In this statement I will concentrate on the nature and abundance of intermediate and high temperature geothermal systems in the United States. A general overview of all aspects of geothermal energy can be found in USGS Circular 1125, *Tapping the Earth's Natural Heat.*

The last nationwide geothermal resource assessment (USGS Circular 790) was published in 1978, and a comparison of its findings with the current state of knowledge and development highlights some important points.

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a. Nine western states (Alaska, Arizona, California, Hawaii, Idaho, Nevada, New Mexico, Oregon and Utah) have potential for at least 100 MW of electrical power generation per state from identified geothermal systems.

b. The total identified high temperature geothermal resource in these nine states was estimated at approximately 22,000 MW. On a state-by-state basis, only California has realized a significant fraction (22%) of this potential (2,600 out of 12,000 MW). Estimates of undiscovered resources ranged from 72,000 to 127,000 MW.

c. The Great Basin region, which lies mostly in Nevada and Utah but also encompasses parts of California, Oregon, and Idaho, has the lowest percentage of developed power with respect to the Circular 790 estimates. Only about 500 MW are produced in the Great Basin compared with an estimated high-temperature resource of about 7,500 MW.

Table 4 summarizes the results of the state-by-state comparison for the nine states highlighted in the 1978 resource assessment and the installed electrical power generating capacity as of 1998 (Source—Energy Information Administration (EIA)).

Table 5

If the entire estimated resource for these nine states could be exploited as electrical power, it would equal 21.5% of the electrical power generated from all other sources. The possible reasons for the large difference between the estimated geothermal resource and installed capacity are varied and, in the absence of another systematic resource assessment, difficult to quantify.

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Among the factors limiting geothermal resource development are the following.

Economics—Until recently, the 5- to 8-cent per kilowatt-hour (kwh) cost of geothermal energy was not competitive with fossil fuel-generated power costing as little as 3 cents/kwh.

Water—Reservoirs exploited with flash-steam power plants lose a significant fraction of the produced water from their cooling towers. In many western states water for reinjection into geothermal reservoirs is either unavailable or in short supply.

Remote Locations—Many geothermal systems, particularly those in the Great Basin, are dispersed in relatively remote locations with limited access to electric power transmission lines and other facilities.

Validation of the Resource—Because geothermal reservoir development requires drilling, it has often proven difficult for power companies to obtain financing in the absence of up to date resource assessments.

Uncertainties in the Circular 790 Assessment—The state of knowledge about geothermal resources has advanced dramatically in the past 20 years, and there is evidence that Circular 790 may have overstated the abundance of high temperature resources in the western U.S.

There are also a number of technical reasons why geothermal resource development could approximate some of the estimates contained in Circular 790.

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Binary Power Plants—The maturation of binary power plant technology has provided a means of exploiting geothermal reservoirs with little or no loss of water. In addition, binary power plants have enabled the development of intermediate temperature systems not included in the Circular 790 estimate.

Reclaimed Water—Effluent pipelines carrying reclaimed water from urban areas have become a cost-effective and environmentally sound means of providing water for reinjection into declining or depleted geothermal reservoirs. For example, reclaimed water is now being used to replenish The Geysers geothermal field in California, which produces approximately 1,200 MW of electricity.

Enhanced Geothermal Systems—With DOE support, scientists and engineers have been developing a geothermal reservoir stimulation technique known as Enhanced Geothermal Systems (EGS). Through the hydraulic fracturing of the hot but impermeable rock surrounding geothermal reservoirs, power companies will be able to increase the amount of hot rock available to heat geothermal fluid, increasing the capacity and extending the lifetime of existing geothermal systems.

Exploration Technology—Improved geochemical and geophysical tools for geothermal exploration, together with targeted test drilling, have allowed power companies to more accurately predict the productivity of a specific geothermal resource before embarking on an expensive program of production drilling.

Recent efforts to incorporate some or all of these developments in updated assessments have led to widely varying results. According to a 1999 report prepared by the Geothermal Energy Association (GEA) and the

DOE (*Geothermal Energy, The Potential for Clean Power from the Earth),* the domestic geothermal energy potential ranges from 6,520 MW with existing technology to 18,880 MW with enhanced technology. A geothermal industry consultant's re-examination of the Circular 790 assessment with the addition of potential Enhanced Geothermal System sources gives a range of values between 6,300 and 27,400 MW (J. Sass, unpublished report). The Strategic Plan for the DOE Office of Power Technologies has a goal for geothermal energy to provide 10% of the electric power requirements of western states by the year 2020. This would require more than 10,000 MW of additional geothermal power, and a review by the National Research Council (NRC) suggests this goal is unlikely to be met (*Renewable Power Pathways: A Review of the U.S. Department of Energy's Renewable Energy Programs,* NRC, 2000). By contrast, the Energy Information Administration of DOE estimates an installed geothermal power capacity of 4,140 MW by 2011 (*EIA Annual Energy Outlook 2001— http://www.eia.doe.gov/oiaf/aeo/aeotab—17.htm).*

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Uranium Resources

The first and only national uranium assessment was the National Uranium Resource Evaluation (NURE) program, completed by the U.S. Department of Energy in 1980. The NURE program mapped and tabulated uranium deposits by county and various energy regions in the United States. Energy Information Administration still uses this assessment of uranium endowment to make annual calculations of the economic portion of the 1980 resources and of the few new identified endowments.

Uranium first became a fuel for commercial generation of electricity in 1953; today, 22 percent of our electricity comes from nuclear generating plants. According to EIA statistics, the U.S. nuclear power industry achieved its second year of record power generation levels in 2000.

Also according to the EIA, in 1999, U.S. utilities received a total of 47.9 million pounds UOe (equivalent), at an average price of $11.63 per pound. Compared with 1998, the quantity of uranium received increased 12 percent and the price decreased 4 percent. Foreign-origin uranium accounted for 36.5 million pounds (76 percent) of the deliveries at an average price of $11.47 per pound. Approximately 26 percent of all uranium purchased by U.S. utilities was of Canadian origin, while 24 percent was of U.S. origin. In rank order, the next five foreign countries of origin were Australia (15 percent), Russia (13 percent), South Africa (6 percent), Uzbekistan (5 percent), and Ukraine (4 percent).

Since 1980 in the U.S., new resource areas have been developed, new types of deposits have been discovered, new mining methods have become available, and new resource-estimating methodologies have been developed. Because of these new discoveries, the original assessment is significantly out of date.

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Mr. Chairman, this concludes my remarks. I would be happy to respond to questions you or Members of the Subcommittee may have.

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Chairman **BARTLETT.** Thank you very much. Dr. Montgomery.

STATEMENT OF DR. W. DAVID MONTGOMERY, VICE PRESIDENT, CHARLES RIVER ASSOCIATES

Dr. **MONTGOMERY.** Thank you, Mr. Chairman. I was also honored by your invitation to appear today. And I am very glad to be here. I don't have a particular cause or of set of recommendations that I represent. But I have been doing energy policy now since mostly here in Washington for the last 25 years. And I thought a few observations that I would like to make. These are brief and they are necessarily incomplete. And, therefore, I will leave out the qualifications and maybe we can address those in the colloquy.

Mr. Chairman, you mentioned our current energy crisis. And I would describe that largely in terms of the sudden re-appearance of high prices for energy in many parts of the country, and we have become used to very stable prices. And shortages, which seem to have become chronic in California, but have appeared occasionally other places in natural gas markets and gasoline markets. Mostly regionally and mostly temporarily, but they have been frightening.

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I believe that what we are seeing in energy markets are policy failures, not any evidence that we are running out of energy supplies at any point in the near future. I think that our long-term policy failures have seriously restricted access to oil and gas resources in the U.S. And they have discouraged the construction of pipelines and power plants. And that has contributed a great deal to what we are seeing today. I think we have pretended energy conservation was all we needed. We have had huge improvements in the energy efficiency economy. We have effectively decoupled energy and economic growth but it wasn't enough. Cheap energy has won our hearts and minds. And I think that a number of policies have prevented us building the infrastructure that was required to keep delivering that energy at the rates of growth in—that the rates of growth and demand required.

We have had some more immediate problems that have come from environmental regulations that ignored market realities. Like gasoline regulations that have kind of carved up the market in a way that made regional markets unstable and more susceptible to the kind of inevitable, you know, accidents that occur at refineries and kind of temporary disruptions of supply.

But I would argue that there is no problems of supply absent these policy mistakes. There are ample resources of oil and gas and coal in the United States and the world. I brought along a slide that I wanted to use to illustrate this that actually uses Dr. Weedman's numbers that I took from the Energy Information

Administration's annual energy outlook. What I did was compare the current rates of production in the U.S. and what we might get those rates up to over the next 20 years or so with our domestic oil and gas and coal resources.

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And this is it. In terms of natural gas resources, the 3 tall blue columns represent the proved, unproved and total resources. The total resource is approximately the same as the number I think you cited. The very low bar is our current annual production of natural gas. We run a reserved production ratio of about eight for natural gas, that is eight-year supply. But that is an inventory problem. It is not worth drilling up more than that in the short run. We have resources which 1000 divided by 20 look like about 50 year supply at current production rates. That means, there is not an infinite resource there, but it is one that we will have a gradual transition off of. In terms of oil resources, U.S. production is declining. But relative to our resource base we are again looking at a very substantial larger resource base than our current production. In the case of coal, I was doing some calculations in my head and it looks like something like 50 years supply.

I believe there is no long-term supply. The issue is kind of, you know, one of a long-term transition, not something that is going to be a problem currently.

If we could see the next slide. I would also point out that market indicators strongly indicate a return to normal times over the next few years. I have plotted here the spot price of crude oil in today's dollars since 1989. That is the dark blue line. And then at different points in time the price of futures contracts in the oil market. Futures contracts that you can buy today to buy or sell oil 3 months, 6 months, 9 months, out to 2 years and 3 years in advance. The futures contracts kind of point to where the market thinks prices are going. And what this shows is the future's prices have consistently pointed toward crude oil being about $20 a barrel. And the market expects about the same thing now.

I think we are looking at temporary disruptions in supply that have come about for a number of reasons. Our real concern is whether we will allow markets to respond in a way that makes sense, in the way that markets want to in order to reach store supplies. Because when we see high prices we see incentives for energy demands to reduce. We see incentives for supply to be created. We need to worry about policies that create obstacles to those market forces working.

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Thank you. I think I will stop here and hope we can pursue this later.

[The prepared statement of Dr. W. David Montgomery follows:]

PREPARED STATEMENT OF W. DAVID MONTGOMERY

Mr. Chairman and Members of the Subcommittee:

Thank you for your invitation to participate in today's hearing. My name is David Montgomery, and I am Vice President of Charles River Associates, where I head my company's Energy and Environment Practice.

For the record, I would like to make it clear that I am speaking for myself today, not on behalf of Charles River Associates or any client.

I could not resist the opportunity to participate in today's discussion. I have been involved in energy policymaking and analysis for over 25 years, and this hearing deals with perennial issues: concerns about high energy prices and availability of energy; the effects of shortsighted policies and regulations; fears that we will run out of energy; and speculations that we really don't need energy after all.

Since the Gulf War in 1991 reminded the American people about the instability of energy supplies and prices, we experienced a tranquil decade of generally stable or falling energy prices. Events of the past two years have shattered our complacency. I would suggest a brief chronology of events to set the stage for current concerns:

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An unexpected cold spell in the Northeast during the winter of 2000 coupled with inadequate natural gas transportation capacity and storage caused a shortage of natural gas in the Northeast. When utilities switched from natural gas to fuel oil, prices of heating oil spiked for a few weeks and created widespread concern.

Rising world oil demand and more effective than usual discipline among the members of the Organization of Petroleum Exporting Countries caused oil prices to surge from $13 at the end of 1999 to a peak of over $35 per barrel earlier this year.

Rising natural gas demand and low inventories drove natural gas wellhead prices from $2–$3 per Mcf in 1999 to a brief peak around $10 per Mcf earlier this year, as drilling and supply have been slow to respond.

A combination of events in California—including decades of opposition to building new powerplants or gas pipelines, a flawed approach to restructuring of electricity markets, and controls on prices charged to electricity consumers—led to shortages and surging wholesale prices of gas and electricity.

Gasoline prices spiked last summer in the Midwest, due to supply shortages that are at least partially attributable to tight new rules for reformulated gasoline that segment the market and make those segments far more vulnerable to inevitable accidents in the refining and distribution system.

There are a few things we do well to remember about these problems. First, in free markets, price increases are not sustained. Both oil and natural gas prices have dropped dramatically from their peaks earlier this year. High prices serve as a signal to oil and gas producers that it is time to invest in new exploration and development, to bring additional supplies to the market. That is just what is finally happening. They also signal to consumers the need to conserve energy. Under these competitive pressures, even OPEC has proven incapable of the production restraint required to maintain high prices for long periods of time.

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We have gone through numerous cycles of oil and natural gas prices rising and falling. Gas prices peaked due to supply and pipeline problems in December 1995, December 1996, and October 1997, to levels comparable to prices in today's dollars. Oil prices hit levels comparable to current prices in today's dollars in January, 1997, and were far higher in today's dollars at the end of 1990, when trader's feared Saddam Hussein's ability to conquer or destroy Kuwait and Saudi Arabia.

The experience of the Gulf War in 1990 and 1991 is instructive to those who fear or predict sustained high prices. No sooner did the Allies convince markets through military action that Saddam Hussein could not inflict harm on Saudi Arabia, the world oil price collapsed back to pre-war levels. Between 10/12/90 and 2/25/91, oil prices collapsed from $40.42 to $18.37 in today's dollars.

Responsible forecasters also predict that over the next few years, oil and gas prices are likely to return to historical levels. For the past several decades, futures markets have provided clear indications of how the market expects oil and gas prices to behave. Futures markets have consistently indicated an expectation that oil prices will trend toward an average of about $20 per barrel in nominal terms. When spot prices have been higher that $20 per barrel, futures prices have predicted they will fall, and when spot prices have been below $20, futures prices have predicted they will rise. Natural gas futures markets have generally predicted similar behavior for wellhead gas prices, that they will move back toward a range of $2 to $3 per Mcf.

The Energy Information Administration also continues to predict that oil and gas prices will fall from their current peak. AEO 2001, recently released, has a reference price path for oil falling to $20 per barrel and natural gas to $2.50 per Mcf over the next few years.

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Estimates of the world's supplies of oil and natural gas have not changed dramatically over the past few years. In 1999 the National Petroleum Council reviewed its outlook for natural gas in the United States, and concluded that all its scenarios for future gas demand could be covered with gas costing between $2 and $3 per Mcf to produce. The world has huge supplies of crude oil (and natural gas) though large parts of that resource are located in unstable regions like the Middle East. With these resources available, I do not believe that energy policy should be driven by fears that we will run out of energy, and I do believe that if energy markets are allowed to work freely and efficiently, energy will be available at affordable prices like those we have enjoyed for the last decade.

Why, then, have we had so many problems recently? I believe that the reason is largely the accumulation of policies that restrict access to energy resources, constrain our ability to transform our wealth of energy into useful supplies, and prevent consumers from seeing the correct incentives to conserve energy when supplies are short.

The policies that cause me concern include:

Constraints and disincentives for construction of new powerplants, including nuclear

Opposition to construction of natural gas pipelines and electricity transmission capacity, to allow energy to flow to areas that experience growing demand or supply problems

Regulations on fuels that carve markets up into small pieces and make it impossible to balance shortages in one area from supplies available in another

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Environmental regulations that discriminate against particular fuels or facilities

Restrictions on access to oil, gas and coal resources, both offshore and onshore

Caps on prices that can be charged to consumers

Our strong desire to protect and improve environmental quality is not the problem. The problem is ill-conceived environmental and other regulatory policies that unnecessarily constrain energy markets and prevent us from using the cleanest and cheapest technologies and fuels. These policies are frequently promoted as improving environmental quality. The alternative, which needs to be taken much more seriously, is shifting our focus off energy inputs and onto environmental performance. Our current fuels—oil, gas, coal and nuclear power—have proven capable of clean and cost-effective operation when subjected to intelligently designed regulation. We can avoid creating artificial shortages if we design environmental policy by starting with the overall reduction in emissions, from all sources, that is desired, and then use market-based systems to achieve those goals. The sulfur trading program under the Clean Air Act Amendments is the best known example of such a program. By replacing unit-by-unit percentage reduction requirements with a program that capped total sulfur emissions and allowed utilities to use any means at their disposal to reduce emissions, the sulfur trading program led to major improvements in air quality and large reductions in cost. Even in this case, the benefits of the sulfur trading program have been muted by insistence on maintaining regulatory requirements such as New Source Performance Standards that only limit flexibility and raise costs when combined with an overall cap on emissions. If we want adequate supplies of energy at adequate prices, it is necessary to replace policies that unnecessarily raise costs and constrain energy supply with policies directed at the actual environmental outcomes.

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There is a fundamental misunderstanding of how past policies have created our current situation, and a strong tendency to look for scapegoats. I testified earlier this year in proceedings dealing with natural gas prices at the California border. The facts were that natural gas prices in California reached close to $10 per Mcf, while gas prices at the other end of the pipelines serving California were in the $3 per Mcf range. The difference clearly exceeded the cost of transportation by a large margin. Parties in California argued that shippers and pipelines were misusing market power to raise prices at the California border.

Nothing could have been further from the truth. The problem was lack of pipeline capacity going into California, the result of decades of regulatory opposition. Every time the price in California exceeded the price where gas is produced plus the cost of transportation, the pipelines into California were full. The high price was just what happens in competitive markets when demand rises above the amount that can physically be supplied.

High prices also serve to solve supply problems, when allowed to work through to consumers. The one time a California electric utility was able pass some of its cost increases through to consumers, which occurred in San Diego last summer, showed that price increases at the retail level could produce sufficiently large reductions in demand to alleviate electricity shortages.

It does not make sense to respond to temporary price spikes and shortages, especially when they are due to past policy failures, with mandates for changes in fuel use. The history of our efforts to manage utility fuel choice would be amusing if it were not so depressing. In the late 1960s, environmental regulators on the East Coast required utilities to replace coal-fired boilers with oil-fired units to generate electricity. These replacements occurred just in time to catch utilities in the oil price shocks of the 1970s. We then passed the Powerplant and Industrial Fuel Use Act, which banned the construction of new natural gas fired units and encouraged replacement of natural gas and oil units with coal. These regulations, finally repealed in 1987, ran exactly counter to the market trends and environmental concerns that began to favor gas over coal in the 1980s and 1990s. And now we have proposals, based on fears of global warming and other environmental issues, for laws and regulations that would force utilities to stop burning coal and replace coal-fired with natural gas generators. It is very depressing to have a long memory in energy policy.

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Alternative fuels programs have also tried to unsuccessfully to achieve environmental improvements by means of a fuels policy. Proposals for alternative fuels for automobiles (and California's current electric vehicle) mandates were rationalized as means of improving air quality, but really were designed to shift the nation away from gasoline onto more expensive fuels. More careful evaluation of the programs revealed they had virtually no chance of improving air quality, and instead were structured in a way that would likely slow down the process of replacing older, dirtier vehicles with newer, clean ones.

Finally, access to resources. We need to re-examine the basis for bans on drilling on the Outer Continental Shelf and in wilderness areas. I have not seen a competent economic analysis of these issues from any source. Banning exploration makes it impossible to exploit a potentially valuable domestic resource. The value of that resource is the difference between its expected cost and the cost of the next best alternative. In the case of oil, the alternative to domestic production is oil imports. When it costs less to produce oil from a domestic source than it costs to import the same amount of oil, a ban on exploration causes the nation to lose the difference. That value must be compared to the potential environmental damages of exploiting the resource. Programs to limit environmental impacts of exploration can limit damages and make the tradeoff between bans and use less stark. The details require careful work, but the principles are very simple.

The issue is in all of this is not whether there are important environmental problems to be addressed, because there are. The issue is whether environmental policy will continue to be implemented through micromanagement of decisions best left to the private sector or by means of market-based programs that focus on the ultimate environmental quality objectives. Forcing conversions from coal to natural gas or other fuels, will put pressure on gas supplies and prices, and raise serious questions about adequacy of electric generating capacity. Placing onerous requirements on new, clean powerplants will just exacerbate the problems of electricity supply. Fantasizing about alternative sources of energy or energy conservation will just place additional pressures on supply when those alternatives continue to fail to materialize. Refusing to address questions of access to resources will guarantee those resources are not used, no matter how valuable they might be. Focusing on improving the environment rather than constraining energy supply, and letting producers and users of energy from oil, coal, natural gas and nuclear sources figure out how to provide energy supplies while satisfying overall emission limits, will solve the problem.

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Education

Ph.D. Economics, Harvard University
Fulbright Scholar, Cambridge University
B.A. Social Studies, Wesleyan University

Experience

Vice President, Charles River Associates

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Assistant Director, Congressional Budget Office

Director, Office of Energy Markets and End Use, Energy Information Administration

Senior Fellow, Resources for the Future

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Deputy Assistant Secretary for Systems Analysis, U.S. Department of Energy

Assistant Professor of Economics, California Institute of Technology

Selected Publications and Testimony

"Market Power And The California Natural Gas Price Index," California Public Utilities Commission, Rulemaking 99–11–022, October, 2000, on behalf of the Cogeneration Association of California.

An Assessment of the Potential Impacts of Proposed Environmental Regulations on U.S. Refinery Supply of Diesel Fuel, with I. Moncrief, M. Ross, R. Ory, and J. Carney, Charles River Associates, August, 2000.

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"The Future of Natural Gas." With W. Hughes. In W. Mogel (ed.), *The 1992 Natural Gas Outlook.* New York: Executive Enterprises, Inc., 1992.

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Chairman **BARTLETT.** Thank you very much. Mr. Geller.

STATEMENT OF MR. HOWARD S. GELLER, EXECUTIVE DIRECTOR EMERITUS, AMERICAN COUNCIL FOR AN ENERGY EFFICIENT ECONOMY

Mr. **GELLER.** Thank you, Mr. Chairman and members of the Committee. I appreciate the opportunity to testify again before the Science Committee.

Energy efficiency improvement has contributed a great deal to our nation's economic growth and increased standard of living over the past 25 years. Consider these facts. Total primary energy use per capita in the United States in 2000 was almost identical to that in 1973. And over the same period our economic output increased 74 percent. Our energy intensity or energy use per unit of GDP fell 42 percent between '73 and 2000. About three-quarters of this decline is attributed to real efficiency improvements. And about one-quarter to structural shifts and fuel switching.

And then third, over the last four or 5 years between '96 and 2000, our economy boomed. We had 19 percent GDP growth in 4 years. But only 5 percent growth in total energy use. Imagine how much worse our energy problems would be today if we had 10 or 15 percent energy growth over the past four or 5 years.

Even though the U.S. is much more energy efficient today than it was 25 years ago, there is still enormous potential for cost effective energy savings. The Department of Energy estimates that increasing energy efficiency throughout the economy could cut national energy use by 10 percent or more in 2010, and about 20 percent in 2020, with net economic benefits for consumers and businesses.

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Increasing the efficiency of our homes, appliances, vehicles, and industries should be a cornerstone of national energy policy. It would reduce energy waste, increase productivity, save consumers and businesses money, improve the reliability of over-taxed electric systems, reduce energy imports, reduce air pollution of all types, and lower the green house gas emissions that are causing global warming.

Now I would like to present the main energy efficiency policy recommendations of my organization. First is to reject the deep cuts in funding proposed for DOE's energy efficiency programs by the Bush Administration in fiscal year 2002. And instead expand these programs. These programs have made many valuable contributions to increasing the efficiency of our buildings, appliances, vehicles and industries. The DOE recently documented that 20 of its most successful projects have already saved the nation 5.5 quadrillion BTU's worth about $30 billion in avoided energy costs. This is over 3 times the amount appropriated for these programs over the past decade.

Unfortunately, the administration has proposed cutting energy efficiency R&D and technology deployment programs by $180 million or 29 percent in fiscal year 2002. Some programs would be cut by 50 percent or more. These cuts should be rejected by the Congress considering the success of the programs and the serious energy problems our nation in now facing. In fact, we recommend increasing these programs by $170 million or 20 percent. This will help consumers and businesses lower their energy bills in the near term, while developing new technologies to address our energy needs over the medium and long-term. With this increase, energy efficiency programs would receive about 5 percent of the total DOE budget.

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A second recommendation is to increase the Corporate Average Fuel Economy standards for cars and light trucks. We suggest an increase of 5 percent a year for 10 years or a 60 percent increase by 2012 in the standards. It is technologically and economically feasible. The standards have not been increased since they were first adopted in 1975, signed into law by President Ford in '75. I won't go into further details except to say that if we increase the fuel economy standards in cars and light trucks to the extent I have recommended, we could save about 1.5 million barrels per day of oil by 2010, and 4.8 million barrels per day by 2020.

And over the next 40 years increasing vehicle efficiency could save 10 to 20 times more oil than the projected supply from the Arctic National Wildlife Refuge, and more than 3 times total proven oil reserves in the U.S. today. That is based on the USGS—the latest USGS figures.

I am running out of time. I will just briefly mention the other policy recommendations. I won't go into detail. We recommend adopting a national system benefit trust fund, which would involve a small charge on electricity that all consumers and utilities would pay into a national trust fund. Then states and utilities would get money back out of the fund to match the funding that they put up for energy efficiency programs, R&D programs, renewable energy development, and assistance to low income consumers. This could greatly boost the energy efficiency programs run by states and utilities.

Fourth, we are recommending adopting tax incentives for innovative advanced energy efficient vehicles like the Hybrid and Fuel Cell vehicles that are beginning to hit the market place. For also very efficient new homes, commercial buildings and appliances. And then lastly, we are recommending stronger appliance efficiency standards be adopted. These standards have been very successful. They are already saving consumers about $9 billion per year. With additional standards we can more than double the savings over the next 10 years. And we are urging the Congress to proceed with some standards on other products. The State of California is moving ahead with some new state standards that the Federal Government ought to make national standards.

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To conclude, support for greater energy efficiency is very broad and bipartisan. The Council for Foreign Relations just completed an in-depth report on our energy challenges. And recommended giving energy efficiency greater priority. Urged the Government to take a more proactive position on demand management and recommended increasing the CAFE standards on cars and trucks. This is not the Sierra Club. This is the Council on Foreign Relations.

The current Bush—the Bush—the current Bush Administration should make improving energy efficiency a cornerstone of its energy strategy. But if it fails to do so, the Congress should insist that energy efficiency be properly valued and strongly supported in new energy legislation and in appropriations.

Thank you very much.

[The prepared statement of Mr. Howard S. Geller follows:]

PREPARED STATEMENT OF HOWARD S. GELLER

ACEEE is a non-profit organization dedicated to increasing energy efficiency as a means for both promoting economic prosperity and protecting the environment. We were founded in 1980 and have contributed in key ways to energy legislation adopted during the past 20 years, including the Energy Policy Act of 1992 and the National Appliance Energy Conservation Act of 1987. I appreciate the opportunity to appear again before the Science Committee.

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There are a variety of serious energy challenges confronting the United States at this time. California is experiencing power shortages and severe electricity price spikes. Power reliability problems could spread this summer or in coming years to other regions such as the Pacific Northwest or New York. Natural gas prices have significantly increased in many parts of the country, causing skyrocketing home energy bills this past winter. And our reliance on imported oil has grown due to a combination of declining domestic oil supply and growing demand linked to the lack of fuel efficiency improvement in motor vehicles. Oil imports more than doubled during the past 15 years and oil imports now exceed domestic oil production.

Energy efficiency improvement has contributed a great deal to our nation's economic growth and increased standard of living over the past 25 years. Consider these facts which are based primarily on data published by the Energy Information Administration:

1) Total primary energy use per capita in the United States in 2000 was almost identical to that in 1973. Over the same 27-year period economic output (GDP) per capita increased 74 percent.

2) National energy intensity (energy use per unit of GDP) fell 42 percent between 1973 and 2000. About three-quarters of this decline is attributable to real energy efficiency improvements and about one-quarter is due to structural changes and fuel switching.

3) If the United States had not dramatically reduced its energy intensity over the past 27 years, consumers and businesses would have spent at least $430 billion more on energy purchases in 2000.

4) Between 1996 and 2000, GDP increased 19 percent while primary energy use increased just 5 percent. Imagine how much worse our energy problems would be today if energy use increased 10 or 15 percent during 1996–2000.

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Even though the United States is much more energy-efficient today than it was 25 years ago, there is still enormous potential for additional cost-effective energy savings. Some newer energy efficiency measures have barely begun to be adopted. Other efficiency measures could be developed and commercialized in coming years, with proper support. The Department of Energy estimates that increasing energy efficiency throughout the economy could cut national energy use by 10 percent or more in 2010 and about 20 percent in 2020, with net economic benefits for consumers and businesses.(see footnote 8) ACEEE estimates that adopting a comprehensive set of policies for advancing energy efficiency could lower national energy use by as much as 18 percent in 2010 and 33 percent in 2020, and do so cost-effectively.(see footnote 9)

Whether the energy savings potential is 20 or 30 percent, increasing the efficiency of our homes, appliances, vehicles, businesses, and industries should be the cornerstone of national energy policy today since it provides a host of benefits. Increasing energy efficiency will:

reduce energy waste and increase productivity, without forcing consumers or businesses to cut back on energy services or amenities;

save consumers and businesses money since the energy savings more than pay for any increase in first cost;

reduce the risk of energy shortages and improve the reliability of overtaxed electric systems;

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reduce energy imports;

reduce air pollution of all types since burning fossil fuels is. the main source of most types of air pollution;

lower U.S. greenhouse gas emissions and thereby help to slow the rate of global warming.

Furthermore, increasing energy efficiency does not present a trade-off between enhancing national security and energy reliability on the one hand and protecting the environment on the other, as do a number of energy supply options. Increasing energy efficiency is a "win-win" strategy from the perspective of economic growth, national security, reliability, and environmental protection.

Energy Efficiency Policy Recommendations

Here are five "top priority" energy efficiency policy recommendations from ACEEE and our allies. These policies involve a combination of "carrots" and "sticks"—new incentives, funding for R&D and technology deployment, and new regulations. The policies would significantly increase the efficiency of energy use in our homes, commercial buildings, factories, and vehicles. They would not entirely solve our nation's energy problems, but they would make a major contribution towards addressing the energy challenges our nation is now facing.

1) Reject the Deep Cuts in Funding Proposed for DOE's Energy Efficiency Programs and Instead Expand These Programs in FY2002

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The Department of Energy (DOE) has made many valuable contributions towards increasing the energy efficiency of U.S. buildings, appliances, vehicles, and industries. Consequently, the President's Committee of Advisors on Science and Technology stated in 1997 that "R&D investments in energy efficiency are the most cost-effective way to simultaneously reduce the risks of climate change, oil import interruption, and local air pollution, and to improve the productivity of the economy."(see footnote 10)

This is not just a rhetorical statement. DOE recently documented that 20 of its most successful energy efficiency projects have already saved the nation 5.5 quadrillion BTUs of energy, worth about $30 billion in avoided energy costs, over the past two decades.(see footnote 11) The cost to taxpayers for these 20 activities was $712 million, less than 3 percent of the energy bill savings so far. In fact, the energy bill savings from these 20 projects alone is over three times the amount of money appropriated by the Congress for all DOE energy efficiency and renewable energy programs during the 1990s, demonstrating that spending taxpayers money on energy efficiency R&D and deployment is a very sound investment.

There are other indicators of success and effectiveness besides the 20 projects reviewed in this report. DOE's Office of Industrial Technologies (OIT) tracks the adoption and utilization of new technologies it has funded over the years. It recently documented that OIT has contributed to the development of over 45 commercially available technologies. These technologies, as well as some of OIT's technical assistance activities, have reduced industrial energy use by over 1.6 quadrillion BTUs cumulatively through 1999.(see footnote 12) This is equivalent to industry cutting its energy bills by $6.5 billion.

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DOE's Office of Building Technology, State and Community Programs (OBTS) has helped to develop and commercialize a number of important energy efficiency technologies including low-emissivity window coatings, electronic ballasts for fluorescent lamps, high efficiency compressors for refrigeration equipment, and new housing designs and retrofit techniques. Appliance efficiency standards established by DOE have already saved consumers tens of billions of dollars on their utility bills. Likewise, building code development, adoption, and support activities carried out by OBTS have saved about 0.5 quadrillion BTUs of energy or $3.5 billion in energy costs cumulatively through 2000.

DOE's Office of Transportation Technologies (OTT) has helped to increase the fuel efficiency of both passenger vehicles and heavy trucks. OTT contributed to the development of new composite materials such as reinforced polymers and techniques for using aluminum and metal alloys in order to reduce vehicle weight and improve fuel economy. OTT also is contributing to the development of the hybrid-electric vehicles U.S. manufacturers will introduce over the next few years. These vehicles will get 25–100% better fuel economy than typical vehicles produced today. OTT also has helped to increase the efficiency and reduce the emissions of diesel engines used in heavy vehicles, and its Clean Cities program has played a critical role in promoting the purchase and use of alternative fuel vehicles.

DOE's Federal Energy Management Program (FEMP) has helped to reduce energy use per square foot of floor area in Federal buildings by 19% since 1985, thereby cutting Federal energy expenditures by over $6 billion cumulatively. The FEMP has trained over 13,000 Federal energy managers, assisted with the design of over 200 energy savings projects in Federal facilities, and helped Federal agencies make use of energy savings performance contracts. For each dollar invested in energy efficiency in Federal buildings, there are typically $4 in energy cost savings for Federal agencies over the life of the project.

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The Bush Administration has proposed cutting energy efficiency R&D and technology deployment programs (apart from grants to low-income households for home weatherization) by $180 million (29%) in FY2002. Some programs would be cut by 50% or more. Cutting funding for DOE's energy efficiency programs will increase consumers' energy bills, hurt U.S. economic growth, increase the likelihood of power shortages, put upward pressure on energy prices, increase oil imports, and increase air pollution. Deep cuts in DOE's energy efficiency programs also would harm public-private partnerships that have been built up over many years and harm the energy efficiency R&D and deployment "infrastructure" that exists at the national labs, state energy offices, and elsewhere. These cuts should be rejected by the Congress. In light of the serious energy problems our nation is facing, we should expand, not cut, energy efficiency R&D and deployment programs.

ACEEE and our allies recommend increasing DOE's energy efficiency programs, both technology R&D and deployment programs including grants for weatherization of low-income households, by $170 million (20%) in FY02. The increase should be spread across the programs, covering R&D projects in all sectors as well as deployment programs. Increasing funding for a broad array of energy efficiency programs will help consumers and businesses lower their energy bills in the near term, while developing the new technologies needed to address our energy challenges over the medium and long term. In relative terms, this increase is less than one percent of the overall DOE budget and would result in energy efficiency programs receiving just 5 percent of the total DOE budget. Further details concerning our budget recommendations are included in a new report titled *Sensible Energy Policies for Our Growing Economy* which I would like to submit to the Subcommittee.

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Increase Corporate Average Fuel Economy (CAFE) Standards for Cars and Light Trucks or Adopt an Equivalent Fuel Consumption Cap

The average fuel economy of new passenger vehicles (cars and light trucks) has declined from about 26 miles per gallon (mpg) in 1988 to 24 mpg in 2000 due to increasing vehicle size and power, the rising market share of light trucks, and the lack of tougher Corporate Average Fuel Economy (CAFE) standards. The original CAFE standards for cars were adopted in 1975 and reached their maximum level in 1985.

We recommend increasing the CAFE standards for cars and light trucks 5% per year for 10 years so that they reach 44 mpg for cars and 33 mpg for light trucks by 2012, with further improvements of 3% per year beyond 2012. Alternatively, the standards for cars and light trucks could be combined into one value for all new passenger vehicles, specifically 38 mpg by 2012. This level of fuel economy improvement is technically feasible and cost effective for consumers, and it can be achieved without compromising vehicle safety.(see footnote 13) The 5% annual fuel economy improvement is the rate of improvement that Ford has indicated it will achieve voluntarily for its SUVs over the next five years. If this rate can be achieved in SUVs, it can be achieved in all new vehicles made by Ford as well as other manufacturers.

Car manufacturers will protest and say "it can't be done" or "it will cost a fortune," as they did when the original CAFE standards were debated. The initial CAFE standards were enacted by the Congress and signed into law by President Ford in 1975 in the face of industry opposition, and the car companies complied with these standards at reasonable cost. Tougher standards are now long overdue find should be adopted before we face another oil price shock or crisis, considering "technological feasibility, economic practicability, and the need of the nation to conserve energy," as stated in the Energy Production and Conservation Act of 1975.

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Tougher fuel economy standards should be complemented by tax credits for purchasers of innovative, highly efficient vehicles (see policy 4 below), expanding taxes on gas guzzling vehicles, increasing labeling and consumer education efforts, and continuing vigorous R&D on fuel-efficient, low emissions vehicles. This combination of policies would facilitate compliance with the tougher standards. An alternative approach would be to establish a cap on the use of petroleum products by passenger vehicles and then come up with the policy mechanisms, including but not limited to stronger CAFE standards, that would enable the cap to be met. This approach was included in recent Senate legislation (S. 597), which sets the cap at 105% of fuel consumption in 2000 starting in 2008.

The CAFE standards proposed here would save about 1.5 million barrels of petroleum per day by 2010 and 4.8 million barrels per day by 2020.(see footnote 14) Over 40 years, increasing vehicle efficiency as suggested above would save 10-20 times more oil than the projected supply from the Arctic National Wildlife Refuge (ANWR) and more than three times total proven oil reserves today.(see footnote 15) The avoided carbon dioxide emissions would reach about 82 million metric tons (MMT) of carbon equivalent by 2010 and 225 MMT by 2020. The fuel consumption cap proposed in S. 597 would result in a similar level of energy savings and avoided C02 emissions in the near term (i.e., by 2010).

3) Adopt a National System Benefit Trust Fund

Electric utilities historically have funded programs to encourage more efficient energy use, assist low-income families with home weatherization and energy bill payment, promote the development of renewable energy sources, and undertake research and development. Experience with utility energy efficiency programs in New England, New York, and California shows that they provide energy bill savings for households and businesses are around twice costs (both the program costs and measure costs).(see footnote 16) However, increasing competition and restructuring have led to a decline in these "public benefit expenditures" over the past five years. Total utility spending on all demand side management programs (i.e., energy efficiency and peak load reduction) fell by nearly 50% from a high of $3.0 billion in 1993 to $1.6 billion in 1998 (1998 dollars).

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In order to ensure that energy efficiency programs and other public benefits activities continue following restructuring, 15 states have established system benefits funds through a small charge on all kilowatt-hours (kWhs) flowing through the transmission and distribution grid. We recommend creation of a national systems benefits trust fund that would provide matching funds to states for eligible public benefits expenditures. Specifically, we recommend a non-bypassable wires charge of two-tenths of a cent per kWh. This concept and specific amount were included in utility restructuring bills sponsored by Senator Jeffords (S. 1369) and Rep. Pallone (H.R. 2569) in the last Congress.

This policy would give states and utilities a strong incentive to expand their energy efficiency programs and other public benefits activities. All states and utilities would pay into the fund, but they would only get money back out if they establish or continue energy efficiency programs and other public benefit activities. However, individual states, not the federal government, would decide how the money gets spent in each state.

We believe this policy would lead to widespread energy efficiency improvements in lighting, appliances, air conditioning, motors systems, and other electricity end uses. We estimate it could save as much as 130 TWh (3.5% of projected electricity use) in 2005 and 340 TWh (9% of projected use) in 2010.(see footnote 17) With these levels of electricity savings, the risk of power shortages in the future will diminish, there will be fewer price spikes caused by periods of tight supply and demand, and there will be less need to build often contentious new power plants. In addition, pollutant emissions from power plants will fall, thereby improving public health and helping cities and states meet the ambient air quality standards.

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4) Enact Tax Incentives for Highly Energy-Efficient Vehicles, Homes, Commercial Buildings, and Other Products

Many new energy-efficient technologies including fuel cell power systems, hybrid and fuel cell vehicles, gas-fired heat pumps, super-efficient refrigerators and clothes washers, and super-efficient new buildings have been commercialized in recent years or are nearing commercialization. But these technologies may never get manufactured on a large scale or widely used due to their initial high cost, market uncertainty, lack of consumer awareness, and other barriers.

Tax incentives can help manufacturers justify mass marketing for innovative energy-efficient technologies. Tax credits also can help buyers (or manufacturers) offset the relatively high first cost premium for the new technologies, thereby helping to build sales and market share. Once the new technologies become widely available and produced on a significant scale, costs should decline and the tax credits can be phased out.

We recommend providing tax incentives for a variety of highly energy-efficient vehicles, buildings, and other products. A key element in designing the credits is for only highly efficient products to be eligible. If the eligibility level is set too low, then the cost to the Treasury will be high and incremental energy savings low.

We recommend tax incentives for the following products:

Appliances. A tax credit of $50–100 for manufacturers of highly efficient clothes washers and refrigerators will help save energy and water (with a cap on the total credit per manufacturer). This proposal has been introduced by Sens. Grassley and Allard, Rep. Nussle, and others. It is strongly supported by the appliance industry.

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New Homes. A tax credit of up to $2,000 for highly efficient new homes will stimulate efficiency and help lower housing costs for American families. Versions of this proposal have been introduced by Sen. Bob Smith (S. 207) and Rep. Bill Thomas and others, and variants are included in both the Murkowski-Lott (S. 389) and Bingaman-Daschle (S. 596) energy bills.

Other Building Equipment. We support a 20% investment tax credit with caps for innovative building technologies including very efficient furnaces, stationary fuel cell power systems, gas-fired heat pumps, and electric heat pump water heaters. This proposal is included in the Bingaman bill.

Hybrid Electric and Fuel Cell Vehicles. Tax credits of up to $5,000 for hybrid electric vehicles and $8,000 for fuel cell vehicles will help jump start introduction and purchase of these innovative, fuel-efficient technologies. The incentives should be based primarily on energy performance and provide both fuel savings and lower emissions, as is the case in the CLEAR Act introduced April 24 by Sen. Hatch and others.

Commercial Buildings. We support a tax deduction of $2.25 per square foot for investments in commercial buildings and multifamily residences that achieve a 50% or greater reduction in heating and cooling costs compared to buildings meeting current model energy codes. This proposal is included in legislation sponsored by Sen. Bob Smith (S. 207).

Combined Heat and Power. We support either a 10% investment tax credit or seven-year depreciation period for combined heat and power systems with an overall efficiency of at least 60-70% depending on system size. This proposal has strong industry support and is included in both the Murkowski and Bingaman bills.

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5) Enact or Strengthen Efficiency Standards on Various New Products

Federal appliance and equipment efficiency standards were signed into law by President Reagan in 1987 and expanded under President Bush in 1992. Minimum efficiency standards were adopted because many market barriers, such as lack of awareness, rush purchases when an existing appliance breaks down, and purchases by builders and landlords, inhibit the purchase of efficient appliances in the unregulated market. Standards remove inefficient products from the market but still leave consumers with a full range of products and features to choose among. Appliance and equipment standards are clearly one of the federal government's most effective energy-saving programs. Analyses by DOE and others indicate that in 2000, appliance and equipment efficiency standards saved 1.2 quadrillion Btu's (quads) of energy (1.3% of U.S. electric use) and reduced consumer energy bills by approximately $9 billion with energy bill savings far exceeding any increase in product cost.(see footnote 18) By 2020, standards already enacted will save 4.3 quads/year (3.5% of projected U.S. energy use), and reduce peak electric demand by 120,000 MW (more than a 10% reduction).

In order to provide additional cost-effective savings under this program, we recommend three actions:

DOE, with adequate funding and encouragement from the Congress, should commit to completing equipment standard rulemakings in a timely manner. These rulemakings include initial standards for distribution transformers as well as new, updated standards for commercial air conditioning systems and residential heating systems. On-going proceedings should be completed within two years, new proceedings within three years.

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The Congress should adopt new efficiency standards for products now or soon to be covered by state efficiency standards. Among the products that should be included are distribution transformers (Congressional adoption will be quicker and easier than a DOE rulemaking), commercial refrigerators, exit signs, traffic lights, torchiere lighting fixtures, and ice makers. California is now adopting standards on many of these products and Massachusetts and Minnesota already have standards on distribution transformers. None of these standards have been controversial and all involve highly cost-effective energy savings. In addition, the Congress should adopt limits on standby power consumption for household appliances and electronic products such as televisions, VCRs, cable boxes, and audio equipment. Doing so would substantially reduce the amount of electricity consumed when products are not "on".

The Congress should urge the Bush Administration to permit final adoption of a SEER 13 efficiency standard for residential central air conditioners and heat pumps. The Administration recently proposed rolling back the standard issued in January from SEER 13 to SEER 12. The controversy over the residential air conditioner standard will continue through this summer as DOE's extended rulemaking process coincides with likely electric reliability problems and surging prices in the west. Stepping up from SEER 12 to 13 will cut peak electricity demand by 18,000 MW once the standard is fully phased in and cut consumer electricity bills by over $18 billion over the next 30 years. This is one of the most important steps the Federal government can take to help California and other states avoid future power shortages.

ACEEE estimates that these three steps can cost-effectively reduce energy use in 2020 by 1.0 quad, nearly a 1% reduction in projected U.S. energy use. Consumers and businesses would see their energy bills decline by approximately $7 billion per year by 2020. Savings in 2010 would be a little less than half this amount.

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Conclusion

ACEEE and our public interest allies are not the only organizations suggesting that national policy makers should increase support for and adopt new policies to raise energy efficiency. The Council on Foreign Relations convened an independent task force that just completed an in-depth report on our energy challenges and what should be done about them.(see footnote 19) The Council concludes, *''Energy policy has underplayed energy efficiency and demand management measures for two decades.'' ''Take a proactive government position on demand management.'' and ''Review and establish new and stricter CAFE mileage standards, especially for light trucks.'' This is not the Sierra Club speaking, it's the Council on Foreign Relations.*

Ten years ago the previous Bush Administration issued its National Energy Strategy. It gave considerable priority to greater energy efficiency and called for expansion of energy efficiency R&D and technology deployment programs, new policies to stimulate utility energy efficiency programs, establishing new appliance and equipment energy efficiency standards, and new federal incentives to increase energy efficiency.(see footnote 20) Many of these proposals were incorporated in the Energy Policy Act of 1992, and the budget for and impacts of DOE's energy efficiency programs rose throughout the previous Bush Administration.

To cite one other example, the PCAST report mentioned above recommended doubling DOE's energy efficiency R&D programs between FY1998 and FY2003, and estimated that this investment could produce a 40 to 1 return for the nation.(see footnote 21) The Congress increased funding for DOE's energy efficiency programs about 30% during the past three years, but this falls well short of the doubling called for by the PCAST. The PCAST panel that produced this report consisted mainly of distinguished academics and private sector executives.

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Thus, support for increasing federal funding for and enacting new policies to improve energy efficiency is very broad. The current Bush Administration should make improving energy efficiency a cornerstone of its energy strategy. But if the Bush Administration fails to do so, the Congress should insist that energy efficiency be properly valued and strongly supported in new energy legislation and in appropriations for energy programs.

That concludes my testimony. Thank you for the opportunity to present these views.

BIOGRAPHY FOR HOWARD S. GELLER

Howard Geller is the Former Executive Director of the American Council for an Energy-Efficient Economy (ACEEE) and has been with the organization since 1981 when he established its Washington, DC office. He stepped down as Executive Director in February, 2001. The not-for-profit Council is dedicated to advancing energy efficiency as a means of promoting both economic prosperity and environmental protection. The Council fulfills its mission by conducting technical and policy assessments, advising policy makers, designing and evaluating energy efficiency programs, informing consumers, organizing conferences, and disseminating publications.

Mr. Geller has advised and conducted energy conservation studies for utilities, governmental organizations, ,and international agencies. He frequently testifies before Congress on energy efficiency and has influenced key energy legislation including the National Appliance Energy Conservation Act in 1987 and the Energy Policy Act of 1992. He is author or co-author of three books: *Efficient Electricity Use: A Development Strategy for Brazil*, *Energy Efficiency in Buildings: Progress and Promise*, and *Energy Efficiency: A New Agenda.*

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In addition to his work in the United States, Mr. Geller has spent over three years working on energy efficiency issues in Brazil. He helped to start and frequently advises Brazil's National Electricity Conservation Program (PROCEL). Most recently he assisted PROCEL with the preparation of a $120 million energy efficiency initiative involving funding from the World Bank and the Global Environmental Facility.

Mr. Geller was awarded the 1998 Leo Szilard Award for Physics in the Public Interest by the American Physical Society in recognition of his contributions to appliance efficiency standards and more efficient energy use. In 1979–80, Mr. Geller worked on rural energy technologies at the Indian Institute of Science in Bangalore, India through a Fulbright-Hays scholarship.

Mr. Geller received a Masters degree in Mechanical Engineering from Princeton University in 1979. While at Princeton, he collaborated with faculty and researchers in the Center for Energy and Environmental Studies. He received a Bachelors degree in Physics and Science, Technology and Society from Clark University in 1977.

Mr. Geller is a member of the editorial advisory board for the journal *Energy Policy*. He is also the associate editor for energy efficiency of the new Macmillan Encyclopedia of Energy.

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Chairman **BARTLETT.** Thank you very much. Mr. Courtright.

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STATEMENT OF MR. HENRY A. COURTRIGHT, VICE PRESIDENT, POWER GENERATION AND DISTRIBUTED RESOURCES, ELECTRIC POWER RESEARCH INSTITUTE

Mr. **COURTRIGHT.** Thank you, Mr. Chairman and members of the Subcommittee. I represent EPRI, which is a non-profit collaborative organization conducting electricity R&D for the public interest. My 3 main points will involve strengthening our nation's electricity infrastructure.

First, we must develop and deploy a portfolio of advanced generation technologies utilizing American's diverse energy sources, fossil, nuclear and renewables. We believe a portfolio strategy offers flexibility to deal with future uncertainties. And we recommend policy actions and increased R&D funding in the following areas: Advance coal technologies with over 50 percent efficiency and near zero emissions are a high R&D priority. Coal provides over half of the U.S. electricity today and needs to be a major component of our portfolio for fuel diversity and cost control for the future.

Significant R&D funding increases are recommended for technology such advanced gasification with hybrid systems. And coal refining or a "powerplex" which has hydrogen separation, fuel production, and includes carbon sequestration. A study now being completed by EPRI shows a societal value of over $350 billion from conducting the necessary coal R&D to enable upgrading about 25 percent of our coal capacity to cleaner coal technologies.

And last year, EPRI started a global coal initiative to build industry support for these technology developments and linked with public programs like DOE's Vision 21 Program.

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Nuclear power is the second largest generating source in the United States. Technology developments such as the recently certified Advanced Light Water Reactor design are needed to lower the costs for new nuclear plants. And in the longer term, new designs will be needed featuring high-utilization fuel cycles and modular, gas-cooled reactors. You may have seen an article in The Wall Street Journal recently in the Pebble Bed Reactor which is that modular design.

The generating options portfolio, however, should also include R&D for gas turbines. Because many of the advanced systems use turbines and we should work on improving their efficiency. Renewable energy, where we still see significant improvement possibility and photovoltaic biomass gasification and energy storage to match the demand with the load. And distributed systems that the power grid can connect to, to provide the reliability and power quality demanded by business and customers.

My second point is that R&D programs are needed to strengthen the power delivery system and effectively serve the growing digitally-based society we are in. Power grid is being used for ways in which it wasn't designed and has resulted in system limitations, reliability problems and even outages.

We have launched two programs at EPRI with our members to address these. One is a reliability initiative which has involved over 40 utilities on reliability assessments of transmission, software tools, and best practices and operations. We are also launching an ambitious program called CEIDS, which is the longest acronym I have ever heard. But it is consortium for the electric infrastructure to support a digital society. But CEIDS is basically designed to ensure high quality electric power is delivered reliably to the emerging digital society. The new consortium is designed to build public and government partnerships along with business to create state-of-the-art power delivery and use devices to meet the energy needs of a high tech industry and tomorrow's businesses.

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We are already securing multi-year commitments from the electricity industry. And we are looking toward the high tech industry and the Federal Government as critical partners in this program to ensure the viability of our power delivery system.

Third, we need to conduct more public/private partnerships to conduct strategic long-term research for the public benefit in the future. The present level of electricity R&D both in the public/private sectors is insufficient, given the increasing importance of electricity of our economy. And as a proactive initiative, EPRI is establishing a new non-profit organization called the Electricity Innovation Institute. EPRI's board and its public advisory council have endorsed the creation of this entity. And we anticipate activation in August of this year.

The Electricity Innovation Institute will focus on strategic electricity related R&D to create public—by creating public/private partnerships to leverage funding from both the industry and public government sources. The institute will have an independent board of directors selected from outside stake holders outside the electricity industry, to provide strategic guidance on the R&D agenda, and provide public oversight of the use of the funds. And our focus is on implementing the long-term societal needs we have identified of what we called our Electric Technology Roadmap to build toward energy sustainability. The development of the institute has been discussed with key personnel in several Federal and state agencies. And we have gotten very good comments on its focus and objectives.

I would like to summarize my remarks by making 3 key points. Energy policies should include a portfolio of advanced generation technologies using diverse fuels. We must strengthen the power delivery infrastructure to prove reliability. And new public/private partnerships are needed to conduct long-term research for the public benefit. Thank you.

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[The prepared statement of Mr. Henry A. Courtright follows:]

PREPARED STATEMENT OF HENRY A. COURTRIGHT

Mr. Chairman and Members of the Subcommittee:

Thank you for this opportunity to address the Subcommittee on Energy. I would respectfully request that the Subcommittee enter the following written remarks into the record as well as my oral testimony.

EPRI commends the leadership of the Chairman and the Members of the Subcommittee in convening this hearing on energy policies to address the critical energy supply and infrastructure needs of the United States.

EPRI, the Electric Power Research Institute, was established 27 years ago as a non-profit, collaborative research and development (R&D) organization to conduct electricity-related supply, delivery, end-use, and environmental R&D in the public interest. EPRI has been supported voluntarily since our founding in 1973, and we have from the outset enjoyed the strong support of the state public utility regulatory commissions. Our members, public and private, account for more than 90% of the kilowatt hours sold in the U.S., and we now serve more than 1,000 energy companies and related institutions in more than 40 countries. EPRI operates as an independent technical organization maintaining access to and engaging the best technical talent in the world to solve energy and environmental problems.

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My testimony will focus on the technology innovation needed to provide future energy options and strengthen our nation's electricity infrastructure. This infrastructure is a critical component of our economy and unless important issues are addressed we may face losses in our economic prosperity, environmental improvement objectives and the overall quality of life of our citizens. EPRI and over 200 stakeholders from government, business and academia addressed these issues as part of the Electricity Technology Roadmap Initiative. I have provided a copy of the Executive Overview of the Roadmap synthesis report to each Member of the Subcommittee.

I would like to emphasize three points in this testimony:

I. A CRITICAL PRIORITY IS THE DEVELOPMENT AND DEPLOYMENT OF A PORTFOLIO OF ADVANCED POWER GENERATING TECHNOLOGIES UTILIZING DIVERSE FUEL SOURCES—FOSSIL, NUCLEAR AND RENEWABLES.

A portfolio strategy offers the greatest flexibility and risk management in meeting the uncertainties of the future, as well as the opportunity to seize technical breakthroughs wherever and whenever they occur. A number of factors can shift the balance of the portfolio, including the availability and price of fuels, the pace of technological development, regulation and policy.

Coal Technologies—Advanced technologies for coal utilization with near-zero emissions are a high R&D priority. Coal now provides about 53% of U.S. electricity generation and despite growing contributions from natural gas and renewable energy, it is anticipated that coal will continue to be the backbone of electricity generation well into the 21st century. However, the continued use of coal will be predicated on improving its energy conversion efficiency and environmental performance while retaining coal's cost advantage. Clean-coal technologies, such as integrated gasification combined cycles (IGCC) and hybrid combustion/gasification systems have the potential to achieve greater than 50% electricity conversion efficiency at a competitive or lower cost of electricity as equivalent natural gas combined-cycle systems. Compared with natural gas, coal has a significant fuel cost advantage that offsets the higher capital cost of coal-based options. And recent gas price spikes show the value of maintaining diversity in the energy sources used to produce electricity. A study, now being completed by EPRI, shows preliminary findings of significant societal value from coal R&D to enable the upgrading or replacing about 25% of the coal capacity over the next 20 years with clean coal technologies, versus replacing this coal capacity with natural gas generation. The analysis shows that, through the lower cost of electricity from coal, societal savings of over $350 Billion (driven by consumer cost savings), can be achieved while maintaining overall environmental quality. If so desired by the Subcommittee, a copy of the report can be provided when it is completed.

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Last year, EPRI introduced an Advanced Clean Generation Initiative to accelerate the development of new technologies such as clean coal, renewables and fuel cells. The clean coal component of this effort, The Global Coal Initiative, is intended to build industry support and funding for such technologies. This effort would link with public programs, like DOE's Vision 21 program, to develop advanced coal technologies with higher efficiencies and low emissions, including a coal refinery or "powerplex" concept with hydrogen separation, chemical production, and carbon dioxide sequestration in addition to electricity generation. This result would be a far more efficient and complete utilization of coal's total resource value. But the programs to develop these technologies and achieve commercial viability will require major infusions of R&D funding beyond currently planned expenditures.

Carbon sequestration—Technologies are needed to further improve the capture of CO at the point of generation followed by long-term storage in sinks, or the removal of CO from the atmosphere at locations distant from the generation sources. Research is needed to develop low-cost carbon capture technologies that operate at ambient pressure and temperature and to demonstrate long-term carbon storage technologies. Such technologies are critical to the strategic long-term use of all fossil fuels—coal, gas and oil.

Gas Turbines—The recent boom in the installation of natural gas combustion turbines is the result of significant developments in materials and combustion technologies. Continuing to push the efficiency of combustion turbine technology is an important because the turbines themselves are expected to be key components in most high-efficiency combustion systems. In the 2020–2050 time period, the use of combustion turbines in hybrid systems with fuel cells could achieve efficiencies of nearly 80%. DOE's Advanced Combustion Turbine System (ATS) program is an important initiative to sustain.

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Renewable Energy—Both traditional and advanced renewable energy sources will be important contributors to the energy system. However, a significant scale-up of the size and number of generating capacity and energy output will be needed if renewable generation is to meaningfully hedge price risks or significantly reduce carbon emissions. Wind energy capacity has increased over 30% during 1999–2000 and today's cost of wind generation, in some areas, is becoming competitive with natural gas based combined cycles. However significant breakthroughs are still needed, particularly in photovoltaic applications. Development of improved gasification technologies for biomass fuels should help to make that fuel more flexible for application in advanced, related, technologies such as fuel cells. Other hybrid approaches are being considered and developed—some hybrids of two or more 'renewable' technologies, others hybrids of renewable with advanced 'traditional' technologies. As renewable energy systems become larger contributors, there is an increasing and compelling requirement for R&D to ensure appropriate and efficient system integration. In addition, reliable energy storage capabilities must be developed and integrated with renewable power systems. For example, developments in electrolytic hydrogen, batteries, flywheels and other storage technologies may have the potential to extend the use of intermittent renewable applications, helping to couple the output with periods of peak demand.

Distributed Generation/Resources—The rapidly growing interest in distributed power technologies is a result of not only power interruptions, but also the need for higher quality power for digital computerized controls, advanced manufacturing and communications systems. The effective integration of distributed technologies is an important part of an energy policy for the future to create the nation's "electricity superhighway" supporting a digital society. This system (discussed later in these remarks) is essential to continued productivity growth and competitiveness in a global economy.

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Nuclear—Nuclear power is the second largest contributor to electricity production in the U.S. and represents almost 70% of the emission-free generation. The electricity production from our 103 operating nuclear plants has increased by over 30% in the last decade, reaching 760 billion kilowatt-hours in 2000. There is growing interest in building new nuclear plants in the U.S. However, the capital cost for new nuclear plants must be such as to keep the production costs competitive. Advances in new technology are required to assure competitiveness. In addition to the need for competitive capital costs, progress must be made in the management of spent nuclear fuel. The improvements in the reactor regulatory process realized in the last few years must be maintained and extended. Finally, we must focus on enhancing the public awareness of the benefits of safe, competitive, environmentally friendly electricity generation by nuclear plants.

Today's operating nuclear plants are competitive with other power generation technologies on a cost of electricity basis. Over the past five years, significant improvements have been made in aging management technologies, new inspection and repair technologies, and adaptation of state-of-the-art digital technologies, which has paved the way for License Renewal that will extend the operating period for the current fleet of plants for at least 20 years.

Technology developments that will address the capital cost issue and enable new plant construction, based primarily on recently certified evolutionary and passively safe Advanced Light Water Reactor designs, include:

A suite of state-of-the-art modular design and construction technologies.

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Advanced nuclear instrumentation, controls, and man-machine interfaces.

Comprehensive, life-cycle electronic information management systems.

Risk-informed modernization of nuclear regulations related to both nuclear plant design and operation, to allow further optimization of designs and further reduction of construction costs and operating costs, while maintaining safety.

In the longer term, new designs will be needed, featuring:

High-utilization fuel cycles to improve generation economics at a time in the future when nuclear fuel resources become more costly.

High-temperature, modular, gas-cooled reactors for higher efficiency and process heat applications in addition to electricity generation in a variety of sizes.

II. FOCUSED R&D PROGRAMS ARE NEEDED TO STRENGTHEN THE POWER DELIVERY INFRASTRUCTURE TO IMPROVE RELIABILITY, MEET THE NEW DEMANDS OF ELECTRICITY COMPETITION AND EFFECTIVELY SERVE THE GROWING DIGITALLY BASED SOCIETY.

As a result of dramatic increases in inter-regional bulk power transfers and accelerating complexity of transactions among parties, the electric power grid is being used in ways for which it was not originally designed. Grid congestion and unusual power flows are increasing at the same time as customer expectations of reliability are rising to meet the needs of a digital society. Consequently, limitations of the current system are becoming apparent, manifested by increasing frequency of reliability problems, including outages affecting large numbers of customers at a huge cost to society. EPRI and its members have launched two programs to address these issues.

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Reliability Initiative—Phase one of this collaborative effort started in late 1999 and involved more than 40 EPRI member utilities focusing on identifying ways to reduce the risk of future reliability problems in the near future. This initiative was endorsed by the North American Electric Reliability Council and the IEEE Power Engineering Society. The initiative developed:

Reliability assessments of major North American transmission systems

Software tools to improve transmission system planning and operation

Assessments of representative distribution systems to develop best practices data

Tools to perform self-assessments of distribution system operations

Phase two will begin in 2001 and will expand on the development of reliability tools and field applications to enhance their use.

Consortium for Electric Infrastructure to Support a Digital Society (CEIDS)

A new mega-infrastructure is emerging from the convergence of energy, telecommunication, transportation, Internet, and electronic commerce. This is a cornerstone of the emerging "24–7" world and will require new, digital-grade quality infrastructure and services. In response to the growing demand for high quality electricity supply fostered by the digital revolution, EPRI initiated an ambitious program designed to ensure high quality digital-grade electric power is delivered reliably to meet the needs of a digital society. The newly created Consortium for Electric Infrastructure to Support a Digital Society (CEIDS) will build *public/private partnerships* to explore state-of-the-art power delivery and end-use technologies, as well as yet-to-be-developed technologies to meet the energy needs of high technology industries and businesses. Meeting the energy requirements of an increasingly digital society will require applying a combination of advanced technologies—from generating devices (e.g., conventional power plants, fuel cells, microturbines) to interface devices to end-use equipment and circuit boards. In addition, new technology is needed if society is to leverage the ever-expanding opportunities of the Internet and electric utilities' natural connectivity to customers to revolutionize both the role of a rapidly changing industry and the way customers may be connected to electricity markets of the future. CEIDS can enable such a transformation and ushers the direction for building the future infrastructure technology needed by a digital society.

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Meeting the challenge of defining, designing and building the technologies that will provide the backbone for the infrastructure of the digital society requires a multidisciplinary program of technology development. CEIDS will concentrate on developing technology and products to support the following four technology platforms:

1. *The Self-Healing, Digital-Quality Electricity Superhighway*—Develop science and technology that will increase the control, capacity, and reliability of power systems so as to supply consumers with the quantity and quality of energy they need at competitive prices and provide the necessary "hardening" that will allow the systems to survive conceivable threats from natural and man-made disasters.

2. *Energy Solutions for End-Use Digital Applications*—Provide options to energy consumers for meeting their energy needs by developing innovative technologies that provide greater tolerance to power disturbances. Options will include changes to the power requirements of digital devices as well as integration with the power system, distributed resources, and power conditioning equipment.

3. *Value-Added Electricity-Based Services*—Develop and implement technologies that will enable consumers to access a variety of electricity-related services allowing greater choice of providers and enhanced opportunities to manage consumption and costs.

4. *Digitally Enabled Energy Efficiency*—Develop innovative technologies that provide options for consumers to manage and use energy more efficiently. Options will include application of solid-state electronics for the control and utilization of electric power and load management programs.

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Multi-year commitments from the electricity industry to participate in CEIDS are now being secured. Participation by the high tech industry and the federal government are critical next steps to forming this public/private partnership to ensure the viability of our power delivery system.

III. THE CREATION ON NEW PUBLIC/PRIVATE PARTNERSHIPS IS NEEDED TO CONDUCT STRATEGIC-LEVEL R&D FOR THE PUBLIC BENEFIT.

Last, I want to emphasize the importance of a public/private collaborative approach as part of the comprehensive energy R&D policy needed to develop electricity supply, delivery and utilization technologies.

U.S. federal energy R&D funding is also at its lowest level in 30 years relative to GDP. Under-investment in energy technology R&D is detrimental to both long-term energy security and global sustainability. The lack of realistic incentives for R&D investment by the energy industry and its suppliers—given the need that exists—is a major concern. The U.S. energy industry today invests only about 0.5% of its revenues in R&D, and the trend is downward. In comparison, the overall U.S. industry average is around 7%. Energy has been, and remains, at the bottom of the R&D investment ladder, a prescription leading to a precarious and threatening future, especially given the increasingly central role that energy will play in global economic and environmental issues in the 21st century.

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An effective response is needed to renew public/private collaboration that recognizes infrastructure excellence as a prerequisite for productivity growth, economic prosperity, and environmental health. With private-sector budgets cut and refocused on near-term results, collaborative efforts enable companies to explore R&D options that otherwise would be screened out, and to pursue opportunities for a longer time horizon. At the same time, it permits federal dollars to be stretched. Thus, the alignment of public and private support permits the leveraging of increasingly scarce R&D dollars on issues of joint importance. In addition, the current trends in both private and public sector energy-related R&D investment must be reversed.

As a proactive initiative to revitalize the public/private partnership for electricity related R&D, EPRI is establishing a new supporting organization, The Electricity Innovation Institute. EPRI's Board and its Advisory Council (which is comprised of representatives from state public utility commissions, government, academia and business) have endorsed the creation of this new entity, with anticipated activation in August of this year.

The Electricity Innovation Institute will conduct strategic electricity-related R&D by creating public/private partnerships to leverage funding from electric utilities, energy companies and other businesses with funding from federal and state governments and other public oriented organizations. The Institute will also provide the forum for strategic guidance of the R&D agenda and public oversight of funding.

The Institute has been created to enhance the public/private partnership for electricity R&D. Due to industry restructuring, the level of funding for strategic R&D has significantly declined and has eroded the existing public/private partnership that EPRI was created to provide. However, global economic prosperity depends on technological innovation in electricity and the environment, thus there is a critical gap in strategic R&D investments to achieve the destinations articulated in the Electricity Technology Roadmap.

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The Institute has been chartered as a non-profit 501(c)(3) supporting organization and a scientific organization in the state of California. The Institute is affiliated with EPRI as a supporting organization, however the Institute will has its own board of directors selected from a diverse group of stakeholders, most from outside the electricity industry. Although the two organizations are linked by similar purpose for electricity R&D, the focuses of the organizations are different, as set forth in the following chart.

Table 6

The creation the Institute as a public/private partnership provides the benefits of:

Joint assessment of R&D requirements

Leveraging public and private funding

Accelerated development of solutions

Enhanced commercialization potential from results

The development of the Institute has been discussed with key personnel in several federal and state agencies and we have received very favorable comments on its objectives. We look forward to a successful startup of this new public/private partnership later this year.

CONCLUSION

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I would like to conclude my remarks by summarizing the key recommendations:

1. Recognize that energy policy should reinforce the development and deployment of a *portfolio* of advanced power generating technologies utilizing *diverse* fuel sources including fossil, nuclear and renewables.

2. Focused R&D programs are needed to strengthen the power delivery infrastructure to improve reliability, meet the new demands of electricity competition and effectively serve the growing digitally based society.

3. The creation on new public/private partnerships is needed to conduct strategic-level R&D for the public benefit.

Thank you for the opportunity to present these recommendations and I welcome your questions and comments.

BIOGRAPHY FOR HENRY A. COURTRIGHT

Henry A. "Hank" Courtright is Vice President of Power Generation and Distributed Resources at EPRI in Palo Alto, California. As VP Power Generation and Distributed Resources, he provides executive leadership to EPRI's technology program in fossil, hydro, renewable generation and distributed resources. The Power Generation sector consists of four product lines which integrate the customer and market needs to provide high quality solutions to energy and environmental issues.

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Previously, Mr. Courtright was Vice President of Product Management at EPRI and led the organizations' four business general mangers for the Power Production, Power Delivery, Environment and Retail Sectors. He was also Vice President of Marketing & External Relations Group. The Marketing & External Relations Group focuses on corporate communications, marketing, domestic and international relations, regulatory and government relations.

Hank has 18 years experience in the electric utility industry and was Director—Marketing and Economic Development for Pennsylvania Power and Light Company (PP&L). His utility experience included the areas of generation, industrial services and marketing. He has also served as a Vice President, Marketing for the Buckeye Pipeline Company, one of America's largest independent pipeline companies.

Hank received a B.S. in Mechanical Engineering from the Pennsylvania State University in 1972 and a Masters in Business Administration from Lehigh University in 1983. He is a licensed Professional Engineer in Pennsylvania and California.

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Chairman **BARTLETT.** Thank you very much. Now, Dr. von Meier.

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STATEMENT OF DR. ALEXANDRA VON MEIER, DIRECTOR, ENVIRONMENTAL TECHNOLOGY CENTER, SONOMA STATE UNIVERSITY

Dr. **VON MEIER.** Mr. Chairman and committee members, thank you so much for having me. I would like to focus on 2 key areas today where we have energy solutions just waiting to be used.

Energy efficient buildings and renewable resources, in particular solar and wind power. Residential and commercial buildings account for about a third of the energy use in the United States, counting both electricity and fuels. This amount can be cut in half, if not better by doing all the things that we already know how to do to make buildings more energy efficient and at the same time more comfortable. As well as was already mentioned, the ETC that we are building at Sonoma State with funding from the National Science Foundation and The California Energy Commission. And that building is described in more detail in my written testimony.

There is a wide spectrum of techniques available to architects and builders today who choose to build in an awareness of energy. Some techniques as avoiding "indecent exposure" like having all the big windows on the north side. And some techniques as fancy as "smart building technology" where a computer opens and closes windows or sunshades to make maximum use of natural ventilation and daylighting. Then there is other tricks like thermal masks to keep a building's temperature steady over the day. And for drier climates there is evaporative cooling technology that is much more energy efficient than traditional air conditioning. All of these techniques work. They are commercially available. They pay for themselves. And the reason they are not being used more widely I think has much more to do with cultural factors than with economic and technical factors.

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I think that we urgently need 2 things. Building codes that are much more stringent with regard to energy consumption. And also, large-scale educational effort to address the knowledge gap among architects and builders in simply their awareness because they are accustomed to traditional wasteful building approaches.

Miss Woolsey also mentioned the integrated photovoltaic tank or PV system that we have at the ETC. The key factor that makes that kind of system attractive is net metering where the meter runs backwards and excess power can be sold to the grid often at the times when the prices are high, which is when the sun is shining. PV is the most expensive of the renewable energy technologies starting around 20 cents a kilowatt hour. But it is often worth it because photovoltaic have unique benefits. You can install them just about anywhere you want and walk away and they will work and they won't bother anyone. And that is a lot to say for power plants. On the larger scale for bulk generation, there is solar thermal power, which is a proven commercial technology producing at around 10 cents a kilowatt-hour. And of course, there is wind for as low sometimes as 4 to 5 cents a kilowatt-hour. And that is definitely reasonable even before you start to consider the additional benefits of resource security, long-term price stability, environment. And also the fact that these technologies are inherently good for market competition.

So by any measure of common sense, I think the question is not whether solar and wind power should be used, but how fast we can get that generation on line. To get that to happen, I think we need to help small investors hedge the financial risks. And we also need leadership that says, these are the right things to do for our country.

Yet I think there is a tendency to dismiss renewables as to not really being able to contribute a substantial part, if not ultimately all of our nation's energy needs. It is what I call the "myth of wimpy green electron." Like it just can't quite make it, you know. But when you look at it technically as in how much area would you actually need, it is really quite doable. Better though then fossil fuels and more easily than with nuclear technology.

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So between efficiency, solar, wind and other renewable resources, we have already everything we need for positive and sustainable energy solution. I can't help but be reminded of when the good witch, Glinda, tells Dorothy that she already has everything she needs to get back home. Now solving the energy problems will take more than clicking our heels together, but we can do it and it is not rocket-science. I believe that what we need is the brains to apply our common sense, the heart to recognize the good that can come of it, and the courage to make it happen.

And I most sincerely thank you for your efforts to that end.

[The prepared statement of Dr. Alexandra von Meier follows:]

PREPARED STATEMENT OF DR. ALEXANDRA VON MEIER

Mr. Chairman and Committee members, thank you for the opportunity to contribute to this hearing.

The subject of energy is currently drawing fresh attention and awareness nationwide, which is a good thing—insofar as the general public is recognizing the importance of the choices to be made, understanding that the consequences of these choices will be with us for a long time, and sincerely wants to do what is right. Of course, the circumstances that bring us to this increased awareness are troublesome and, to some extent, painful. My testimony will focus on two key areas where solutions can be found: reducing energy use in buildings, and taking advantage of renewable resources, particularly solar and wind energy. Finally, I will conclude with some observations regarding the comparison of renewable and nuclear energy for securing long-term supply.

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Energy Use in Buildings

Residential and commercial buildings use approximately 35% of the energy in the United States, counting both electricity and fuels. This amount of energy can be cut in half, if not more, by implementing the things we already know about how to make buildings more energy efficient and, at the same time, more comfortable.

At Sonoma State University, with funding support from the National Science Foundation and the California Energy Commission, we are just completing the Environmental Technology Center (ETC) that demonstrates building science "live." This building uses 80% less energy than California's codes allow, which are already the most stringent in the nation as to energy efficiency. How can such a dramatic reduction of energy use be accomplished, and still make for a charismatic building that is comfortable year-round?

There is a wide spectrum of techniques at the disposal of architects and builders today who choose to build with an awareness of energy. These techniques range from the very simple to the very sophisticated. They begin with zero-cost design methods such as simply considering which way a house is oriented, and avoiding what some architects call "indecent exposure"—like having all the large windows on the north side.

In the ETC, we use large glazed areas including a clerestory window facing south for passive solar heating and for daylighting, allowing us to cut down dramatically on heating and lighting energy. In order to prevent glare and overheating in the summer, there are different types of adjustable shading devices. Those mounted on the exterior of the window surface are particularly effective, because they keep the glass itself from transferring heat. Interestingly, we had to buy our exterior Venetian blinds from a European manufacturer, because nobody in the United States makes them.

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The architect's toolkit of energy conserving measures includes many other basic features such as insulation and thermal mass to even out the building's temperature swings. The ETC, which takes advantage of our colder nighttime temperatures to pre-cool its concrete and earth walls in the summer, does not even have an active cooling system installed. Sonoma State University is now also considering a retrofit of existing buildings with evaporative cooling systems (I/DEC, for Indirect/Direct Evaporative Cooling) to replace conventional air conditioning, at a fraction of the energy use. I/DEC technology is proven, readily available, and highly effective in the drier climates of the western United States.

After numerous other techniques and devices for increasing energy efficiency, at the most sophisticated end of the spectrum there is "smart building" technology, which allows all the energy-relevant components—heating and cooling, ventilation, windows, lighting and shading—to be controlled automatically in real-time, based on measurements of indoor and outdoor data such as temperature, humidity, wind speed, and light levels.

Finally, it is worth considering not only the energy used in an occupied building, but also the embodied energy and resources required to manufacture the building materials themselves. Among other "green building materials" that are now available on the market, the ETC also pioneered the use of an energy-efficient concrete mix. This mix replaces half its Portland cement with fly ash and rice hull ash, providing superior structural strength while reducing energy inputs and CO emissions. Note that cement production accounts for about 6% of CO emissions worldwide.

A more comprehensive list of energy-saving features in the ETC is provided in Appendix I of this testimony. Not every one of the diverse techniques showcased in the ETC is necessarily appropriate for every building. Some options are feasible for retrofitting existing buildings, while the most dramatic savings can be obtained in the earliest phases of new building design. The key point is that an entire arsenal of building techniques and off-the-shelf technologies exists today for dramatically reducing energy use, and these options are available to anyone with an interest or incentive to take advantage of them.

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The fact that even those efficient building options with negative first cost or very short payback times are not finding the widespread application they deserve suggests that demand for energy efficiency is not driven by economic factors alone. I believe that two things are urgently needed:

Building codes that are far more stringent with respect to energy consumption, and

A large-scale educational effort to address the gap of knowledge and simply energy awareness among architects and builders accustomed to traditional, wasteful building approaches.

Solar Energy Options: Photovoltaics

On the roof of Sonoma State University's Environmental Technology Center is an integrated photovoltaic (PV) system that produces 3 kilowatts of electricity, roughly the same as the building's consumption. The system is grid-connected with net metering, allowing the building to draw power from the grid when necessary and to return excess power back into the grid, running the meter backwards. The availability of such net metering arrangements is key to opening the opportunity for small-scale, distributed generation to benefit the entire grid.

Of the renewable energy technologies, PV is by far the most expensive. The installed cost of a small-scale residential or commercial system, depending on many specific factors, currently ranges between $5 and $10 per watt of peak output. Spread out over the lifetime of such a system—a calculation whose result is very sensitive to the initial assumptions about sunshine and financing terms—the levelized cost comes to anywhere between 20 and 50 cents per kilowatt-hour (kWh) of electric energy. Until quite recently, such figures sounded exorbitant. They no longer do.

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Even when the price of photovoltaic power is above market wholesale or retail rates, this technology offers distinct benefits that may balance or outweigh its costs. These benefits include the following:

Reliability of supply, protecting against blackouts;

Absence of problems associated with conventional (diesel or natural gas fired) back-up generation, including air pollution and noise;

Unique simplicity and practicality owing to no moving parts, minimal maintenance, and zero fuel requirement;

Unique ease of siting owing to the above factors and agreeable aesthetics;

Flexibility in sizing and modularity, allowing installations to be expanded over time; and

Technical benefits to the electric distribution system including power quality (voltage, reactive power, and harmonic suppression) and reduction of line losses by locating more generation closer to demand.

Owing to current events, and a well-conceived rebate program offered by the California Energy Commission (which reduces the installed cost to the consumer by $3 per peak watt), the phones of PV installers in California are ringing off the hook. Interestingly, this jump in the general interest level and actual installation orders has occurred even before the impact of electricity price increases has met retail customers. The ultimate potential energy contribution of photovoltaics depends on the proportion of overall electric demand that stands to benefit from the specific advantages of distributed PV generation, and on whether an economic mechanism exists to capture its benefits to the transmission and distribution system and translate this into an investment incentive. Without specific analysis, my rough estimate of this proportion would be on the order of several percent of total demand.

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Bulk Generation from Solar and Wind

For generation of bulk electricity on the megawatt and gigawatt scale, the most plausible resources available today include solar thermal and wind power. Solar and wind are particularly important because their availability is less site-specific than other renewables such as hydro, biomass, ocean, and geothermal power.

Solar thermal electric generation, which essentially uses mirrors to boil water that then drives a standard steam turbine, is a proven commercial technology. In Southern California, roughly 350 megawatts (MW) of parabolic trough generating systems are currently on line and reliably producing electricity, with individual generating units on the 30 to 80 MW scale. These systems employ thermal storage tanks and can also supplement the solar heat with natural gas, which offers the advantage of making the generation dispatchable (i.e., controllable depending on the needs of the grid).

The cost of generating solar thermal electricity with parabolic trough mirrors has varied and generally declined throughout the years of development and refinement; it is now in the neighborhood of 10 cents per kWh, if not below. This is not only far less than California's average spot market price of recent months, but comparable to the rates at which the State of California is outright purchasing electricity through long-term contracts. Furthermore, as the cost of solar energy represents payments on an up-front investment, it is completely predictable and the supply absolutely certain, in contrast to natural gas-fired generation which exposes society to the risks of fuel price increases and supply or delivery constraints. By any measure of common sense, the question for California today is not whether solar power can or should be used to alleviate our electricity shortage, but *how fast* we can get more solar generation on line.

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In addition to the well-established parabolic trough technology, extremely interesting developments are taking place in the area of more modular point-focus solar concentrators that generate from five to 60 kilowatts (kW) with each unit. These devices use round parabolic mirrors to focus sunlight onto a Stirling or Brayton engine mounted directly in the center, which produces electricity at high efficiency directly from a hot gas (without the need for water).

While these engines are available off-the-shelf, the key to the commercialization of point-focus concentrators lies in the economical production of mirrors. Unfortunately, the National Thermal Test Facility at Sandia National Laboratories, where research and development of this technology was conducted, has recently experienced drastic funding cuts. Development efforts are continuing in the private sector, and one Texas-based company projects generation costs as low as 2 cents per kilowatt-hour based on a new and inexpensive mirror manufacturing process.(see footnote 22) Whether or not one believes this specific projection, it is beyond doubt that solar thermal concentrators can work effectively and at reasonable cost, and that they can fill a potentially large market niche for intermediate-sized distributed generation.

The ultimate contender as to low-priced, commercially available renewable energy is, of course, wind. Large wind turbines are on the market today at costs barely above $1 per watt of rated output. Depending on the local wind resource (and again the financing assumptions), this investment converts to a levelized energy cost as low as 4 cents per kWh in a prime wind location, and certainly below 10 cents for more average sites. Indeed, in some parts of the United States, wind is now altogether *the* least-cost energy option.

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Resource Potential

The undisputed environmental advantages of solar and wind power combined with altogether reasonable costs should make them obvious choices for expanding future energy supply. Yet the conventional wisdom on the subject, reflected in popular media coverage as well professional and academic discourse, contains a surprisingly persistent fallacy regarding the potential contribution from these resources. A recent article in the *New York Times* exemplifies the problem: "Environmental advocates call for investments in efficiency and in 'renewable' sources like wind and solar, but so far those sources are tiny compared with demand."(see footnote 23)

This logic is fallacious because it implies some causal connection between what was done in the past and what can be done in the future, without examining what this connection is or whether it exists. Certainly, it is legitimate to wonder about the possible ramp-up rates in the production of solar cells or wind turbines, but this is no different in principle from stepping up the manufacture of other devices like gas turbines or nuclear reactors to unprecedented quantities. It would also be fair to argue that the idea of acres upon acres covered with solar collectors and wind farms simply doesn't match our vision of what an advanced technological society should look like; this is a legitimate question of cultural and aesthetic preferences. What is false and misleading, however, is to claim that it would be technically or economically infeasible.

U.S. electricity demand in 2000 was approximately 3,700 TWh (billion kilowatt-hours). Generating this *entire* amount from solar thermal energy would, by conservative estimate, require a land area of roughly 20,000 square miles of Southwestern desert land, or a square of about 140 miles on a side.(see footnote 24) Alternatively, generating the same *entire* amount of energy from wind farms in the Midwestern plain states (where the land can be simultaneously used for agriculture) would require an area of perhaps twice that size.

(see footnote 25)

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Though this is no doubt a large piece of real estate, it is certainly plausible on the geographic scale of the United States, and indeed not even as large as one might think in comparison with traditional energy resources once their various components such as mining and infrastructure are taken into account. For example, the Yucca Mountain nuclear waste repository is designed with an exclusion zone that extends 12 miles, or an area of about 450 square miles that will be inaccessible for other uses.(see footnote 26) If covered with solar collectors, this area could produce in the neighborhood of 2% of U.S. electric energy.

Or, to consider another example, wind generation occupies four to five times more area per megawatt than coal generation, but only about 5% of the land on the wind farm is actually "used" or physically affected, while 100% of a surface coal mine is affected. In this sense, renewable resources are actually *less* land intensive than the conventional alternatives.(see footnote 27) Furthermore, land used for solar or wind generation can be readily restored to other uses in the future, while land used for fossil fuel extraction or nuclear facilities becomes permanently sacrificed.

A common misconception holds that intermittent resources like solar and wind require energy storage such as batteries to back them up. This is only true for stand-alone applications such as remote residences, where energy must be stored so that it will be available when the sun isn't shining or the wind isn't blowing. For grid-connected applications, whether distributed or centralized, the grid simply absorbs the variations in the output, just like it absorbs the continual variations in demand as people switch their appliances on and off. Physically, it is the large rotating steam and hydro generators that are capable of absorbing and compensating for these variations in real-time. Solar thermal generation, it should be noted, also takes advantage of thermal energy storage on-site to smooth its output or shift it to the later afternoon hours when the electricity is needed most.

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Indeed, from the perspective of technical grid operation, it is quite plausible to envision an electric supply system running on 100% renewable energy. This would require some baseload generation such as hydro and biomass to operate consistently throughout day and night; some dispatchable hydro and/or biomass generation to can absorb the variations in demand and supply; wind power to generate whenever wind is available; solar thermal and photovoltaic power to generate during the daytime when the sun shines and demand is greatest; and finally a modicum of pumped hydroelectric storage (as is currently used) to help optimize the utilization of all available generation assets.

Let me stress, then, that there is *no physical or technical reason* why our country could not supply 100% of its energy from renewable resources. This same conclusion has been reached by numerous other authors in the energy field.

Policy Implications

Given the tremendous resource potential of solar and wind power along with energy efficiency, these technologies undoubtedly offer positive externalities, or benefits to society and the environment beyond those captured in markets. These benefits, which have been more or less widely discussed in the literature, include the following:

Environmental benefits owing to absence of pollution or greenhouse gas emissions;

Continuous resource availability and price stability to offer reliable support for long-term economic planning;

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Potential development of a lucrative and socially responsible export commodity; and

Intrinsic compatibility with competitive markets.

The last point requires brief annotation. Energy efficiency and especially small-scale renewable generation technologies offer some potential to correct the three most important failures of electricity markets. These failures have been evidenced most dramatically in California recently, but are generally applicable to electricity markets unless specifically addressed in market design (though their impacts are sometimes avoided by the sheer luck of oversupply). These key market failures are:

Low or zero price elasticity of demand, meaning that consumers will not demand less power as the price increases—either because they are shielded from spot market prices (as in the California design), and/or because they lack the capability to reduce electric demand while meeting their essential needs and obligations;

Market power, the polite term for the situation in which certain sellers can essentially name their price; and

Congestion, or the inability of the electric transmission system to deliver any desired amount of power from one location to another.

Efficient buildings and appliances provide consumers with one alternative to energy consumption and thus make demand more price elastic, albeit on the intermediate time scale of hardware investments. On a shorter time scale, the emerging combination of responsive buildings with real-time energy pricing is particularly promising, as it allows devices to automatically be shut off when the price rises. (Constrained by metering technology, this approach is now being implemented for larger commercial customers in California.)

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On the supply side, solar and wind generation intrinsically do not favor aggregation in the hands of a small number of suppliers with market power, unlike ownership of traditional large and complex generation assets and ownership of fossil-fuel resources or their delivery capacity. This property, of course, owes both to the ubiquitous access to the resources and the relative absence of economies of scale in the technology.

Finally, owing to their smaller scale and the feasibility of siting solar or wind generation close to consumers, these technologies can alleviate transmission bottlenecks by being placed exactly where they are needed, and thus help avoid local price spikes or market power of already conveniently situated producers.

Given the current policy priority of encouraging competitive markets, it would stand to reason that technologies which assist rather than impede competitive behavior deserve some measure of governmental support, as means to an end. This new factor appears in addition to the other long-term positive externalities such as environmental benefits that have historically (and, in my view, correctly) justified policies aimed at increasing the supply of desirable energy technologies for the benefit of society at large.

Government-sponsored research and development has traditionally been an important component of such subsidies, and I find it most regrettable that this funding has now been substantially reduced. I also believe, however, that the most urgent need in view of our energy situation today lies in the area of commercialization and implementation of the technologies we already know, rather than research on new approaches and devices. In this regard, I believe that two simultaneous efforts are called for:

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Education and decisive leadership to demonstrate and emphasize the feasibility of renewable resources on a national scale and to dispel popular myths about their limitations; and

Facilitation of market entry for renewable energy suppliers by reducing the uncertainties and investment risks encountered particularly by small firms facing competition with large and well-established actors.

In the United States today, we have the resources, technology, and know-how at our disposal to bring about a positive, sustainable solution to our energy future. The situation reminds me of the Good Witch Glynda telling Dorothy that she already has everything she needs in order to get back home. Of course, solving the energy crisis constructively with energy efficiency and renewable resources will take more than clicking our heels together. But it is not an implausible effort, nor is it rocket science. What we need is simply the brains to apply our common sense, the heart to recognize the tremendous good that can come of a new approach to energy, and the courage to implement it. I thank you most sincerely for your efforts to this end.

Renewable Energy and the Nuclear Option

If the popular claim were true that renewable resources are either insufficient or the technologies not ready to supply energy on the national scale, then it would be legitimate to argue, as advocates of nuclear energy do, that nuclear fission represents the only option for securing our long-term energy supply without environmentally unsustainable CO emissions. However, as my preceding testimony underscores, the premise of this argument is incorrect.

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Recognizing the ultimate resource and environmental constraints on fossil fuel use, the issue is not whether we as a society need to accept the costs and risks of nuclear technology in order to maintain energy security. Rather, the question is whether nuclear energy can compare favorably with renewable energy options, specifically solar and wind, in order to achieve the same objective.

The economic comparison of nuclear and renewable energy is interesting because the overall costs for deploying a large-scale supply system of either type may well be similar. Yet the cost *structure* of such deployment is very different, as is the degree of uncertainty.

Nuclear industry representatives assert that a new generation of inherently safe light-water reactors could produce electricity at a levelized cost below 5 cents per kilowatt-hour, which would make it competitive with wind power. However, such levelized cost calculations in general contain important tacit assumptions, and for the nuclear case in particular they mask numerous potentially profound complications.

While the science of nuclear fission is compellingly elegant, it is important not to falsely extrapolate from the beauty and compactness of the fission process to the industrial and institutional reality of implementing a nuclear energy supply system in society. Indeed, you might say that nuclear power becomes more complicated and messy the farther you extend your view away from the reactor core. Once human institutions and infrastructure conditions are accounted for, the overall cost, or the level of effort required of society to sustain the nuclear endeavor, becomes greater and more uncertain.

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Thus, with regard to projections of energy costs from a new generation of nuclear plants, the following areas warrant inquiry:

Liability Insurance. The Price-Anderson Act, which limits nuclear plant operators' liability for damages (effectively representing a substantial Federal subsidy) is due to expire in 2002. If the current policy priority of non-interference with competitive markets were to be consistently applied to this case, then the issue of whether a properly insured nuclear program can be economically viable on its own merits ought to be determined through the competitive private insurance sector.

Reliability of Electric Grid. The traditional operating context assumes a reliable electric grid that allows the continuous and undisturbed operation of nuclear reactors as baseload power plants. Grid disturbances or outages, while historically very rare in the United States, are extremely costly to nuclear plants, not only in terms of lost revenues, operational effort, and mechanical fatigue of plant components, but also in terms of the investments required to assure safe unit shutdown upon the loss of off-site power. Adapting the design and operation of nuclear reactors to function in the context of less reliable electric grids, as may emerge under competitive market pressures, entails potentially high costs in addition to those of basic reactor design and operation.

Waste Disposal. The U.S. Department of Energy is presently expending significant effort and funds in order to accommodate and assure the safe disposal of spent fuel from existing commercial nuclear plants, of which it assumed responsibility in 1998. While nuclear plant operators contribute substantial sums to decommissioning and waste disposal funds, these contributions are by no means certain to cover the actual costs of properly cleaning up after fission.

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Time Delays and Contingencies. The actual cost of existing U.S. nuclear facilities has vastly exceeded original projections in large part due to construction and licensing delays, which in turn resulted from political controversy and the need to demonstrate an extremely high level of safety. Though advocates of nuclear energy argue that political dynamics have unfairly distorted the costs of our nuclear program, these dynamics nonetheless represent the reality of our democratic society, and few would disagree with the demand for safety, however cumbersome to assure, as an absolute priority. Due to its intrinsic complexity, nuclear technology is particularly vulnerable to cost overruns resulting from delays or unanticipated complications, and realistic projections must account for such contingencies.

The Closed Fuel Cycle. The reprocessing of spent commercial nuclear fuel for the purpose of extracting fissionable plutonium to supplement mined uranium in fresh fuel (the "closed fuel cycle") has been prohibited in the United States by past Administrations, for reasons of preventing the proliferation of key technology and materials for nuclear weapons. However, from the perspective of nuclear engineering, our present "once-through" fuel cycle is wasteful and illogical, and it condemns nuclear energy to a far more limited resource supply (only the naturally fissionable uranium-235, which is a small fraction of total uranium reserves) than it could enjoy if the conversion of abundant uranium-238 into fissionable plutonium were exploited. In the context of ambitious plans for long-term energy supply through nuclear fission, revisiting the issues of reprocessing and breeder reactors (those designed for the explicit purpose of converting the abundant uranium) would become inevitable, and arguments in favor of such a policy reversal would undoubtedly be voiced once the nation had committed to the nuclear path. Yet the complexities and risks (and thus the potential economic and political costs) of a closed fuel cycle and breeder program would vastly exceed those of our accustomed once-through cycle.

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It should further be noted that nuclear technology, owing to its intrinsic hazards and economies of scale, is antithetical to the philosophy of competitive markets. A nuclear program cannot be done piecemeal—at least not economically. Indeed, the lack of standardization among U.S. reactors and procedures has often been cited as a reason for the high cost of our nuclear program (and unfavorably compared in this regard with the French system, which is completely centralized). And a nuclear program cannot be done in good conscience without government oversight.

Despite the high historical costs of nuclear technology, people tend to find it easier to imagine large amounts of inexpensive electricity produced by nuclear power plants than from renewable resources. I believe this to be a perceptual distortion resulting from the different cost *structures* of these two very different approaches to energy supply.

A nuclear energy program presumes a substantial investment in an extensive infrastructure, from uranium mining, fuel fabrication, plant design, construction, and decommissioning, identification of appropriate sites, spent fuel storage, transport, and disposal to personnel training, security, insurance, and regulatory design. In every country with a nuclear program today, this infrastructure is government-subsidized, and some of its costs may be further masked by being exported into the future.

However, once this infrastructure is assumed to exist, the marginal cost of each additional megawatt-hour generated is very small. It thus becomes easy to neglect or underestimate the sunk infrastructural cost and focus on the low marginal energy cost, which becomes lower per unit of energy the larger we assume the initial infrastructure to be. This type of declining cost structure entails the psychological effect of de-emphasizing awareness or selectiveness of energy consumption—in essence, promising a world in which you needn't worry about turning off the light when you leave the room.

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The cost structure of renewable resources, by contrast, is never declining. Rather, it is excruciatingly linear: each additional megawatt of solar or wind power, from the first to the last, will use the same amount of additional land area, and will cost about the same. Thus, while renewable resources can supply all our essential energy needs, they will never do so without confronting us with the question: Do we really need that last megawatt? I believe it is this implication of an omnipresent and undeniable awareness of the costs of producing energy that many people find so unpalatable about renewable resources.

Yet these costs reflect the reality of a finite planet. A society of indiscriminate energy consumption is not the future; it is history. At the present juncture, where resource scarcity, economic pressures, and the limits of our environment's ability to absorb the impacts of our activities are all becoming apparent, a significant investment in a new energy strategy is inevitable. Alas, crisis has a tendency to shorten one's time horizon for making decisions. But today it is more important than ever that we choose to invest prudently, intelligently, and for the long run.

Thank you.

Appendix: Environmental Technology Center, Sonoma State University

Table 7

Objectives for Material Selection:

Use products that conserve resources, i.e., materials that are reused, recycled, use by-products, uses faster-growing species of wood from sustainable forests, sustainable agricultural practices;

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Use products made from, with, and packaged in renewable resources obtained in a sustainable manner;

Use products that have low embodied energy, including transportation, i.e., products whose production is efficient in the use of electricity, petroleum, water, etc.

Use products that are durable, low maintenance, and do not require painting or coatings; consider life cycle cost and longevity including resistance to weather, fire, vermin, seismic and wind stress;

Use products with low(er) toxicity in mining, manufacturing, installation, use, and maintenance;

Consider deconstruction and use components that are reusable, recyclable, or at least biodegradable.

Table 8

BIOGRAPHY FOR ALEXANDRA VON MEIER

Alexandra von Meier, 7335 Baker Lane, Sebastopol, CA 95472; (707) 823–3690; *vonmeier*@sonoma.edu

Education

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Ph.D. Energy and Resources, University of California, Berkeley, 1995.
M.A. Energy and Resources, U.C. Berkeley, 1990.
B.A. Physics, U.C. Berkeley, 1986.
Abitur, John-F-Kennedy School, Berlin, 1981.

Experience

Assistant Professor, Department of Environmental Studies and Planning (ENSP), and *Director*, Environmental Technology Center (ETC), Sonoma State University, August 1999-present: Teaching courses on energy technology and environmental issues; developing curriculum for the ENSP program. Administering construction and developing design, research, and utilization strategies for the ETC, a teaching building for energy efficiency and sustainable design (completion in Summer, 2001).

Consultant, California Independent System Operator (CAISO), June-July 2000: Helped draft a reform proposal for transmission congestion management, submitted by CAISO to the Federal Energy Regulatory Commission (FERC).

Associate Specialist/Postdoctoral Research Fellow, Center for Nuclear and Toxic Waste Management, U.C. Berkeley, August 1996-July 1999: Developed interdisciplinary research methodologies to analyze the management of technical-institutional systems, esp. for nuclear materials management; conducting discourse analysis study on disposition of excess weapons plutonium and spent fuel transport.

Lecturer, Energy and Resources Group, U.C. Berkeley, August 1996-May 1999. Courses developed and taught include Electric Power Systems, Energy and Society, Interdisciplinary Energy Analysis, Renewable

Resources for Electric Generation, and Quantitative Methods in Energy and Resources.

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Postdoctoral Research Fellow, Department of Electrical Engineering and Computer Science, U.C. Berkeley, September 1995-August 1996: Studied technical and institutional aspects of electric power systems and industry restructuring.

Graduate Student, Energy and Resources Group, U.C. Berkeley, 1988–95: Practiced interdisciplinary research and analysis of electric energy technology, including engineering, economic, and social issues. Various teaching responsibilities as instructor and teaching assistant, courses developed and taught include Environmental Physics and Quantitative Aspects of Global Environmental Problems. Ph.D. Dissertation titled "Cultural Factors in Technology Adoption: A Case Study of Electric Utilities and Distribution Automation." Master's Project titled "Grid-Connected Photovoltaics: A Comparison of Three Siting Strategies."

Research Assistant, U.C. Berkeley, High Reliability Organizations Project, 1989–1992: Researched the management of complex and hazardous technologies; performed field interviews and observations at fossil and nuclear power plants and nuclear training facilities in California, Germany, France, Switzerland, and Sweden.

Consultant, Pacific Gas and Electric Co., Research and Development Department, 1989–1992: Performed research and analysis in the areas of hydrogen energy systems, photovoltaics, and distributed utility.

Teacher, The College Preparatory School, Oakland, CA, 1986–1988: Developed and taught 12th grade physics course; taught 11th grade chemistry.

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Publications

A. von Meier and Gwen Ottinger, "Being Informed: Complexity of Socio-Technical Systems in the Construction of Risk and Safety," presented at Workshop on the Social Construction of Risk and Safety, LinkoAE4ping University, Sweden, March 15–17, 2000.

"Cultural Conflict as a Challenge to Technological Innovation," *IEEE Transactions on Engineering Management*, Vol. 46, No. 1, Feb. 1999.

"Three Stories About Plutonium: A Narrative Analysis," International Forum Youth and the Plutonium Challenge, Obninsk, Russia, July 3–11, 1998.

"Ambiguity in Framing Risk: Contrasting Narratives on Nuclear Materials," PSAM 4, International Conference on Probabilistic Safety Assessment and Management, Sept. 1998, New York.

A. von Meier, Jennifer Lynn Miller and Ann C. Keller, "The Disposition of Excess Weapons Plutonium: A

Comparison of Three Narrative Contexts." *The Nonproliferation Review*, Winter 1998.

"Manufacturing Energy Requirements and Energy Payback of Crystalline and Amorphous Silicon Photovoltaic Modules." *Proceedings,* American Solar Energy Society, Solar 94 Conference, San Jose, June 26–30, 1994.

"The Integration of Supple Technologies into Utility Power Systems: Possibilities for Reconfiguration" in J. Summerton (ed.), *Changing Large Technical Systems,* Westview Press, 1994.

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Gene Rochlin and A. von Meier: "Nuclear Power Operations—A Cross-Cultural Comparison," *Annual Review of Energy and the Environment*, Vol. 19, 1994.

A. Suchard (von Meier) and Gene Rochlin: "The Control of Operational Risk in Nuclear Power Plant Operations: Some Cross-Cultural Perspectives," *Proceedings,* American Nuclear Society, Boston, MA, June 1992.

Daniel Shugar, Mohamed El-Gasseir, Allan Jones, Ren Orans and A. Suchard (von Meier): "Photovoltaics in the Distribution System: The Evaluation of System and Distributed Benefits," Pacific Gas & Electric Co. Report, 1992.

Gerry Braun, A. Suchard (von Meier) and Jennifer Martin: "Hydrogen and Electricity as Carriers of Solar and Wind Energy for the 1990s and Beyond," *Solar Energy Materials,* Vol. 24, 1991.

Publications currently in progress

Electric Power Systems: A Conceptual Introduction. Textbook to be published by John Wiley & Sons.

Grants, Awards and Fellowships

U.C. President's Postdoctoral Research Fellow, 1995–96.
Switzer Environmental Fellow, 1994–95.

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Outstanding Graduate Student Instructor, UCB, 1992.
Teaching Effectiveness Award, UCB, 1992.
Educational Improvement Grant, UCB, 1991.

Personal Information

Born October 7, 1964 in New Brunswick, NJ;
Raised in Berlin, Germany; U.S. Citizen;
One child (born 1/95).

Language Skills

Native German speaker; conversant in French.

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Introduction to the Panel Discussion by Chairman Bartlett: Conversation With Vice President Cheney on the DOE Budget

Chairman **BARTLETT.** Thank you all very much for your testimony. Let me just make a very brief remark and then I will turn to my ranking member for her questions and comments.

I have said it publicly before and I will say it now, I think it is already on the record but I will say it again, this is my president. And I don't want him to look dumb. And I met with the Vice President and told him that. And I said, help me understand why it is not dumb to cut the energy budget when we are facing an energy crisis. The Vice President sent me to talk with the people at OMB because he really didn't know the details of the budget for energy.

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It is not as bad as it looks at first sight. They have cut meaningful amounts of money from the energy budget, but they put it back almost dollar for dollar in tax incentives. The argument was that if there is a market out there that the R&D can be done in the private sector, if we were putting adequate amounts of money in basic research. And we are not. Not only in this area but in any area across our country. If we are putting adequate amounts of money in basic research, and if we were helping with tax incentives to develop a market then I am reasonably sanguine about cutting our R&D.

Because most of the renewable energies now are concerned—many of them, at least, particular in solar, are concerned with very large corporations which have deep pockets. And I have no question about BP's. And they—I mention them because they bought Solarex, which is headquartered in my district just a few miles from my home. And they certainly are perfectly capable of supplying the R&D dollars necessary. With another big advantage. I am sure they are a whole lot smarter than we are or government bureaucrats are as to where those R&D dollars ought to be invested. So if we are providing adequate basic research money, and we are not, and if we are providing adequate market incentives, and we are not but they have promised that they are going to provide more, then looking to the private sector with appropriate tax incentives like tax credits for R&D to do the R&D, and I don't really philosophically have a problem with that if we do those other two things.

Let me turn now to my ranking member for her questions and her comments.

Role of Renewable Energy Versus Nuclear Power

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Miss **WOOLSEY.** Thank you, Mr. Chairman. Dr. von Meier, in your written testimony I notice that you commented on the role of nuclear energy as an energy source compared to renewable options. As many of us know with the current energy crisis, particularly in California, some policy makers are using this situation as a way to revive nuclear option. I find this very, very troubling. And I would like you, if you would, to comment on this subject as it compares to the potential of investing in renewable energy sources.

Dr. **VON MEIER.** Yes. Thank you. Let me preface my remarks about nuclear energy by saying that I have spent a fair amount of time myself at nuclear power plants, both here and in Europe. And I have a tremendous respect for the people who operate them. I also have a tremendous respect for the magnitude of the task before them. Because I believe nuclear power is never simple. And I believe it is never cheap.

Now there are proposals and there has been some advances made in making reactor designs more simple. But a problem is that even by simplifying the reactor itself, you can't in—simplify the entire infrastructure that supports the nuclear plant itself. And that infrastructure has technical, it has social, and economic complexities and political complexities.

If you start from the assumption that renewables cannot make a substantial contribution, then I believe it is a legitimate argument to say that fossil fuels cannot produce energy for us sustainably. We, therefore, need to move to nuclear. However, that premise is false. And given that we now are really looking at comparable costs for solar and wind power on the one hand, and nuclear on the other hand, the question really comes down to, if we can provide energy from either of those sources at about the same costs which would we rather have. And which are we more confident that can stay within the confines of the cost projections.

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Making the Transition From Fossil Fuels to Sustainable Fuels

Miss **WOOLSEY.** Thank you very much. I have a question to ask you, Dr. Bartlett. That is, which is the right path?

Dr. **BARTLETT.** I'm sorry. I believe the conservative path is the right path to save energy, to develop non-renewable—or to develop renewables and to really concentrate on conservation of energy. There is enormous gains to be made from that. And I think that the conservative path. Because if that turns out to be the wrong path then you haven't hurt anything. But if you go on the liberal path and just use everything up as fast as we can, keep meeting all the demands for growth, then if we find that is the wrong path, and in fact resources are finite, then we are in big trouble.

Miss **WOOLSEY.** Do you see the possibility of where we are now with using the fossil fuels and transitioning—I mean, continuing while we are building up the renewables and then finding a nexus where we just transition over? Or do you think we need to just jump over to renewables now?

Dr. **BARTLETT.** I think the enormous financial investments necessary to make the transition will mean that it will necessarily be a long period, a long transition period. But I think we ought to make our way along that transition as rapidly as we can so that we can say, for instance, fossil fuels for their chemistry, for their base for chemical production, fertilizer production and things like this that we shouldn't really be burning these fossil fuels the way we are now.

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Energy Futures Markets

Mr. **WOOLSEY.** Okay. Thank you very much. Now Dr. Montgomery, have there been instances where the future's market have not predicted the course of energy prices? And if so, when did that occur?

Dr. **MONTGOMERY.** The—there have always been times when the market gets—when the consensus of the market or the future's price ends up being different from where the market is going. In fact, I think that there is a fundamental uncertainty that everyone has to recognize about where short-term energy prices are going to go. And I think just the chart that I showed, if I remember it correctly, shows that frequently the future's price was pointing down when prices in fact went up. Something unexpected came along that happened to the market. Another points the future's price was pointing up and the market went down. So there was a mistake. But if we look at the process over the long-term, what we see is, first of all, the spot price has cycled back and forth around $20 a barrel for oil. And that it is—that prices have come down from the peak that everyone was worried about in, say, January of this year, very rapidly for both oil prices and natural gas prices. And that the tendency over time has been that the future's prices pointed in the right direction. Has it always gotten right? No. Would I right now bet my entire portfolio on the future's price being right and the spot's part turning out to be there? Absolutely not. But over the long-term, the future's price has pointed very clearly toward and of where prices are going. It has not always been right.

Chairman **BARTLETT.** Thank you. We'll have several rounds of questioning here, because I know that you have a good deal more to contribute and more questions to ask. Let me turn now to my fellow scientist in the Congress, Dr. Vernon Ehlers.

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Energy Planning Time Horizons

Mr. **EHLERS.** Thank you, Dr. Bartlett. I am fascinated with this topic. And as Dr. Bartlett knows, I have been involved in this since the 70's. And I feel very strongly about it. I also have been completely disappointed at numerous times in any efforts I have made within the legislative arena, in local, state and Federal Government to make a difference with energy legislation. It is—and I have some theories on this I don't have to get into now. But I think part of this is just intrinsic to the nature of energy. It is intangible. The public doesn't know what it is. The only tangible aspect they see is the bill at the end of the month or the dollar signs on the gas pump.

But it is very difficult to get support from the public or from the legislative bodies for any meaningful changes in energy policy. I have advocated with the Chairman that we should take advantage of the fact we are both on this panel to try to develop a decent energy policy for this nation. But I really think much of the difficulty, and I would like your comments on this, much of the difficulty is the difference in planning horizons. Those people in the industry have short-term planning horizons. They—whether they are worrying about the spot price on the market today or whether they are worrying about their supplies for next year or maybe even 5 years from now. Dr. Bartlett is a long time horizon, long planning horizon. Fifty years, 100 years, 150 years. I have to confess, I have also been either blessed or cursed with a long range plan horizon. So I tend to side with Dr. Bartlett very strongly on the issues. And I think that is the point of view we have to take.

The question is, if that is true, how do we get the public, how to we get the legislative bodies to take a longer term view of the issue? I regard it as an issue of justice. Justice for succeeding generations, because that is what we are dealing with here. And the question is, how can we communicate that? Now if you think I am crazy, you are willing—you may have my permission to say that, too. But I think that is essential that to put this in context. The disagreement in my mind of many of these issues are not about the science or about the numbers. The issue is how much do we worry about future generations and what is our responsibility to them. I would appreciate comments from any of you on this. Yes.

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Energy Research and Development Needs Versus Past Energy Policies

Dr. **MONTGOMERY.** Mr. Ehlers, perhaps surprisingly from what I said before, I think I agree with you completely about the issue of time horizons. But where I would take that is, I think that what this committee has jurisdiction over is in fact what is more important for those future generations, which is establishing a base of R&D which will make the technologies available in the future that we need to be able to move off the fuels that, you know, we may well find are in short supply and use other forms of energy. Whether it is nuclear, renewable, coal, the things that, you know, have more abundance.

I think that—I think it is really important to focus on what decisions we can make today that really matter for the next generation. Because I think—I agree with you. I have watched lots of policy cycles in energy that got us nowhere. What has gotten us somewhere is the steady support for R&D that creates new options out in the future. I think it is really important to distinguish that from kind of adopting fuels policies that try to give a short run fix to something that's really a very long-run problem.

And for example, the kind of sorry sequence we went through for electric utilities, you know in the 1960's. We had environmental regulations that got utilities to move off coal onto oil just in time for the oil embargo to make them regret it seriously. We passed the Fuel Use Act that said, get off oil and gas and get onto coal. We did that just in time for us to start worrying about global warming and start telling utilities, get off coal and get back onto natural gas. Now we are worried about natural gas supplies. I think the steady course has to focus on what we can do for the future generations through R&D and try to get that right for once.

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Public Education

Mr. **EHLERS.** I appreciate your comments because I am totally in support of R&D. But also, I think we have to avoid the danger, which we often get into that we build in the public's mind the idea, don't worry about resources or supplies. If we do enough research we will find other sources that will solve our problems. Or we will find new means of efficiency that will solve our problems. And it is not that simple. Energy—the basic problem I think in dealing with the public is not only that energy is intangible, but it is our most basic natural resource. You can't use any other resource without energy. And it is also the only non-recyclable resource that we use. We can recycle all our material resources. Energy is non-recyclable. You use it, it is gone. You degrade its quality. Probably the most important thing the public should learn is the 3 laws of thermal dynamics. Unfortunately, those are rather hard to learn without a good background. And even when you simplify them it is hard to understand that.

A quick question for Dr. Bartlett, because my time is almost out. And then we will have a second round later. Dr. Bartlett, I was involved some years ago, I saw a calculation of how long our petroleum supplies would last if the entire earth consists of petroleum. And we continued to use it at our current rate and at the rate of increase of our use. I would like to see an updated number. I just simply haven't had the time to calculate it in my job. I wonder if you have run across it or if you had done that calculation?

Dr. **BARTLETT.** Thank you, sir. I used to use that in my talks. If the earth was a sphere full of petroleum and we were using it at the rate that we were using it approximately 20 years ago with no change, no growth, it would last the order of 10 to the 11th years. Which is, you know, like the geological age of the earth. But if you put it on the 7 percent annual growth curve which the earth had been on for 100 years of petroleum consumption, you are down to 350 years.

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Mr. **EHLERS.** Okay. But there have been no new calculations with the new rate of increase?

Dr. **BARTLETT.** The rate of increase now is slower so it would be correspondingly longer.

Mr. **EHLERS.** Yeah. Thank you very much. I yield back.

Chairman **BARTLETT.** Thank you. We recognize our members after gavel fall in the order of their appearance at the Committee. So now it is my pleasure to recognize Mr. Rohrabacher.

Energy Alternatives and Energy Policies

Mr. **ROHRABACHER.** Thank you, Dr. Bartlett. I come from California. And as you all know, we have a problem out in California. And is it possible that renewables alone could solve California's problem?

Dr. **VON MEIER.** Yes.

Mr. **ROHRABACHER.** Okay. Go for it. Tell me.

Dr. **VON MEIER.** Well, I think in my testimony I have included essentially the evidence that we need, which is to say that technologies are available, they work, they work reliably. The resources are available. I think really the difficulty is in figuring out what policy instruments are going to be the best to get the small investors to feel safe really getting into this market and participating. One thing that troubles me greatly about the California market is that some of the qualifying facilities under the former PURPA contracts such as wind generators and biomass generators were the ones that were lower on the priority list for getting paid. So we have in fact some renewable generation capacity sitting in California that is not being used because the companies have not gotten paid.

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Mr. **ROHRABACHER.** But we have a problem. Wind generators on a windless day. Or sun—solar generators on a day when it is cloudy and things such as that.

Dr. **VON MEIER.** Fortunately, the days when it is cloudy aren't the days when the independent system operator calls the emergencies. Because that is not when the air conditions are running.

Mr. **ROHRABACHER.** I just stopped by a technology group in my district out in Huntington Beach, California, for aerospace engineers. And they actually showed me a new idea for using wave action for the generation of electricity. And I find it fascinating that—that is that as the fall goes down this flow plunges down into some sort of liquid that has some sort of magnetic capability and it creates electricity. Well, pardon me. Yes. And do you think that there is a possibility of this—is this something that people should look at?

Mr. **COURTRIGHT.** Wave action is feasible. Again the main issue there would be looking at the cost of getting it to a competitive position. But that is actually kind of a trend on the hydro area of looking at both wave action and smaller run of river that you don't get into a damming situation of—for loads. Going back to your original question, I do think though that we do need to look at the time horizons in terms of what can the different energy sources do for any state or for the nation. And we need to look to the different planning horizons. If we try to put all the emphasis on one area for one short-term effort push, that is where we have got ourselves into trouble in the past. I think we need to look at the long-term scenario, different options. And keep a portfolio going.

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Mr. **ROHRABACHER.** But just for the record, in California, we have a supply shortage, all right.

Mr. **COURTRIGHT.** Uh-huh.

Mr. **ROHRABACHER.** And I had the governor, which—who had been governor 2 years now and we realized there was a problem coming. Even is—people who are more liberal are supposedly more inclined toward renewables. I don't think that is true because I am not a liberal and I am really open-minded toward these different methods and new ideas. But had we simply just said there is going to be a tax credit for anybody who brings on line new power, anybody who puts new solar powers on the houses, you know, solar collectors on their buildings, or anybody who puts new windmill, or whatever way you are going to bring new power into the system, even if it was the—just totally renewables, by now we would have added 10 percent new power generation. We probably could have averted it. But if we give them tax credits. Because government would have been then paying for it. But instead, we did nothing. Our state did nothing about the supply, did not offer tax credits or anything else. And so we ended up with not only no supply, but there has been about $20 billion that has evaporated from our state budget. That $20 billion alone could have created electricity and we would have had it coming out of our ears for that. So we have to have responsible policies in dealing with energy. And it can't be just wishful thinking.

One last question and I would like to get to it, if I have time, and that is, I will say one of the big problems, and it is not just a left/right thing. Because people always—on my side always tend to blame the liberal environmentalist for not giving us that supply. But, frankly, my own experience is, is that conservative Republican NIMBYs are as responsible for preventing the development of new energy supplies as are whacko environmentalists on the liberal side. And I was wondering what your thoughts are on that. Can we develop new energy sources which will take care of the NIMBY problem?

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Mr. **GELLER.** Can I make a—can I jump in and say that whichever supply source you prefer, the job of providing for our requirements, our service requirements, we don't really have energy requirements. We need heat and light and motive power in our factories and refrigeration, etcetera. It is services. And providing those services will be a lot easier if we are energy efficient in the way we use energy. There will be less need for expansion and whatever the expansion you have. Whether it is windmills or nuclear plants or fossil plants, there is a nimbi issue. And it might seem ridiculous to us. But, you know, if you live down the block or a half-a-mile away from that proposed power plant it is a very real issue. And serious issue. And so——

Mr. **ROHRABACHER.** Good point. Excellent point.

Mr. **GELLER.** I would suggest that, you know, we—in thinking about energy try to keep a broad prospective. It isn't just about supply. It's demand and supply. And the tax credits that I think do make sense at both the state and Federal level make sense for innovative energy efficient technologies as well as innovative supply technologies.

And I just wanted to add, if I can, in terms of R&D versus tax incentives, it is true that the Administration has proposed tax incentives for renewable technologies, along with the proposed budget cuts in R&D. But for energy efficiency, R&D and deployment, they have proposed cuts, period. They have not proposed in their budget and tax submittal, so far they have not proposed tax incentives for energy efficiency technologies. I sug—we have suggested and hoped that the package that the Chain and Task Force is working on will include those. But I would encourage——

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Mr. **ROHRABACHER.** You have made a very good point. And the Chair will indulge me just one investigation of that. But if you have energy efficiency improvements, shouldn't they—that in itself be an incentive for people to invest in those new types of refrigerators or new type of air conditioners or new type of whatever it is, vehicles, because they are now more energy efficient and saving money. And if they are not, why aren't they?

Mr. **GELLER.** Well, because there is just a lot of reasons. Manufacturers may not make them. They are making fine profits on the technologies that are already there. They have their existing investment. They don't want to make further investment, they don't want to take risks necessarily, there are time horizons, you know. The Wall Street pressures, they are pushing them to shorter and shorter time horizons. It is the performance next quarter, not thinking 4 or 5, 8, 10 years down the road.

Consumers, you know, are all busy. We are all preoccupied with lots of difference decisions. Your water heater conks out. Your air conditioner conks out. You don't necessarily have time to do a lot of research and figure out what is most cost effective for you. You call up a contractor and say you know, get me a water heater in here today so I can take a shower in the morning. And so there is a lot of lack information, imperfect decisions. And, therefore, there is a need for public policy.

Dr. **MONTGOMERY.** Thank you very much for your indulgence. I can't resist jumping in on this. Because I think it is real important as you—as Mr. Rohrabacher suggested, too, separate the policies from the technology. Because, I mean, we are looking at a very short-run problem in California that needs to be solved on the right time scale. In fact, gas could solve the California problem, too. I mean, this is pretty neutral. If we built gas pipe lines into California, if we built gas fired power plants, that would also deal with the problem. But Mr. Geller is also correct. We need to forget the demand side. But I think you are leaving something out. There is one very simple reason why no one in California has an incentive to use more efficient appliances to deal with the current crisis shortage. It is called price cap. It is very important. The consumer—the price is actually reflects the true scarcity of energy if we are going to have sensible decisions being made. And you can't make up for kind of bad regulatory policies with energy efficiency programs.

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Energy Policies and the Effect of Prices

Chairman **BARTLETT.** Thank you. I am just going to note an answer to Mr. Rohrabacher's question of why the market place wouldn't take care of the efficiency. I think the major reason is that electricity is too cheap, gasoline is still too cheap to really drive those efficiencies. I bought the first electric hybrid car in Maryland. One of the first ones on the east coast, the first one in Congress. I think there are now 5 congress persons who have those cars. But I will tell you, the difference between the gasoline costs for that car and the other car that I drove is not going to break the bank. I didn't buy that car because I couldn't afford the gasoline for the other car we drove. I bought it because I thought it was the right thing to do. And I think you have to be looking further than just your next paycheck, and will I be able to pay that electric bill for that gas hog in the basement. If you look beyond that, long-term, clearly, clearly, we have to go to a greater efficiency.

But for the average consumer for the incentive to do that, he has to have an incentive beyond just the market place. He needs a tax incentive or something to do that. Because the cost of energy is still too cheap.

It is a willing slave that is very, very cheap. And were you in Europe you would feel differently about the cost of gasoline for your car. Because it cost, what, about 4 times as much for a gallon over there. Three or 4 times as much as it does here. Dr. Bartlett, you had an observation. Turn you mike on. Thank you.

Electric Power System Growth in the '90s

Dr. **BARTLETT.** Sorry. In response to your question. Here are some figures for the U.S. as a whole for the decade of the 90's. Electric generating capacity grew three-quarters of 1 percent. Population grew 1.2 percent per year. That is .76 percent per year. I didn't say that correctly. Population grew 1.2 percent. And overall the national energy—electric energy consumed in the U.S. grew 2.1 percent. Now you look at those different percentages, it is very clear that they are not building plants to even to keep up with the population, let alone the growth in per capita demand.

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Now you have to look at the price of building new generating plants. And it costs the order of $1 a watt to build a new generating plant. Now that's for a coal plant. Gas, natural gas is a cheaper plant. Nuclear is more expensive. If you look at this decade of the 90's, the census figures showed that the U.S. population increased by about 37.2 million people. The average consumption of electric energy per person in the U.S. is like 1b kilowatts, which would mean that power generation 24 hours a day. If you wanted to supply 37.2 million people with 1b kilowatts of generating capacity each, the cost per year for every man, woman and child in the United States is $20 a year of just capital construction costs. That means the decade's population growth in the U.S. would require $200 for every man, woman and child in the U.S. just to build the electric plants. It wouldn't operate them, it wouldn't get the electricity to the consumers. Just operate them. And I think the growth figures in California are larger than the national average.

Renewable Energy Competitiveness

Chairman **BARTLETT.** Thank you. Before turning to Miss Jackson, my I—I would just like to comment on that $1 per watt. It costs about $5 per watt I think currently for a photovoltaics. But there is a big difference there. You don't get all of the electricity that you produce in that power plant. Because unlike gas or oil, you put a gallon or cubit foot in one end of a pipe, that's exactly how much comes out the other end of the pipe. When you put electricity in a wire, if the wire is long enough, nothing comes out the other end of the wire. And so when you have distributed electric production as you do with photovoltaic that $5 per KW suddenly becomes very competitive with the $1 per KW. And also, if you are looking at the total cost of producing it, when you have a coal-fired plant, the total cost of producing electricity is not what it costs at the plant. It is what it costs for all of the clean-up and all of the environmental damage that it does. And you have to look at a full cycle cost. And when you look at those the renewables are pretty darn competitive right now. And they are getting better as the market enlarges. Miss Jackson Lee.

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Energy Market Price Savings and Low-Income Citizens

Miss **LEE.** Thank you very much, Mr. Chairman. I thank you and the ranking member for holding this very important hearing. And to the members of the panel, I think the Committee is fairly diverse. I happen to be from Texas and hold in my district, if you will, a number of the large energy companies and have worked in the area for a number of years. And would probably be viewed as sympathetic to, of course, my constituents. And I am. But I think it is important as we discuss these issues that we do look at it globally and we look at it as it reaches all levels of our population.

I might offer my analysis on the willingness of Europeans who certainly have to deal with what they have been dealt, which is not a large opportunity of their own in-country resources. But, of course, many of their countries that pay for others of their needs, socialistic medicine and others. And so they might be more inclined to be willing to accept that high gasoline price so that they can be on the Autobahn going at 100 miles an hour. In this country we are a capitalist system. And I have to be concerned about individuals where the energy prices consume a third or more of their income. Whether or not it is air conditioning or heating, or whether or not it is trying to get back and forth to work. Just about 2 summers ago shockingly it sort of came to our attention that about 130-plus people died in the State of Texas during the very terrible heat because they could not access coolness. Either because they lived in those kinds of conditions or because they couldn't make it to somewhere that was cool. So energy is a crisis as it relates to people who are vulnerable.

And I raised the question about how we got to this point. And is it all about the all-mighty dollar. I believe consumption restraint is important. And I think that we have not made the kind of educational effort. We talk about health issues, we talk about prevention and education. We really have not waged a campaign to educate our consumers about the utilization. But what troubled me, and I hear this from my corporate constituents, is capacity and being able to have the capacity to refine the product. That the product may actually be there, but because there is not the kind of return on the investment, we are not going to do it. If any has a comment on how we break past that impasse, how do we break past an impasse that, and I think Mr. Geller, if I am pronouncing it correctly, you said Wall Street is involved. Is it not sufficient to get a 4 percent return on the dollar? I think that is something we need to be concerned about.

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The other question that I would raise is whether or not if you had to do the budget as we are debating the budget on the floor of the house now, how much would you focus on renewables, how much would you foc—how much would you allot for government participation, if you will, in renewable incentives, clean energy. For example, I think I heard the term 350 years to go. We have a lot of coal. I tend to think that you could produce energy through some technology dealing with clean coal. And so I am interested in whether or not how much you would think would be worthwhile in focusing on this energy question from the research perspective. And also how would you respond to individuals or companies that would suggest that we are not going to do any refining because we don't get any return on the dollar.

I would simply close by indicating that I am in another hearing and I apologize for having to leave. And I would ask the Chairman to be allowed to submit my statement into the record, my opening statement into the record.

[The prepared statement of Miss Sheila Jackson Lee follows:]

PREPARED STATEMENT OF CONGRESSWOMAN SHEILA JACKSON LEE

Chairman Bartlett and Ranking Member Woolsey, thank you for this opportunity to discuss what advanced technology options may be available to provide energy in the future since energy demand growth is outstripping current production and the nation faces the increasing risk of energy shortages in the future. However, I would like to make it clear that I think it is premature to discuss the limits of the fossil energy resource should not preclude the reality that fossil fuel is what drives our nation's economy.

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We must explore the potential that renewable energy technologies have to contribute to fulfilling an increasing part of the nation's energy demand and how that can occur, while increasing the economies, that can be reach through more efficient and environmentally sound extraction, transportation, and processing technologies.

The first hearing held by the Full Science Committee in the 107th Congress was on the issue of our nation's energy future. It is appropriate that this subcommittee review closely this portion of the Administration's budget, because the United States does need to develop a long-term national energy policy. Our nation's energy priorities should remain constant regardless of the changing dynamics of energy supply.

I represent residents and businesses that call the 18th Congressional District of Texas their home. Energy and energy related companies such as Reliant, Enron, Vaalco, Equilon, Motiva, Equiva Trading, Equiva Services, Edge Petroleum Company, Houston Exploration Company, Altra Corporation, and dozens of other exploration companies are the backbone of the Houston economy. For this reason, the 18th Congressional District can claim well-established energy producing companies and suppliers as well as, those engaged in renewable energy exploration and development.

I believe that the effects of rising energy prices have had and will continue to have a chilling effect on our nation's economy. Everything we as consumers eat, touch or use in our day to day lives have energy costs added into the price we pay for the good or service. Today, our society is in the midst of major sociological and technical revolutions, which will forever change the way we live and work. We are transitioning from a predominantly industrial economy to an information-centered economy. While our society has an increasingly older and longer living population the world has become increasingly smaller, integrated and interdependent.

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As with all change, current national and international transformations present both dangers and opportunities, which must be recognized and seized upon. Thus, the question arises, how do we manage these changes to protect the disadvantaged, disenfranchised and disavowed while improving their situation and destroying barriers to job creation, small business, and new markets?

The cost of doing business globally has increased because of higher oil and natural gas prices. We know that energy is a key component of economic expansion. From the beginning of the Industrial Revolution this nation has heavily depended on the fossil fuels of coal, petroleum and natural gas.

Fossil fuels and the quality of life most citizens enjoy in the United States are inseparable. The multiple uses of petroleum have made it a key component of plastics, paint, heating oil, and of course gasoline. All fossil fuels are used to produce electricity; however, our national addition to petroleum was painfully exposed in 1973 when the Organization of Petroleum Exporting Companies (OPEC) implemented an oil embargo against the United States. This event resulted in the rapid conversion of oil-fired electricity production electric plants into coal- and natural gas-fired plants.

Energy and the interconnected nature of our national and global economy is highlighted by rising oil, and gasoline prices experienced by producers and consumers over the last ten months.

This hearing will allow us to delve into what impact higher energy prices have had on our nation's economy, the viability of small, medium, and large businesses, and the quality of life of ordinary citizens. Higher energy prices have a cascade effect through out our economy. No one area is isolated or immune from the economic shocks caused by rising fuel prices.

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Recently, I read an article that appeared in the *Houston Chronicle* which related the in state travel experience of a State Representative from the Houston area who complained that he was charged an additional fee while on overnight travel in the State due to the energy crisis. His concern was that the energy crisis was not in the State of Texas, but in the State of California and thus he should not have been charged an additional fee based on an energy crisis.

The United States Postal Service has reported that for every 1 cent increase in the price of gasoline, they have an additional $5.5 million in transportation costs. Based on their national fleet of 2002 vehicles resulting they had a cost of $275 million added to the expense of their vehicle fleet for Fiscal Year 2000.

I held a fact-finding hearing in Houston, Texas on October 2 of last year to address the energy crisis and its impact on consumers and businesses in my District. I wanted to listen to what producers, suppliers, and consumers were experiencing due to the current energy crisis in our nation. I wanted to take from that discussion valuable insight that might be helpful to me in encouraging the House leadership to take up legislation that I hope will address many of their concerns.

As legislators, we must boldly define, address and find solutions to future energy problems. We know that the geological supply of fossil fuel is not infinite, but finite. We know that our nation's best reserves of fuel sources are in the forms of coal, natural gas and uranium. We know that if we do not look for and expanded on existing forms of fuel that one day—although it may be some point in the distant future—the well literally and figuratively will run dry.

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I would only caution my colleagues, administration officials, academics, industry leaders, environmental groups and consumers not to assume that we have learned all that is knowable about energy generation, but that we are still learning. We must bring to this debate a vigor and vitality that will enliven our efforts to not have a future of energy have and have nots, due to out of control energy demand with few creative minds working on the solution to this pressing problem.

During the 1970s some argued against the use of natural gas in electric utility generation, while others argued that it was necessary in order to free this nation from dependence on foreign sources of fossil fuel. In response the Congress passed the Powerplant and Industrial Fuel Use Act, which prohibited the use of natural gas in new powerplants, and the Natural Gas Policy Act, which removed vintages of natural gas from regulation.

As a result, natural gas production rose dramatically and Congress repealed the "off-gas" provisions of the Fuel Use Act, which resulted in increased use of that fossil fuel.

I look forward to hearing the testimony of the learned members of the panel offering testimony before our Subcommittee today. I thank you for your expertise and your willingness to offer comment on the issue of our nation's energy future.

Thank you.

Chairman **BARTLETT.** We have already done that at the beginning of the hearing. Thank you.

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Miss **LEE.**Thank you very much. And so I would appreciate it if as we proceed we keep in mind the vulnerable people in this country that cannot afford to pay the extremely high cost that is occurring, and make choices such as some of the new technologies that are out there. You wouldn't want to comment on the capacity question, Dr. Montgomery?

Dr. **MONTGOMERY.** Yes. I think there are several aspects to the capacity question. I think the first one is that when we find ourselves short of capacity, whether it is short of refining capacity or short of, you know, to get gasoline into the upper mid-west at the beginning of the reformulated gasoline season, or short of capacity for generating electricity in California, short of natural gas capacity to go to New England, we see price spikes. And those price spikes are very harmful to the people who have to kind of survive through the winter in the cold climates and the summer in the hot climates.

It is not expensive to produce electricity or to produce gasoline or to use natural gas when the capacity is there. We are seeing price spikes when the market finds there is a shortage and that is how the market deals with it. I think those price spikes would be very much less frequent, maybe a lot less. We would—and we would have a lot less concern about what was happening if we had adequate capacity to ensure that people didn't find these sudden price increases. Because it is not because it is expensive to generate electricity. It is because the capacity isn't there to run in order to get it to people.

Miss **LEE.** Is it not there though, Dr. Montgomery, because the companies themselves have put a cap on it. They say, I am not going to. I have got older equipment and I am not going to invest in it because my return is low. Don't they have an obligation. You look at the profits in the first quarter of some of our majors who I am certainly gratified that they are putting energy into the economy. But the point is, is that they don't seem to be suffering. And why can't they invest in providing for capacity even if the return is only 4 percent?

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And I know that we could go on and on in this, but I am very concerned about that. And I guess the other question I would like to have answered, anybody want to take a stab at what we should put in the budget to help with renewables? I would appreciate it very much. Were you——

Mr. **GELLER.** Yes. I was going to jump in on the budget question. I had suggested in my testimony, a 20 percent increase in the energy efficiency program, which is, you know, relatively modest considering the broad scope of those programs. This is everything from grants to weatherizing low income households to R&D on very, you know, innovative new material technology, new engine technology, building technology, industrial technology. It is a broad range.

I think the renewable energy programs are relatively modest. They are something like $300 million a year covering a lot of different technologies as well, from solar thermal, solar PV, wind, geothermal, bio-energy, bio-fuels, bio-power. And they deserve a substantial increase. They were cut pretty deeply back in the mid-90's. And given the potential for those technologies, the booming world market. The U.S. producers of the technologies are selling more to Europe and developing countries than they are, you know, in this country.

There is a world, tremendous world market. And if we don't support our manufacturers in this public/private partnerships to develop the technology, the leaders now and in the future are going to be foreign companies and, you know, and not U.S. companies. And so I think a 50 percent increase could be warranted in the renewable energy budget. And I think also given our serious energy problems, some increase in the fossil energy program, R&D programs. I think the administration has proposed cuts in the natural gas area which I think are a mistake as well.

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And all energy technology needs support now, and particularly efficiency and renewables.

Miss **LEE.** Dr. von Meier.

Dr. **VON MEIER.** Thank you. Well, a brief comment I think about—and I don't have any numbers for you. But I think a way to think about what would be an appropriate level at which to support renewable energy technologies would be to take a really honest look at the implicit and explicit ways in which fossil fuels are being subsidized currently.

And which includes things like leases for oil drilling and all sorts of other things. And once you had took an honest look at that and added up those dollars, if an equivalent amount were expended on efficiency and renewables that is where you would have the level playing field. So you would want to work upward from that to encourage what is really a social benefit of investing more in renewables.

Miss **LEE.** I think that's a good approach. I thank you very much. Thank you very much, Mr. Chairman, for you indulgence. Thank you.

Chairman **BARTLETT.** Thank you. Miss Lofgren.

The California Situation and the Potential for Fusion Energy

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Miss **LOFGREN.** Thank you, Mr. Chairman for holding this hearing. And clearly we have a major energy problem on our hands. And those of us in California are face to face with the reality right now. And as I have listened and reviewed the testimony, there is not any one answer. There is no magic bullet that is going to solve it. But clearly the renewables is a portion of it, greater efficiency is a portion of it. The market itself is in chaos in California. We were—the California delegation was meeting with the speaker of the assembly yesterday and he pointed out that the cost to transmit natural gas over the same pipeline as last year has risen 2,000 percent. It is just a stunning chaotic market.

And so I think as we look-struggle together with the governor and the legislature and the California delegation which has met on a bipartisan basis on several occasions, there is some things that we need to do immediately, some things that we need to do in the near term, and then some things we need to do on the long term so that we can get ahead of this. And we have got 9 power plants under construction in the state right now. We have got 14 others that have already been approved and are going to be built. That is great. But I personally believe that one of the things that we need to do as a country is to invest in the science of fusion research to see if 50 years from now we will have answer that dilemma and not be persistently facing this problem. And working with the fusion scientists across the country, their estimate is that to get—and also the National Academy of Sciences, to get a plasma burn that would cost less than California, the State of California spent on energy in the month of February this year. So if we want to put it in that perspective, that would be the home run that would really solve a lot of these problems.

But before closing, I just want to raise an issue that I don't think has been covered. And that is the price of gasoline in California, which is now over $2 a gallon for regular, and going up. Tomorrow, I understand, the Environmental Protection Agency is going to give an answer to the State of California for our proposed and requested waiver of MTBE as a additive, which has really skewed the market for gasoline in California, and disrupted the ability to—for supply to meet demand.

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Do any of you have a viewpoint on that issue and whether or not EPA should come to California's rescue on that MTBE issue?

Dr. **MONTGOMERY.** I have been doing some work on MTBE. I think that there is no question that the California's RFD regulations have a great deal to do with the price gasoline in California. I think the real issue is what to do about it. Because I am not sure that the MTBE waiver is actually going to help much with the cost of gasoline. Because the real issue—I mean, the problem is, it is very much more expensive to satisfy the carb regulations with any fuel that does not contain MTBE.

The best option without the waiver is ethanol. And that is very expensive. The best option with the waiver is acolytes. They are a very high cost, high value component of gasoline basically that goes into normally producing aviation gasoline and premium gasoline. You would have to divert that. All the studies I have seen, including those done by the California Energy Commission looking at Feinstein, Bill Gray and things like that suggest that it doesn't make much difference whether you have the waiver or not. The real issue that it is very expensive to replace MTBE no matter how you do it.

Miss **LOFGREN.** Yes?

Miss **VON MEIER.** A general comment about the gasoline prices. It hurts to say this, but I think that higher gasoline prices are necessary and are a good thing. Because it sends the right price signal as to the actual cost, including environmental costs, resource depletion costs that are entailed in consuming gasoline. The great tragedy is that it works—an increase in gasoline price works like a regressive tax in that it affects people of low income more. So I think this is an area where in fact it is appropriate for government to step in and equalize that impact.

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Miss **LOFGREN.** If I may, and I know my time is up. It appears to me that although the in a perfect market the increase in gas would certainly decrease demand or go to efficiencies. Because we have taken, I guess, I think the wrong tact in terms of energy research in this country, we have a situation where a lot of people don't have alternatives. We have got people living in Modesto commuting to San Jose to work every day. And there is no way to take public transit and there is not way to get to work otherwise. So thank you, Mr. Chairman. I realize my time is up.

New Technologies Spurred by High Energy Prices

Chairman **BARTLETT.** Thank you very much. Dr. von Meier, you made the observation I was going to make. When I said that the energy prices were not high enough, what I meant was they were not high enough to drive the market, which is exactly the point you made.

If we wait for the market place to move us to new technologies, this becomes, as you very appropriately stated, a very regressive hidden tax that hurts the weakest in our society. You know, the guy making $150,000 a year can pay another $1 a gallon for gasoline. The minimum wage worker clearly cannot. So this—I think it is the responsibility of government to protect those weakest in our society from the forces of the market place. If we wait for the market place to drive these technologies, the cost of energy is going to have to go up a lot, which is going to be very hurtful to those at the bottom of the—of the—of our economy.

One of the purposes of this hearing was to determine where we were in terms of what we have used in oil and gas and coal and what is out there yet. Let me just ask the panel, from a paper produced by the United Nations I got the data that we have about 1,000 giga-barrels of oil reserves, known reserves in the world, and about 2 percent of that. And Dr. Weedman, that conforms very well with your 20 measured or proven reserves that you have in your table. That would be 2 percent of 1,000. Is there general consensus on the panel that this 1,000 giga-barrels is about the proven reserves in the world? That is the generally accepted value? I see Dr. Bartlett shaking his head in assent? All of you in the panel agree that that is about what the proven reserves are in the world, about 1,000 giga-barrels?

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Fossil Fuels Reserves

Dr. **MONTGOMERY.** Just one technical comment. I am not sure it is proven reserves. Because usually proven reserves means you have drilled it up, you know exactly where it is. I suspect it is resources. But rather than reserves.

Dr. **BARTLETT.** I think you are right.

Chairman **BARTLETT.** What is the term you prefer to use?

Dr. **MONTGOMERY.** Resources. Because those are what we think are there but we haven't actually put the holes in the ground to determine exactly where they are. Just curious.

Chairman **BARTLETT.** Now the numbers that I saw in this same report that if you make some assumptions about what might be there that you haven't found yet, can you make those assumptions in the 95 percent level of confidence that you will find it, or a 50 percent level of confidence that you will find, or be wildly optimistic and a 5 percent level of confidence that you will find it. That that went up and they gave those figures in terms of giga-ton, and 150 giga-tons is about 1,000 giga-barrels. And the known reserves, they said, were 150 giga-tons. And if you were wildly optimistic it might be as much as 295 giga-tons. In other words, there was a—nearly as much out there that we haven't found that we might find if we have this 5 percent level of confidence, which is wildly optimistic about what you will find in the future. Is there general agreement on the panel that this U.N. report has it about right? I noticed, Dr. Weedman, in your assessment of what is in this country that the proven reserves are only 20 out of that 1,000 worldwide giga-barrels. That you note that we have probably 112. But about half of that is anticipated reserve growth. What is that and does it include the oil shales and oil sands and that sort of thing?

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Dr. **WEEDMAN.** No. Reserve growth is the increase in reserves that we expect to be reported in existing fields over the next 20 or 30 years. The reserve growth phenomenon is really poorly understood, but very important when we look ahead to see how much oil we are going to have. Basically, what happens is when a reservoir is discovered and a company reports reserves, they tend to report a very conservative number. If you check back with them 5 years later that number is bigger. The reserves have not grown, but there is discovered more in the same place.

Chairman **BARTLETT.** Oh, okay.

Dr. **WEEDMAN.** We are basically running on reserve growth in this country right now. Another factor is technology. As we develop horizontal drilling, hydra-fraction, various secondary recovery techniques, we can get more oil out of known fields. And that is why that is such an important quantity.

Chairman **BARTLETT.** I noted that in the past we have underestimated the reserves that were there. And so now we have simply increased the projection of what will be there as a result of our historical experience with under estimating in the past. And the assumption is that we are now under estimating also. So if the present is like the past, then we are making the same mistakes we made then. And so we can with some confidence say, well, geez, there is a whole lot more there than we thought was there. That may or may not be true, of course.

Dr. **WEEDMAN.** Well, that's our observation. But obviously it can't go on forever. So it is the—the petroleum industry tends to be fairly optimistic because that is their observation. They tend to always have more than they thought they had. We try to quantify that to give it some limits, to give it a reasonable value. And that is why we report what reserve growth is.

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Chairman **BARTLETT.** I would like to for just a moment, and then I will move on to my ranking member. I would like to put in perspective this 1,000 giga-barrels. In this country we use, and this is a whisker on the high side by not much, but it makes my arithmetic easy, we use about 20 million barrels of oil a day. And that is about a fourth of what the world uses. And they use about 80 million barrels a day. So if we multiply that by roughly 400 days in a year, again to keep my math simple, that is about 32 giga-barrels per year. And if we have about 1,000 giga-barrels of known reserves, those known reserves would last about 30 years, more or less. Now we are growing at 2 percent a year. And so in 35 years we are using twice as much oil as we are now. And so if we have as much in the ground yet to be found as compared to what we found now, that 30 years is probably about the life expectancy.

I have used up my time. We come again to my turn in the cycle. I would invite you to comment on that arithmetic. It seems pretty simple to me. And the point is that oil is not forever. If it is at 30 years or 50 years or 100 years, whatever it is, it is not forever. Dr. von Meier, and then I will move to my ranking member.

Global Warming and Air Quality Issues

Dr. **VON MEIER.** Well, I would like to say that I think the most pressing problem with oil is actually no how much is in the ground. But it is how much of that carbon is in the atmosphere. I think that even on the time hori—on the relatively short time horizon that you mentioned in terms of decades of oil supply, that the impact of global climate change will become felt sooner than that. And that that will be in fact a more compelling reason to stop using fossil fuels than the fact that the resource is running out.

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Chairman **BARTLETT.** When we come to Mr. Rohrabacher again he may have a question on global climate change. Let me turn now to my ranking member.

Miss **WOOLSEY.** Well, I would like to make a couple of comments that our congressman from California, Rohrabacher, brought to the front of my thinking. And be prepared, he doesn't believe in golden —global warming. So just get positioned here.

You did say that you didn't think that California was really particularly good at conserving. You know that we are 48th or 49th out of 50 in consumption of our resources. Meaning good, not bad. I mean, we aren't using more, we are using less per capita. I mean, it is—I was really amazed when we started through our energy crisis. And you also, Dana, mentioned that probably we could have done better and maybe prevented the blackouts, rolling blackouts. Absolutely.

It is my understanding that if California had been held to the standards of conservation and alternatives energies that had been put in place in the early 90's, or even in the middle 70's to 90's, and not dropped in the 90's, we would have prevented these blackouts. I mean, not indefinitely. But it would have made a huge difference.

One other thing I want to point—remind people is the price cap on retail came to Governor Wilson and it was inherited by Governor Davis and caused a huge problem.

I have a question and it is kind of getting to the finite. But, Dr. von Meier, when did we stop having windows open in buildings? What affect has that had? And I think, Dr. Bartlett, you probably answered this —you all probably know the answers to this. And can we go back? I mean, has it been positive? I mean, all these closed systems in buildings?

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Dr. **VON MEIER.** Well, I think it really does come to a question of culture and a question of our values. And whether it is that important to us to live in a world where we don't have to think about energy, or whether using energy wisely can be part of what we do and what brings us value in our culture.

Miss **WOOLSEY.** Does anybody want to respond to that? I mean, can we go—I have a window that opens in my office in the Rayburn Building. I had them put that window in. I can't live without air. Well, who can, you know.

Dr. **BARTLETT.** It is a very interesting problem in building cooling—heating and cooling systems. A situation in our university, a large lecture hall when it is crowded the temperature gradually rises. This can be in the wintertime when there is an infinite supply of cold air outside and they can't get at that cold air because of the way the system was designed to keep it cool. So this is related to your window question. But it is in terms of building systems. And I think we need to look at these building systems so that we can take advantage of the free, cold air that is outside in the winter and to reduce the energy bills. But your point is a good one.

Miss **WOOLSEY.** Thank you. Dr. Montgomery?

Dr. **MONTGOMERY.** I think there is actually—you are getting at a very general point in kind of thinking about how we evaluate and study energy conservation programs. And be this—I mean, policies, regulations, tax incentives, subsidies. It is a huge debate. And sometimes we call it the bottom-up versus top-down debate, or the engineers versus the economists.

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But we have on one side a set of studies that I would classify as being done by engineers that would say, there are dollar bills setting on the sidewalk everywhere. That it is very cheap to conserve energy and people are doing it. The economists say, but people aren't doing it. And they are smart and there is something that is going—and they know what they are doing. And there is something that is going on that is being missed by the engineering study.

I think what you are getting at is an example of what I would call hidden costs. That is that there are thing that people really care about that are not incorporated in the calculations of what it costs to save energy and how much energy you save. Not now a diagnosis of everything but just something I think it is very important to try to look at and question in kind of evaluating this whole field. Are there some hidden costs that are being left out that are like closing buildings and, you know, do people care about having fresh air.

Miss **WOOLSEY.** Okay. Thank you very much. I will yield.

Chairman **BARTLETT.** We will be back for another round. Talking about air conditioning, now I think probably the most harmful thing that technology has done to our country is when it air conditioned Washington so that the Congress could stay here during the summer. Mr. Rohrabacher?

Mr. **ROHRABACHER.** I have to be very quick. Let me just say that you don't have to believe in global warming to believe that we should have clean air. And because we can be concerned about the health of our citizens and the health of people who live in urban areas throughout the world without having to believe in this poppycock, global warming theory that has—every—you know, just last week the Canadians released a report saying that this—all this, you know, the sky is falling about the melting ice caps is all bologna. And that they have done another analysis of the ice caps and after all, there are as thick as they have ever been. And every time—I have had people sneak into my office who were Federal Government—heads of Federal Government agencies to tell me that, well, we can't say this publicly, but it is all—all the figures are nuts. They have taken the temperatures without any reference to cloud cover. They have taken it—all the temperatures around the world without references to the temperature of the ocean, which of course, covers two-thirds of the world. Anyway, we can discuss global warming some other time.

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But the fact is, you don't have to believe in that to want to bring down CO levels that are going into the air because people breathing in this stuff is not good for them. And it is not good for us. It is not healthy for us. In Southern California we know that. And Southern California, let me say that we have had a major—and due to Federal regulations, I will give you that, we have had a major step forward. When I was a kid we could—told that you could not go out and exercise once or twice a week. You could not exercise, the air pollution was too bad. Now al—you know, rarely have those kind of warnings.

Now my colleague from California mentioned fusion. Let me just say, I don't think the panel would agree with her on fusion. When I was chairman of this subcommittee, I tried to cut fusion research because I found that it had sucked up so much money—we spent so much money on fusion that we haven't spent it on other things. And is that—I know there are some people that would disagree with me on that. But I am sure that the renewable people would agree with me on that.

So with that said, Mr. Chairman, I appreciate you holding this hearing. And I actually have to run off to meet with Dan Golden on a very important energy issue right now. So thank you very much. And if anybody would like to see about this wave action theory, there is also a coal—clean coal electricity theory in here as well. And I will leave this for those who would like to see that. And the name of the company is right here. They are incredibly geniuses and decided they would, you know, instead of making rockets and things that explode as they did during the Cold War, they would use their genius to creating things that are better to human kind. And that is a great thing about the Cold War being over. We can use the genius of our people to build clean energy systems, where before those geniuses were being used to shield us from sort of attack from the Soviet Union.

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So with that, thank you very much, Mr. Chairman. And I will leave these for you folks.

Chairman **BARTLETT.** Thank you very much. Now, Mr. Ehlers.

Mr. **EHLERS.** Thank you, Mr. Chairman. And I apologize for popping in and out. We have a mark-up going on in the Education Committee and I have another meeting going on as well. So I just wanted to give others—I made somewhat of a speech the previous time. And only Dr. Montgomery had time to respond. I would like to give anyone else a chance if they want to respond to that. We talked about time horizon, what—but I am really interested now in getting more than just that. And that is, what—where do we go from here in the really long-term picture? And I am talking on that scale, 30 to 40 years planning. If we were developing an energy plan right now in this room of where we should be in 40 years, what would be looking for? And I would appreciate some comments. Yes, Mr. Courtright.

Mr. **COURTRIGHT.** We had developed a road map out looking at 50 years out and some of the options that should be considered. And I think the main point that was in there is that there is a fairly long transition time on the infrastructure for energy. And sometimes 2, 3, 4 decades until you move from one major component and source to another. And so to, I think looking out that we need to look at those long cycles and work on technologies that will be available 20, 30 years out now. Renewables would be one, to be able to increase our renewable supply. Be able to transition our coal capacity from today's technology to an entirely new, clean generation. To be able to transition our nuclear industry to a more modern, safer design reactor. And to be basically work all those options. Because you don't know which ones will work out well and which crises will come out well.

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So I think that the thing we have been recommending is a portfolio and looking at a longer term horizon that you are going to need 2 or 3 decades to move substantial changes in our energy infrastructure. But to plan on that type of cycle.

Mr. **EHLERS.** Since you are from EPRI, let me ask you two questions. One is what is the role of micropower going to be in the future? And I recognize that is not a new source but it certainly changes the distribution requirements.

Mr. **COURTRIGHT.** Yeah. We think the one project I mentioned that we are working on the CEIDS, the new infrastructure, to basically support a change in energy infrastructure. We think there is going to be a significant amount of distributed generation coming into the system that today's system is not designed to handle that. It needs to be modified to be able to handle that for both the benefit of the consumers and for the whole system stability. And that is actually one of the projects we are trying to get growing so that people can understand that, anticipate the needs and start making the technology changes that we need to accept micro-generation, distributed generation in possibly significant quantifies.

Fusion Energy

Mr. **EHLERS.** And when—in your list of things you mentioned you didn't—I didn't catch you saying anything about fusion. Do you see that anywhere on the horizon?

Mr. **COURTRIGHT.** Well, I am not a fusion expert so I really can't comment on that. But I think that is a longer term issue. A lot of people have looked at that. I won't discount it as an option for the long term. But I think it is a number of decades out as a possibility to work. And that we need to deal with probably more in the 20, 30 year horizon of possibilities.

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Mr. **EHLERS.** Okay. And, Dr. von Meier, I see your hand up. But I want to ask you a question, too. At the same time I will hear your comments. I noticed in your—you commented about avoiding the use of—large scale use of nuclear energy. And my question on that is, don't you think we are at the point now we have to worry more about CO emissions than we do about nuclear waste? So you can make your comment and answer that question at the same time.

Dr. **VON MEIER.** Well, I absolutely agree with you. I don't think in fact that the nuclear waste is the biggest problem. I think that nuclear energy simply is not going to be cheaper than solar, wind and other renewable alternatives. And based on that, because of its inherent complexity and because the uncertainty bars on what the price is going to be, those—that uncertainty is higher with nuclear energy than it is with the renewables where you have a capital cost up front and that is what it is going to cost you.

I think from that point of view, the renewables are simply a wiser investment. And the resource that is available, if you look at large areas of the southwestern United States for solar generation, and if you look at the mid-western plain states for wind generation, there really—I mean, there is enough land area available that we could generate in theory. You wouldn't actually do this, but in theory 100 percent of the electricity that we use today in the United States we could do with either solar or wind.

Now in practice, I think the system that we would want to move to is diversified portfolio of different renewable resources. I think to answer the previous question, the first thing to do is to dramatically increase our efficiency. I believe it is technically quite feasible to cut our energy use in half by using efficiency alone without compromising comfort or our level of general well-being, or our level of services that are being provided. I think as fossil fuels, fossil fuel power generation is transitioned out that can be replaced with renewable generation.

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To the extent that we feel that we need to maintain some fossil fuel generation, I think that should be exclusively natural gas. Because coal per unit energy has that much more CO emissions.

Mr. **EHLERS.** Just two quick comments. First of all, I have always disliked the term renewables because it is not really accurate. It is all solar energy whether you are talking about wind, solar shingles, biomass, it is all solar energy. Different ways of using solar energy. And even fossil fuels, of course, are stored solar energy.

The—yes.

Dr. **VON MEIER.** Yes. If I might add, one thing to answer the question about fusion, I think one thing to keep in mind is that fusion also is not—is actually not a zero producer of radioactive materials. You do produce radioactive tritium, which biologically is in some sense more of a concern than some other radio-nuclides that come from fission. So it is also a technology that intrinsically is complicated and that has an infrastructure requirement around it. You can't do it piece-meal in the way that you can without worrying too much about it. Have a competitive market, do piece-meal installations of different solar technologies.

Mr. **EHLERS.** Yeah. I am not too worried about tritium. It has a very short half-life compared to fission products. But you are quite right. It is a very complex system. And I think the only way it would work is to have very, very large systems. And probably electrolyzing water piping hydrogen and oxygen to shore. Have it off shore somewhere.

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Mr. Chairman, I have exceeded my time limit. I apologize.

Coal Reserves

Chairman **BARTLETT.** There will be another round. Let me ask a question or 2 about the reserves of fossil fuels that we have. Dr. Bartlett, I read and hear people saying that have like 500 years of coal reserves in this country. So what is to worry. Could you comment on that?

Dr. **BARTLETT.** That figure came from a report to the United States Senate some years ago when Henry Jackson was—the Honorable Henry Jackson was the Chairman of an energy committee. And in that report it says, at present rates of consumption we have enough coal in America to last 500 years. If you then look at the numbers from the Department of Energy, what are the tons estimates to be available. And then you take the factor that it may be 50 percent recovery. You can't use 100 percent of the coal. And then if you look at it at zero growth, and that is what is meant by that preceding statement of saying, at present rates of consumption, zero growth. Then you could—that number yields something like 500 years if you have 100 percent of the resource. But if you say that the best we can do is 50 percent, then you get 250 years. And if you put it on something like 2.86 percent per year, which was the rate of growth of coal production from 1971 to 1991, a 20 year period, it average 2.86 percent, then you are down to about something like 70 years of coal.

And so it is very common for people to say such and such a resource will last so long at this rate of production. And that may be totally correct. But it is often interpreted to mean, oh, well, we don't have to worry for 500 years. And I think that is a very unfortunate interpretation of these common expressions of how long resources will last.

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And now I have seen some recent reports out of the State of Virginia and Kentucky where it indicates that the big Appalachian coal reserves there, they estimate it may be 20 to 30 years, something, that production is already declining there. And I raise the question, what fraction of the electricity that we consume here in the east coast comes from those coal fields. And I don't know that fraction. But if you have declining production in these giant coal fields that have been the mainstay of our electric industry in the east, then that is a cause for serious concern.

Chairman **BARTLETT.** Thank you very much. I wanted to explore that because there is a feeling among many people that even if oil and gas are limited in supply that we are really home free, because coal is not. And we will get smarter and we will know how to clean it up so that we can use it. And we don't need to worry for probably 500 years.

But as you point out, we are now down—and I read that same report that you read that—where they are projecting 20, 30 years of remaining coal in Appalachia. And just using the figures, the optimistic figures, you are down to like 70 years from that 500 years if you look at what you can really recover and if you look at any reasonable growth rate. And by the way, that growth rate that you had does not assume that we are going to have to use increasing percentages of coal because we are running out of gas and oil. So if you do that, why then the coal reserves shrink well below that, well below that 70 years.

Potential of Solar Power

Chairman **BARTLETT.** [continuing] What percent of our rooftops in this country would we need to cover with photovoltaics to meet our total electric demand? Do some of you have those numbers?

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Dr. **VON MEIER.** Well, on the—with the roof tops, I mean, you can work on the back of the envelope calculation from the bottom up really thinking about the individual buildings. And we are going to supply that electricity demand nationally, if each building could supply its own in effect, you know, imagining sort of a zero flow on average of electricity through the transmission.

Many buildings do in fact have the roof space to produce enough electricity for their own need. Now many of those buildings are not in a climate where photovoltaics would be the most logical approach. But in terms of the order of magnitude of what existing space is, particularly parking lots can be covered with car ports that have photovoltaics over them. So I don't think that there is an area constraint. It is a cost constraint.

Chairman **BARTLETT.** But the cost is currently about $5 per watt installed cost. Which is as we mentioned compares reasonably favorably with new power plants at $1 when you consider that you don't get all of that electricity because of line loss. And when you consider the environmental costs of a coal-fired power plant for instance.

Dr. **VON MEIER.** I think so. I think the problem is that those—the $4 per watt difference that we—that you are accounting for the distributed benefits or other benefits, the problem is those benefits don't have a way of finding their way into the market to appear as incentives. For example, back in 1989 I was working for PG&E on a project to analyze the benefits to the utility distribution system of distributed photovoltaics on the secondary, the customer side of transformers. And they found that for them financially it might be very worthwhile to consider photovoltaics as an alternative to expensive capital investments and upgrading their T&D, transmission distribution.

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Now in the current market situation there is not a single actor who has the correct incentive to trade off those costs and benefits.

Chairman **BARTLETT.** I note that a few years ago Saudi Arabia was the biggest user of photovoltaics for a couple of reasons. One, they have a lot of sunshine, obviously. But the other reason was that they have small communities widely distributed. And it just wasn't economically feasible to transmit power from a large generating plant over the many miles of wire. And so they had a real incentive to go to distributed production of electricity.

If it—it is obviously good for them. It is not so obviously good for us until you look at the numbers. When you start looking at line loss, it then becomes obviously about as good for us as it does them. Yes.

Let me turn now to my ranking member.

Research and Development Policies

Miss **WOOLSEY.** I promise, this is my last round. I can't help but wish that we could equal the amount we invest in renewables, Mr. Ehlers, and smart energy and conservation and efficiency that we do in fossil fuels and in clean coal. Hundreds of millions of dollars that we are investing so we can have 70 years of coal for energy. So all right, now—but I do have a question. I just needed to say that.

Dr. Geller, in your testimony and in your written testimony you recommend that we expand rather than cut the DOE Energy Efficiency Program. In your opinion, which programs offer the potential for achieving the greatest benefit to the public, and which ones offer the greatest benefit for the least expenditure for the Federal Government, if you have any examples. And anybody that wants to answer this I would appreciate it.

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Mr. **GELLER.** That is a good question and a tough question to compare across program.

We really have, you know, a lot of different programs. We are really not putting all our eggs in one basket. It is not a really large effort like the fusion program is, you know, 50, 100, hundreds of millions of dollars per year in particular technologies and particular laboratories. The efficiency programs are very diverse. Distributed to kinds of, you know, $5 million effort on energy efficient lighting, $4 million on energy efficient windows. There is partnerships with the steel industry, aluminum industry, chemicals industry, paper industry. Likewise, you know, in transportation. There is work on lots of different technologies. And not all of those projects pan out, they don't all pay off. But a significant fraction has. And I believe will continue to pay off in the future with proper support and with consistent support.

You can't just sort of turn on, turn off, you know, increase rapidly and then, you know, cut 25 percent. You know, you lose the partnership, you lose the infrastructure, the scientists that are working in these areas. And that is a fear I have if you say, okay, let's shift some R&D for a while to tax incentives. And, well, maybe tax incentives work, maybe they don't, and you want to turn back on the R&D, you know. But all the scientists in the room know what problems that creates.

And so we need consistency. The time scale for energy efficiency can be fairly long, too, if you think about the time scale from research on technology, developing proto-types, testing them in the field, bringing them to the market, working with the early adopters, getting beyond the early adopters to getting them, you know, widely accepted in the market place. And then turning over the stock of light, of appliances, of vehicles, of steel mills. You know, we are talking about decades, literally decades. You know, potentially 50 years from invention of an energy efficient device to full use in all the potential applications.

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And I think it is important to support these technologies consistently. And a combination, a spectrum of R&D support, deployment and promotion support, education, incentives, carrots and sticks, you know, as well as education and R&D incentives to help get them established in the market place. And eventually, standards to make them the norm in the market place. And that is worked. California was a pioneer in, you know, in appliance standards, in good building codes. And then we went national and we have done tremendous things there. The typical new refrigerator uses one-third as much electricity as the typical new refrigerator 25 years ago. It is bigger today and it has more features.

And it is a combination of R&D support, public/private partnerships to develop the new energy efficient refrigerators. Incentives from utilities and other parties to help get them started in the market place. And then standards to make them the norm so that everybody doesn't have to be a Ph.D. economist to evaluate what is optimal life cycle costs and—just make it the norm. And California did it first and now we are doing it with Federal standards. We need to keep doing that on other products and keep upgrading those standards as they become outdated. This July, the third round of standards on refrigerators will take effect, national efficiency standards.

So I didn't really answer your question. I'm sorry. But we should be doing it all and doing more to promote energy efficiency, R&D education——

Miss **WOOLSEY.** Actually, what you said to me is not black and white.

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Mr. **GELLER.** Thank you.

Miss **WOOLSEY.** Mr. Chairman, do we have time?

Chairman **BARTLETT.** Yes, of course.

Miss **WOOLSEY.** I see other interested hands. We will start with Dr. Bartlett and go down.

Dr. **BARTLETT.** I think a few minutes ago I heard something about the possibility that 20 percent increase in the fuel efficiency vehicles to be achieved over 20 years. That is about 1 percent improvement per year. And I think it would be a national achievement of great significance if we could make our overall economy improve in the efficiency of use by 1 percent per year. But if you got 1 percent population growth per year, you are just standing still and you are not gaining on the overall consumption of energy.

In response to your question, I think that we ought to have stable research support. And this has just been mentioned. It is so important that a program that can be continued and planned for. There should be clear goals for the program.

And I think a program that hasn't been much mentioned that needs to support, and that is, the development of hydrogen production from solar energy. Because I suspect that as fossil fuels decline in availability that we will see a move toward hydrogen. There is significant research going on on hydrogen. But it is not clear yet what is the best way to produce it, what is the best way to transmit it, what is the best way to store it. And can it be used, for instance, in vehicles. There is no known real substitute for gasoline, liquid petroleum in vehicles. And hydrogen has the potential.

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But it needs a lot of work. And I would recommend very strong support for the development of hydrogen as a possi—and that is a long-term thing. But it has to be hydrogen from solar energy. If you make hydrogen from fossil fuels you are not getting ahead.

Dr. **MONTGOMERY.** I would like to make a really radical proposal. I think if we really do focus on the long term and think about this use of power, how can policy makers make transitions to another energy source work better. What we really can do—we have to guess, you know, policy makers and their advisors, about where the market is going to be going. But we don't have to look—but we can't be prescient. I mean, right. We can't even tell whether future's prices are going in the right direction. We don't know what the market—what is going to be available 50 years from now.

I think the process of research is one where we want to buy as much information as possible today with our research dollars so we can move ahead as fast as possible to finding new solutions. And there are a couple of things I think come from that.

The first one is, don't let one thing take the whole budget. Because then you are going to foregoing learning about everything else that you could have had in there.

And the second one is, Howard described what I call the continuum from basic research, applied research, development, demonstration, commercialization. I would say, where the money ought to go is as early as possible in that process.

Commercialization, money for commercialization, tax incentives for adoption only work with what we know how to do today. And they don't give us anything new. So I actually think the way you—how I understand what the Administration is proposing it is a very big mistake. Tax incentives don't substitute for supporting the basic research on a broad variety of fronts. I think—and unfortunately, I think probably that means that most of what DOE is doing is not worthwhile. Off of energy research. Basic science is probably where we are going to learn the most about where these new technologies are going to.

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Basic Research

Chairman **BARTLETT.** Thank you. I just wanted to reiterate what I said earlier and, that is, that I think we are spending far too little on basic research. That really is the seed corn for the future. I have a concern for the short-term that we will not remain the world's dominate economic power unless we increase our basic research.

In the long-term I have a concern that we will not be the world's military superpower if we do not invest more in basic research and in education of the professionals in those areas. We will not forever have the best military if we do not turn out the best scientists, mathematicians and engineers in adequate numbers. And are not now doing that.

I think that one of the best ways, and I would like to talk about this when my turn comes to being recognized. It is Dr. Ehler's now. Of supporting R&D is to give tax credits to people that I think are wiser than I and wiser than government bureaucrats. And that is the private sector out there that is involved in this. So when I say that I am supportive of tax credits rather than direct government subsidy of R&D, it is because I believe that the best judgments about where to spend that money are not going to be made here in this committee or in some government agency. It is going to be made out in the private sector. Dr. Ehlers.

Mr. **EHLERS.** Thank you, Mr. Chairman. Just some wrap-up comments. I expressed in my first comments my frustration at 30 years of work in this field and the lack of public interest, acknowledgment, awareness. And I would offer as proof of that the empty chairs in this room. This issue is going to affect people more directly than almost anything under discussion in this building today. And yet the public is not aware of it and, in fact, not interested.

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We clearly have to change that in some way. And it seems the only way we can do it is by increasing prices. But then the anger is directed at us, at the price gougers as they are referred to, everyone else involved. And without looking in the mirror and seeing the responsible party.

So we have a lot of work cut out for us. It is not a matter of just doing research, it is not a matter of sitting here and discussing the problems and developing long-term plans. We have to in some more direct way involve the public. And I certainly will hope to spend more of my time in that of the precious little time I have. And I hope you will all join me in that. It is just absolutely essential that we do that if we are serious about engaging in this problem and not just coasting along until it is a crisis. With that cheery note, Mr. Chairman, I yield back.

Chairman **BARTLETT.** Thank you very much, and thank you for being on this subcommittee and for your commitment to this area.

What I would like to do before we adjourn this subcommittee is to join with my ranking members in a dialogue with you and a dialogue among you as to where we are and what we learned.

First of all, let me ask you, it was our goal to have a spectrum of witnesses that covered the field of those who felt that we never needed to worry about fossil fuels, because the Lord in his wisdom new how profligate we would be in our use of fossil fuels. And hid as much here as we would ever need. And our only challenge is to go out and find it. And those who believe that those reserves are finite. Do we have a fair cross section of witnesses here in our committee?

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Dr. **MONTGOMERY.** I think there are probably more extreme believers in the kind of the generosity of the Divine Providence than you have on this panel. Generally, anywhere that Howard and I are sitting has about as—how covered just about the full range. But I really think there are people who are even—who are more—much more extreme in their views that we are never going to run out of anything than those of us are.

Consensus on Reserves

Chairman **BARTLETT.** Well, we kind of failed then in getting a really broad cross section of the committee. We will keep that in mind as we formulate our policy.

I gather that there is little disagreement among you as to the general assessment of how much of fossil fuels remain. And is the—we talked more about oil because I think we have done more exploring for oil and it has been a bigger factor in our economy. Natural gas is coming up now. But the general feeling is that there is roughly 1,000 giga-barrels remaining of known reserves. And a price or—that much more or so in reserves that we don't now know are there but we reasonably expect, or we sort of expect we can find.

Those are reasonable assumptions. I see heads shaking.

Dr. **WEEDMAN.** I would——

Chairman **BARTLETT.** Yes, Dr. Weedman.

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Dr. **WEEDMAN.** I would like to try to answer. I was a little thrown by the unit giga-barrel. I don't usually think in those units. But I think we are about the same. And we would like——

Chairman **BARTLETT.** A giga-barrel is a billion barrels, I think.

Dr. **WEEDMAN.** Right. I know.

Chairman **BARTLETT.** Yeah. I think it is a European term.

Dr. **WEEDMAN.** Our data base is that we rely on private commercial data bases to have reserve information show about 900 billion barrels. So that is very—fairly close for the world reserve.

Chairman **BARTLETT.** Yeah. So that is in the ball-park. And we have about 2 percent of that?

Dr. **WEEDMAN.** We have—well, by my——

Chairman **BARTLETT.** Of known reserves. You have plenty in your table, I saw.

Dr. **WEEDMAN.** We may be looking at different tables. For reserves U.S. has about——

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Chairman **BARTLETT.** Measured crude reserves of '94. Down at the bottom on your table.

Dr. **WEEDMAN.** I was looking at the world energy assessment—that is right. Trillion—oh, that is not percent. That is in billion barrels. And in fact, I believe this is 1994 data.

Chairman **BARTLETT.** Yes, that is correct.

Dr. **WEEDMAN.** Now it is even higher, more like 22.

Chairman **BARTLETT.** Okay.

Dr. **WEEDMAN.** Right.

Chairman **BARTLETT.** But still 2 or so percent of the total.

Dr. **WEEDMAN.** Right.

Chairman **BARTLETT.** I mentioned to the Vice President that if we have only 2 percent of the known reserves of oil, if we could go out and find and pump that tomorrow then what will you do the day after tomorrow. Because there will be a day after tomorrow. This may be a rainy day, if I lived in California, it really would be a rainy day. But I think that we are going to face an even rainier day. And so I am opposed to more off shore drilling. I am opposed to opening up ANWR. Not because I think there is any environmental impact. I have been to ANWR. It may be to some a pristine wilderness. It looked more like a wasteland to me. In that many hour trip of getting there all the wildlife that they claim, I saw 1 goose on the trip there. They do a very good job of avoiding the environmental impact. They make roads in the winter out of crushed ice. And when the summer comes you can't even see where the road was. I saw the footprint of their rigs there. And I don't think there is any meaningful environmental impact.

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By the way, the caribou nestle up to the pipeline because it is heated, you know. And they don't consider that a degradation of their environment. You see them all along the pipeline there. But I am opposed to drilling simply because we are going to need that 1 day as a feedstock for our enormous petrochemical industry. It needs to be there in reserve. I don't mind exploring and finding what is there. I just want it to stay there for the moment because I don't want us to put a bandaid over a cancer. That when the bandaid comes off the cancer when you known it has grown as cancers do, and are problem is even bigger than it was when I put the bandaid on it. I want us to face now the problem that we face using a fourth of the oil in the world, having only 2 percent of the oil in the world. Using, what, 4 or 5 times as much energy per individual as the average person in the world. We just need to face that reality. And how do we get from where we are to a sustainable energy supply.

I promised at the beginning that we would ask you to make any comment you wish to make now and to question or comment on the observations of any other people on the panel. We want for the record as complete an assessment that we can get of the available energy out there. Because this is one of our first steps in the development of an energy policy. And I thought, Dr. Ehlers, what we needed to substantiate, first of all, is how much is out there and what are the dimensions of the problem. And I think there is fair agreement to that.

By the way, up until the Carter years we used as much oil every decade as we had used in all of previous history. Had we continued on that rate of increase, and I would like to ask Dr. Bartlett to make some observations on the effect of the exponential function that he does so well. But anyway, increased—had we continued in that rate of increase when we used half of all the oil in the world, and that is probably about as we speak. I think the general consensus of that is they are not—for those of you who are familiar with this. I don't see any heads nodding no. That certainly is not true. And I think the general feeling—in this country we had done that, by the way, in—about 1970. We had a little spike at Prudhoe Bay. But it has been downhill since 1970.

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Dr. **WEEDMAN.** Right. 1970 was our production peak.

Chairman **BARTLETT.** That is right. And it has been downhill since then?

Dr. **WEEDMAN.** That is right.

Chairman **BARTLETT.** In 1981, I understand we spent more energy looking for oil than we would get from all the oil we found in 1981. You know——

Dr. **WEEDMAN.** I don't know that statistic.

Chairman **BARTLETT.** This is not a mine that is forever out there for oil. But I think we have agreed on the general dimensions of the problem, that there are 20, 30, 40 or so years of readily available high quality oil remaining. Roughly the same for natural gas. And the thing on how quickly we used the coal, and how much insult we are willing to accept, environmental insult. Roughly those same dimensions in coal. You factor in all of the things. I would like now to ask you just to go down the line and make observations. And, Dr. Bartlett, I would be appreciative if you could make some comments on the—on our inability to understand the exponential functions. And whatever else you wish to comment on.

Dr. **BARTLETT.** Thank you very much, Mr. Chairman. You cited the fact that—and President Carter referred to this in his famous speech on energy, that in each of the last several decades we have used globally as much oil as had been produced—in one decade used as much as had been produced in all the previous history. That is a mathematical consequence of 7 percent growth in world oil production. And that had been the case for about 100 years, up to around 1970. It has fallen since then.

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But if that 7 percent growth had continued following the 1970's, then the world petroleum reserve estimated total to be about 2,000 billion barrels, it would have been used up by now. But this just indicates the impossibility of staying on the growth curve. And yet, steady growth is the centerpiece of our national economy, it is the steady centerpiece of our global economy. And yet, it is mathematically impossible to continue steady growth just because in the rates of consumption of resources. And so I think this is a thing that we need to really understand that the kind of growth that is centerpiece of our economy just cannot go on. And the biggest thing behind that is population growth. And I think we need to recognize that if we are going to have a sustainable situation in the United States we need to have a stop to population growth. And David Hemmontell, who is a global agricultural scientist at Cornell University who looks at food production. And he estimates that a sustainable population for the United States at our present dietary levels is about half of our present population.

Dr. **WEEDMAN.** You asked earlier if you thought this was a—the right to distribution of points of view. And that was an interesting question to me because what I have noticed to talking to the people here, we are very diverse and very different perspectives. From upstream and downstream, as they say in the energy industry.

But we agree on a lot of issues in part because I think the more you know about energy the more you do agree. And I think the biggest challenge we face as a Federal agency is informing the public and the Congress and the Administration about energy. Public education in energy is sadly lacking. We see a lot of ignorance and a lot of misinformation either in how much is left or how soon we will use it up.

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One thing that didn't come up in this discussion, I just want to mention it because we did talk about long range planning, is the potential for gas hydrates to be a source of methane in the future. It is clearly 10 to 15 years off, if it is possible at all to produce hydrates. It is an area that we focus on at the USGS because we think it is part of our mission to identify the future resources and how much is there.

The global reservoir of gas hydrate is twice the size of all known fossil fuels. Or thought to be, I should put it that way. It is hard to measure. So that if we can produce this frozen methane that is on our Continental Slope, that changes a lot of this story. It still leaves us with a CO problem to deal with, but the fossil fuel reserves will change dramatically.

The only thing I would like to say is just please feel free to call on the USGS in the future for assisting you in research issues.

That is one challenge. However, they are concentrated in places. The Japanese are very interested in trying to exploit their gas hydrate resources in the Nanki Trough. They found a fairly concentrated deposit, very large quantity. The challenge is knowing how to produce it.

Chairman **BARTLETT.** Thank you. Dr. Montgomery?

Dr. **MONTGOMERY.** Thank you very much. Mr. Chairman, you have actually given us a tremendous opportunity I think to debate and kind of express our views during the course of the hearing. And I don't think I have anything major that you have not already given us an opportunity to talk about so I won't repeat myself.

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There are 2 small things I thought I would like to mention. One of them is that I think in terms of your kind of summation of the resource estimates, I would think that you are shading a bit toward the pessimistic side. You know, one of my colleagues, Bill Norte House at Yale, has expressed the opinion that when we are talking about energy future, unless something is off by a factor of 2 it is not worth disagreeing about because we don't know even that much.

But I would think that probably I am kind of on the boarder line with you. I think the combination of things like hydrate, in looking at North American, Tarsans and other low quality sources of hydrocarbons, may well add up to as much as what we are talking about in terms of high quality oil and gas and coal. But we are still within a factor of 2, so I don't think we are talking about a very different world.

The other point always comes up that we haven't had a chance to talk about is the issue of subsidies for fossil fuels. I don't think there are any subsidies for fossil fuels that significantly distort choices in the market place. But there are actually 2 excellent studies on that done by the Energy Information Administration and by the Congressional Budget Office. It took a pretty dispassionate review of all of those. And I always think that is worth looking back at, you know, every once in a while.

And that's really all I have to say now. Thank you for the opportunity to be here.

Chairman **BARTLETT.** Thank you. Mr. Geller?

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Mr. **GELLER.** Mr. Chairman, I think I would like to use my concluding remarks to primarily compliment you for your understanding and insight and interest and concern about the long-term nature of these problems, and not just the short-term problem of keeping the lights on this summer and dealing with the price spikes that are occurring in heating fuels and electricity.

And I thought we were going to be talking mostly about the short-term here. That tends to be generally what one talks to when dealing with policy issues. I have been working in Washington for 20 years. I am going to be moving on this summer to a different part of the country. This might be my last opportunity to testify. I brought my family along with me today since it is my—probably my last hearing. And I am really glad that my children here have the chance to hear about the nature of these—of this problem over the long-term. The fact that the vital fuels that power our society, power our way of life are finite and likely to be greatly diminished in a matter of decades. And that if not in our lifetime, in their lifetime we are going to have to come up with alternatives to maintain the society and the standard of living.

And I hope you will be able to lead your colleagues in the Congress and also lead your president and vice president, my president and vice president as well, toward dealing with these challenges in a sensible and—way that leads us toward a sustainable energy future that deals with the long-term challenges as well as the short-term challenges. Thank you very much.

Chairman **BARTLETT.** Thank you. If I were looking only to my next election I would say a very different thing. Much of what I say people don't want to hear and it is politically incorrect. But I have ten children and eleven grandchildren, a great-grandchild. And I am thinking about them. And I think it is irresponsible for us to consume the relatively small reserves that we have of high quality fossil fuels without thinking about their future and what will they do when the well runs dry.

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And so thank you very much for your support. Mr. Courtright?

Mr. **COURTRIGHT.** I would like to expand on Mr. Geller's comments. Because I think that it is good that the Committee is looking long-term. And I think in order to figure out what should be that policy is to take that long view, to look out 10 years, 20 years, 50 years and set what would be the objectives of what you, sir, would like things to be in 2050. And then I think if we can help define that, that is not easy because of all the different opinions of people, but to then work backward as what is needed to get there.

And I think Steven Covey has said in his many speeches that, begin with the end in mind. And I think if we can work forward and kind of look at 2050 and say, where do we want this country to be, we can identify the policy and the technologies to achieve that.

Chairman **BARTLETT.** Thank you. Miss von Meier?

Dr. **VON MEIER.** Thank you. Very briefly, I would like to say something about exports. Because we talked about imports on the oil side, which is not looking too favorably. Export obviously is not an issue if we are looking at exporting fossil fuel, because we need our own. On the side of solar energy, though also on the side of nuclear energy, there is really a potential for the United States to be potentially taking advantage of large expanding energy markets, particularly, in Asia.

On that issue, I would like to argue that we should think very carefully about becoming a major exporter of nuclear technology. Because it is the technology that can only be in good conscience used in an infrastructure and a society that has a certain industrial culture.

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And I think that if we were to position ourselves as an exporter of renewable solar and wind energy and other renewable technologies, that that is something that could also bring tremendous benefits for us and also for the people in the countries where we send these means. And it is something that we could truly be proud of.

And finally, I would like to echo Dr. Geller's compliments. I want to say that when I go back to speak with my students and they ask how the hearing went, I will be very proud to tell them that despite some of the things they have heard from the Administration recently that their leaders in Congress are very sincerely and carefully looking into energy issues. Thank you.

Chairman **BARTLETT.** Thank you very much. As you undoubtedly know, solar is now a major export for us. It is major compared to the size of the industry. I think far more is exported than we use here in solar. But there is lots and lots of potential for growth here.

I want to thank the witnesses very much for their testimony. I would like to encourage you again to come back here at 1:30 for Dr. Bartlett's 1-hour. It will be the shortest 1 hour you ever spent in your life. It really will.

Thank you very much. And we will adjourn the meeting.

[Whereupon, at 12:55 p.m., the Subcommittee was adjourned.]

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Appendix 1:

Answers to Post-Hearing Questions Submitted by Members of the Subcommittee on Energy

Next Hearing Segment(2)

(Footnote 1 return)
"Study Finds Internet Use Unexpectedly Benefits Environment," Mitzi Perdue, Scripps Howard News Service, Global Environment and Technology site, (July 11, 2000; 12:01 a.m. EDT; http://www.nandotimes.com)

(Footnote 2 return)
"Strength through Science: Powering the 21st Century," U.S. Department of Energy, Draft Strategic Plan, February 18, 2000.

(Footnote 3 return)
U.S. Geological Survey, Department of Interior, Washington, DC, Fact Sheet–018–97

(Footnote 4 return)
Dr. Scott W. Tinker, Director, Bureau of Economic Geology, University of Texas at Austin, in testimony April 26, 2001 before the Subcommittee on Energy, Committee on Science, U.S. House of Representatives, Washington, DC.

(Footnote 5 return)
"Nuclear Power's Sustainable Development," Jean-Marie Bourdaire and John Paffenbarger, 22nd Uranium Institute Symposium, 1997.

(Footnote 6 return)

U.S. Geological Survey, Department of Interior, Washington, DC, Fact Sheet–019–97.

(Footnote 7 return)

Nuclear Energy Institute, Washington, DC

(Footnote 8 return)

Scenarios for a Clean Energy Future. Interlaboratory Working Group on Energy-Efficient and Clean-Energy Technologies, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Nov. 2000.

(Footnote 9 return)

H. Geller, S. Bernow, and W. Dougherty. *Meeting America's Kyoto Protocol Target: Policies and Impacts.* American Council for an Energy-Efficient Economy, Washington, DC. Dec. 1999.

(Footnote 10 return)

President's Committee of Advisors on Science and Technology, Panel on Energy Research and Development. *Federal Energy Research and Development for the Challenges of the Twenty-First Century."* Executive Office of the President, Nov. 1997.

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Clean Energy Partnerships: A Decade of Success. DOE/EE–0213. Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, Washington, DC. March, 2000.

(Footnote 12 return)

"Impacts: Turning Industry Visions into Reality." DOE/EE–0240, Office of Industrial Technologies, U.S. Department of Energy, Washington, DC. Jan. 2001.

(Footnote 13 return)

J. DeCicco, F. An, and M. Ross. *Technical Options for Improving the Fuel Economy of U.S. Cars and Light Trucks by 2010–2015.* American Council for an Energy-Efficient Economy, Washington, DC. April, 2001. Also, J. Mark. *Greener SUVs: A Blueprint for Cleaner, More Efficient Light Trucks.* Union of Concerned Scientists, Cambridge, MA. 1999.

(Footnote 14 return)

H. Geller, *Strategies for Reducing Oil Imports: Expanding Oil Production vs. Increasing Vehicle Efficiency*. American Council for an Energy-Efficient Economy, Washington, DC. April 2001.

(Footnote 15 return)

ibid.

(Footnote 16 return)

S. Nadel and M. Kushler. "Public Benefit Funds: A Key Strategy for Advancing Energy Efficiency." *The Electricity Journal*. Oct., 2000, pp. 74–84.

(Footnote 17 return)

H. Geller, S. Bernow, and W. Dougherty, *Meeting America's Kyoto Protocol Target: Policies and Impacts.* American Council for an Energy-Efficient Economy, Washington, DC. Dec. 1999.

(Footnote 18 return)

H. Geller, T. Kubo, and S. Nadel. *Overall Savings from Federal Appliance and Equipment Efficiency Standards.* American Council for an Energy-Efficient Economy, Washington, DC. Feb. 2001.

(Footnote 19 return)

Strategic Energy Policy Challenges for the 21st Century. Council on Foreign Relations, Washington, DC. 2001 forthcoming.

(Footnote 20 return)

National Energy Strategy: Powerful Ideas for America. U.S. Government Printing Office, Washington, DC. Feb. 1991.

(Footnote 21 return)

PCAST, op cit.

(Footnote 22 return)

Vern Goldberg, WGA Associates, Dallas, TX.

(Footnote 23 return)

"Industry Gives Nuclear Power a Second Look," April 24, 2001.

(Footnote 24 return)

Assuming an area usage of about 6 acres per megawatt of installed capacity and a plant capacity factor of 0.20.

(Footnote 25 return)

Area usage for wind may vary from 10 to 80 acres per megawatt, depending on a tradeoff between resource use efficiency (machines not blocking each other's wind) and land use, with capacity factors around 0.25 depending on local wind.

(Footnote 26 return)

Assuming a circular area of 12 mile radius. Actually, this zone borders on nuclear test sites that are also off limits.

(Footnote 27 return)

See Paul Gipe, *Wind Energy Comes of Age*. New York: John Wiley & Sons, 1995.

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