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Energy Sources: Conservation and Renewables

(APS, Washington, DC, 1985)

Edited by
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PREFACE

A decade has passed since the oil embargo of 1973-74. The physics community initially responded to the problem of the "energy crisis" by conducting a summer study at Princeton University on THE EFFICIENT USE OF ENERGY during the summer of 1974. The American Institute of Physics book containing this study (AIP 25, 1975) has been the largest selling AIP Conference Series book; its impact went far beyond the physics community. Many of the technical ideas discussed by physicists in AIP 25 were untested concepts at the time; some of these ideas later became the focus of research, development and, ultimately, commercialization. This effort a decade ago helped shape some of the questions and discussion of how the U.S. should respond to the issue of energy use and planning.

The oil embargo of 1973-74, and the sharp rise in the price of imported petroleum from $2.50/barrel in 1972 to $30/barrel in 1980 forced the world to think more seriously about the fuels that drive our economic engine. Prior to 1973, the era of cheap energy had propelled the industrial revolution and helped develop exuhuberant consumer lifestyles. The government responded to the energy crisis in many ways: incentives for more production of energy from many different sources, incentives to encourage reduced consumption of energy by enhanced end-use efficiency, a strategic petroleum reserve to give the U.S. protection from sudden disruptions in imports, efficiency labels for appliances and automobiles, mileage standards for automobiles, and so forth. As we look back on the results a decade later, it is clear that the new sources of energy did not produce very much in the decade after the oil embargo. What is also clear is that conservation (enhanced end-use efficiency) made the lion's share contribution to our present state of relative well-being.

First, THE GOOD NEWS: Because of progress on energy, the U.S. has improved its status in financial, political and environmental matters. The U.S. is importing about 40% less petroleum than in the peak year of 1977; a drop from 8.8 million barrels per day (Mb/d) in 1977 to 5.4 Mb/d in 1984. This reduction in imports alone has saved the U.S. about $40 billion per year. The total savings of energy from all sources is about $150 billion per year when compared to projections of energy consumption of more than 100 quads/year for 1985. The "lock-step" relation between GNP and energy has been unlocked; as the GNP increased by 30% since 1974, total energy consumption has remained relatively constant. Primarily because of conservation, our national security has been enhanced since we have dramatically reduced our dependence on imports from OPEC, a reduction from 6.2 Mb/d in 1977 to 2.0 Mb/d in 1984.

Now, THE BAD NEWS: The euphoria of the results above should be tempered for a variety of reasons. In February, 1985, the Department of Interior slashed its estimates for offshore oil and natural gas resources by about a factor of two; from 27 to 12 billion barrels of oil, and from 163 to 91 trillion cubic feet of gas. In spite of the $250 billon investment to discover and develop new petroleum wells, the U.S. oil reserves have declined by 13% in 6 years (0.7 billion barrels/year = 1.9 Mb/d), and the U.S. natural gas reserves have remained essentially constant. The U.S. still spends about $60 billion per year to import oil, about 25% of the present deficit. There is continued concern about the CO_2 greenhouse effect since the CO_2 content of the atmosphere has risen from 330 ppm to 345 ppm in the last decade. And, acid rain threatens lakes and forests. Utilities are hesitant to build new power stations since both coal and nuclear have drawbacks.

The chapters in this book, ENERGY SOURCES: CONSERVATION AND RENEWABLES, were initially presented at a conference held at the Congressional Office of Technology Assessment in Washington, D.C. in April, 1985. This book is an appropriate complement to its visionary predecessor since it presents the results of a decade of research since 1975. The technical progress has been very encouraging in such areas as buildings, appliances, lighting, windows, indoor air quality measurements, passive solar, off-peak cooling, smart electrical meters, photovoltaics and wind energy, automobiles, industrial conservation and so forth. The ideas discussed in these chapters are too numerous to summarize, but together they give a clear signal that there are soundly based technical options which can continue to reduce America's energy consumption in the future.

Lastly, one of us (DH) would like to thank Art Rosenfeld and the members of the Energy Efficient Buildings Program at the Lawrence Berkeley Laboratory for their kind hospitality during the summer of 1985.

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August 30, 1985

ENERGY SOURCES: CONSERVATION AND RENEWABLES

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CHAPTER 1

REFLECTIONS ON FIFTEEN YEARS OF ENERGY POLICY

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ABSTRACT. *The events of the 1970's — both the "energy crises" and the measures taken to alleviate them — changed our ways of thinking about energy. We now look at energy consumption as a largely substitutable means to various ends, not a goal or a measure of progress in and of itself. Energy demand growth has dropped markedly, even as the economy has grown. But there are many issues yet to be resolved if the United States is to have a comprehensive, rational energy strategy. This paper tackles four of them: Is there a place for continued government economic and regulatory intervention in the energy marketplace? What should be the federal role in energy research and development? What are our prospects for new discoveries in domestic oil and gas? What is the future of nuclear power in the United States? The author believes that the best way to solve our energy problems is to gauge, and then reflect in our energy policy, the true costs and benefits of energy production and consumption. He concludes that conservation investments have proven to be so rewarding that energy efficiency should be receiving a major amount of attention from energy policy makers for reasons of economic efficiency and in order to minimize the impact of future crises.*

Time flies. Reflecting on only the last ten years of energy policy -- my original intent -- no longer even takes us back to the Arab oil embargo of 1973, the crisis that precipitated much of our current thinking about energy policy. Getting a handle on our present energy situation requires an understanding of energy use and attitudes at least as far back as 1970. A snapshot of that year reveals that:

1. Both average and marginal energy prices had been level or declining for the previous fifty years;

2. Since 1960, the United States had experienced a steady rise in both energy consumption and oil imports;

3. Planners held grand notions of what one could accomplish when prices went even lower. Slogans for the future, such as "energy too cheap to meter" were still taken seriously. There were proposals for outdoor, as well as indoor, air conditioning, and technological visions of using thermonuclear fusion devices to atomize wastes and make them reusable. The Federal Power

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* While the author drew upon OTA material in the preparation of this paper, the opinions given and the conclusions made are personal and do not necessarily represent those of the Office of Technology Assessment.

Commission (FPC) was predicting a 3.4% annual growth in total U.S. energy demand out to 1990, and expected a concurrent 6.7% annual rate of increase in electricity consumption.[1]

4. Nuclear power was hailed as the fuel of the future. It was widely expected that electricity, continuing the downward cost spiral brought on by the advent of cheap nuclear power and abundant coal, would overtake oil as America's primary energy source sometime in the late 20th century; and

5. It was (then as now) difficult to coordinate federal energy policy because pieces of it were vested in various entities. The Atomic Energy Commission controlled nuclear power and energy research, while the Department of the Interior was in charge of fossil fuels and the Environmental Protection Agency wrestled with pollution from energy. Public and private utilities, mostly regulated state-by-state, controlled the distribution of electricity, and private cartels wielded enormous influence over the supply and price of oil.

A sense of a potentially gathering storm accompanied the general optimism, however. Events of the late 1960's highlighted many of the external costs of energy production and consumption. Many of the worsening problems of air and water pollution were directly attributable to use of energy. Apocryphal scenarios envisioned in Limits to Growth,[2] in contrast to those presented by the FPC, warned of the dangers of continuing, unmodified growth in energy consumption. The growth in the power of OPEC and increasing tensions in the Middle East contributed to a growing wariness of import dependence. High projected electric demand growth exacerbated worries not only about oil imports and the environment, but also about the sheer amount of capital investment that was implied. Gas curtailments began to show up along with spot shortages of heating oil and gasoline. And, most surprising to many in the energy field, there were growing doubts about the nuclear option.

As the ramifications of energy consumption were considered, some concluded that what might be needed was a basic transformation in the way we used energy. Easily foreseeable troubles -- a turn around in cost trends, or import constraints -- would require well planned responses. Four major (nonexclusive) options were generally presented as means to avoid increased dependence on energy, particularly oil imports. The United States could:

1. Increase exploration, development, and production of domestic conventional energy;

2. Quickly enter into large-scale development and commercial production of synthetic liquids and gas from coal and shale;

3. Rely more heavily on nuclear power, and even accelerate its already rapid development;

4. Accelerate a shift to more efficient use of energy by a variety of conservation technologies and policies.

I and many others became advocates for conservation (using energy wisely and carefully) or what some prefer to call energy productivity --

decreasing the amount of energy required to sustain a given level of goods and services. Extensive analysis had quickly proved the existence of many technical and economic opportunities to save energy. Efficiency of energy use had increased, especially in industry, for the previous 30 years, despite the fact that energy prices had been declining in real terms all the while. Conservation would have positive impacts on environmental quality and would be a generally distributed, incremental activity that would not prove overly burdensome to any one segment of society. And conservation activities would provide employment opportunities where the people are -- at the point of consumption.

I pursued this choice through several routes: through my work at Oak Ridge National Laboratory (systems and engineering analysis of efficient energy use); in setting up the first federal energy conservation office at the Department of the Interior and, later, at the Federal Energy Administration (FEA); at the Energy, Environment, and Natural Resources Center at the University of Tennessee; as chairman of the demand and conservation panel of the National Academy of Sciences CONAES study; on the Energy Research Advisory Board of the Department of Energy; as a member of the Board of the Tennessee Energy Authority; and finally at the Congressional Office of Technology Assessment (OTA). I recall with considerable pleasure my successful argument with my boss at FEA that we should provide half of the funds to sponsor the 1974 summer study at Princeton on energy conservation opportunities.[3] In a book (Energy: The Conservation Revolution)[3] I coauthored with Bill Chandler, we laid out the ingredients for a comprehensive energy policy that had conservation at its core. We envisaged an energy future from these perspectives:

1. Consider the production and use of energy as means to certain ends, not as goals in and of themselves. Remember always that, given time and the capital for adjustment, energy is a largely substitutable input in the provision of most goods and services;

2. Application of technical ingenuity and institutional innovation can greatly facilitate energy options;

3. Energy decisions, like other investment decisions, should be made using clear signals of comparative total long-run costs, marginal costs, and cost trends;

4. It is important to correct distorted or inadequate market signals with policy instruments; otherwise external costs can increase and resources can be squandered. This correction includes internalizing in energy price, to the extent possible, the national security, human health, and environmental costs attributable to energy;

5. Investment in both energy supply and utilization research and development is an appropriate activity for both the public and private sectors, since costs and benefits accrue to both sectors;

6. There are other, generally more productive, ways to assist underprivileged citizens with their energy needs than subsidizing energy's price to them; and

7. In a world characterized by tightly integrated economies, we need to increase our cognizance of world energy resource conditions and needs, with special regard for international security as well as concern for the special needs of poor nations.

The energy situation today reflects the adoption of some of these ideas. Oil price deregulation is virtually complete, and natural gas is headed in that direction as "old" gas declines in importance. Legislation has been adopted to influence both demand (e.g., the Energy Policy and Conservation Act (EPCA), Corporate Average Fuel Efficiency Standards (CAFE)) and supply (e.g., the Synthetic Fuels Corporation (SFC), Public Utilities Regulatory Policy Act, (PURPA), and the Strategic Petroleum Reserve (SPR)). Thanks to conservation successes, imports are comfortably low (though rising), a condition that, along with the Strategic Petroleum Reserve, gives us better ability to manage energy shocks over the next several years. Our enormous bow wave of overinvestment in electric capacity is slowly ebbing, and cogeneration is making our electric system more diversified and flexible. Energy efficiency is widely increasing as energy-efficient capital stock is replaced throughout the economy, but these improvements are naturally slackening in the face of recently falling energy prices.

The seeds planted in the mid-70's have begun to sprout. Energy demand growth slowed markedly. Total industrial consumption fell 15% between 1974 and 1983, a result of both increased efficiency and product switching. Most importantly, energy use and GNP growth officially divorced, as the E/GNP ratio (energy use per unit of gross national product) fell 22% between 1973 and 1983. But now some energy prices in the United States have peaked and fallen (since oil prices are in $U.S., prices have not similarly declined for many other countries). That is good news for the United States, in as much as it contributes to lowering of inflation and a resurgence of industry, but it also contributes to a complacency about our long term energy situation that could become dangerous. Because of lower prices and domestic oil and gas discoveries far below what was once estimated, there are projections that the United States may, by the year 2000, import as much as 10 million barrels per day of oil -- in excess of our 1977 high.[4] And there have been some casualties along the way, particularly the collapse of nuclear orders and the dearth of both 1) energy research and development expenditures; and, very recently, 2) oil and gas exploration activities. The problems presented by a meager information base, the lack of sustained support of systems analysis, and the cultural, institutional, and political barriers to widespread acceptance of conservation technologies were also grossly underestimated when we first began to extol the virtues of energy efficiency.

There are many issues to be resolved before the United States can claim a coherent energy strategy. I would like to highlight just a few:

- Is there a place for continued government economic and regulatory intervention in the energy marketplace (e.g., price controls, emissions regulations)?

- What should be the federal role in energy research and development?

- What are the prospects for new discoveries in domestic oil and gas?

- What is the future of nuclear power in the United States?

As you will see from my comments, I believe a critical question, which encompasses all of these, concerns our ultimate ability to gauge, and then reflect in our energy strategies, the true costs of energy production and use. Key elements of that ability are committed leadership and access to information.

GOVERNMENT INTERVENTION IN THE ENERGY MARKETPLACE

The first question I would like to address is, Is there a place for government intervention in the energy marketplace?

Price decontrol was a crucial first step in internalizing the costs of energy consumption. The federal government's move out of that marketplace was a big step in the right direction, but not the whole answer. For example, market prices for energy do not reflect: 1) the environmental costs of energy production and use; 2) the costs of defending Mid-East oil production and shipping lanes; 3) the costs of purchasing and storing oil to meet emergencies; or 4) the cost to our allies and the impoverished Third World countries of U.S. competition for petroleum in the world market.

Electricity production consumes one-third of the primary energy used in the United States, yet the price the consumer pays does not reflect the marginal cost of providing that energy; therefore market signals for more efficient use are suboptimal.* Though all but "old" natural gas prices are decontrolled, natural gas transmission and distribution could remain controlled for many years to come.

Energy cannot be treated as a commodity only, for it involves political, social, national security, and environmental implications that must be addressed. Governments have historically intervened in energy markets in order to: 1) control and regulate a monopoly; 2) provide for the health and safety of citizens; and 3) provide for national security.

I was first drawn to energy policy when I began to notice the effects of strip mining on the mountains to the north and west of Oak Ridge National Laboratory. Now it is possible to document the fact that air pollutants are destroying parts of the beautiful Smokey Mountains. There is growing concern about the uncertain but potentially large future costs of acid rain, NO_x, and CO_2 buildup in the atmosphere. All of these problems are linked to energy -- utilities, industry, transportation -- and we should be striving for integrated, least-cost solutions. The government has, in effect, entered the marketplace by enacting legislation (the Clean Air Act, for instance) to protect the health of its citizens and their environment, but is this approach the best possible solution to the problem?

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* There is growing evidence that in this period of overcapacity, with prospects for new kinds of generating technology and life extension of existing plants, electricity prices over the next several years will decline. Therefore marginal and average costs may be converging.

Enforcement of the Clean Air Act has resulted in greatly decreased sulfur emissions from electric power plants -- a great benefit to society. If instead of desulfurizing flue gas we used the same resources to cut energy consumption through conservation technologies, we would help to alleviate a lot of other problems in addition. Similarly, investment in research into advanced combustion technologies might reduce both sulfur and nitrogen emissions. In fact, generation technologies currently in the major demonstration phase of development, such as integrated gasification combined cycle and atmospheric fluidized bed combustion, may be able to produce electricity with lower costs and lower SO_x and NO_x emissions than can conventional coal technologies with scrubbers.(5)

A comparison of the relative costs of applying the Clean Air Act versus enacting appliance efficiency standards is a case in point. Recent research indicates that energy efficiency standards for water heaters, refrigerators, and room and central air conditioners could avoid installed capacity of between 40,000-100,000 megawatts of electricity by the year 2005. Savings at the low end would eliminate the need to burn over 100 million tons of coal each year and provide a 12-20 percent reduction in current annual SO_2 emissions. Installing flue gas scrubbers to achieve a similar reduction in sulfur would cost $5-10 billion; appliance efficiency increases could cost less than a fraction of that amount. Appliance efficiency standards would also enable the reduction of nitrogen oxide and carbon dioxide emissions at no extra cost.(6)

The leap in complexity (i.e., the number of actors) in shifting from utility investment strategies and coal industry initiatives to act on air pollution regulations, to the myriad capital investments in higher energy efficiency and associated regulatory requirements and consumer decisions is enormous. Only a fraction of economically attractive conservation options have been exercised to date. But that leap in seeming complexity should not be sufficient to deter us if the economic and other rewards are attractive. Consumers generally act collectively, and state or federal rulemaking procedures are actions by bodies similar to corporate boards. In other words, what may seem to be the independent decisions of millions of people can actually follow from the actions of only a few people (regulators, marketers, etc.). And, best of all, we have already seen considerable change in consumer habits, despite the complexity of decisions.

The fact that within the Congressional arena, decisions concerning appliance efficiency standards are made entirely separately from decisions to enact emissions standards, means that changing that decisionmaking system to effect a more integrated approach would be extremely difficult. Other governments have intervened in industrial energy policy with very satisfactory results. In the 1970's, the Japanese invested $50-150 million per year in energy efficiency in the steel industry. They concentrated on refitting primary steel plants for higher overall productivity, including such energy-related features as continuous casting and heat recovery. The result was energy demand reduced to 40 percent below the world average per ton of steel produced. Partly as a result of these investments, the Japanese steel industry has remained competitive.(7)

One of the best ways to extend oil supplies and improve air quality would be to improve automobile fuel economy. Yet 1985 is the last year in which American automakers are required to raise gasoline efficiency. Existing legislation requires only that auto manufacturers reach a new fleet sales average of 27.5 miles per gallon (though new American cars are currently only at 22 mpg). The Secretary of Transportation can raise the standard (or lower it to 26 mpg), but either the House or the Senate can override such an action. Legislation that forced American cars to become as efficient as Japanese cars would ultimately (at full fleet turn-over) reduce world oil demand by 5 percent at only a fraction of the cost of enhancing liquid fuels supplies with synfuels or alcohol. Automobile fuel efficiency was headed toward that level of efficiency -- 30 miles per gallon -- when gasoline prices rose precipitously in 1980. But the marketplace alone cannot ensure fuel efficient cars, for it is only one consideration in the consumer's decision. Because there are several major areas of public interest in cutting our dependence on oil imports and in using energy resources more efficiently, it is a legitimate if not essential area for government intervention in the cause of national security.

The advance of technology is often as important to adoption of resource conservation measures as is government intervention in the marketplace. It was the rise of "high-tech" mini-mills dependent upon scrap steel that pulled the junk cars off the hills of Appalachia and back into the marketplace. But the intervention of government -- uniquely equipped to devise integrated measures for resource conservation beyond the capability scope of individual industries or consumers -- is often required to bring that technology to fruition.

THE FEDERAL ROLE IN ENERGY R&D

The idea that government can play a role in forcing technology brings us to the next issue I would like to address, What should be the federal role in energy R&D?

The current Administration has put forward some very reasonable criteria for public investment in energy R&D.(8) They feel that the government should become involved only when the investment has:

• High risk (including technical risks, economic risks, and the risks associated with acceptance of new technologies);

• Potentially high pay off -- either financially or through better understanding (this is a fairly recent addition to the criteria for federal involvement -- past administrations having been criticized for emphasis on short-term pay-off);

• Long term to fruition (beyond the normal interest and ability of the private sector to fund because of the payback period); and

• Generic qualities (will benefit more than one firm and have wide spread applicability).

At the same time, however, the historic over-emphasis of supply technologies at the expense of conservation and renewables continues, and R&D spending in energy has generally been in retreat. Federal support for R&D in energy conservation has survived in the last several years only by Congressional action. In the face of large non-market costs in the energy sector, and great and uncontrollable uncertainties about long-term future energy prices, it is difficult for the private sector to justify extensive investment in R&D for energy efficiency substantially greater than is economic at today's energy market prices. Thus federal investment in the energy sector should be made to ensure reliability and minimum cost of the needs and amenities that energy helps provide. Public benefits of generic R&D in energy productivity include the following:

• Energy savings can lighten the heavy burden of balance of payments, and new, world markets will open to eventual private sector producers of new energy efficient technologies;

• Existing supplies of energy resources will last longer, providing more time for developing successors, just as a strategic oil reserve would last longer, increasing our resilience to short term interruptions;

• The health and environmental impacts of energy conservation technologies can be understood and dealt with prior to wide-spread implementation; and

• Less developed nations will have a better chance for economic growth if energy efficiency in the major energy consuming countries can hold down the rate of energy price increases by reducing demand pressure.(9)

There have been a variety of problems with federal R&D work in energy conservation, for example the early emphasis on near-term pay-offs. Still, there is a role for conservation research and development in expanding the boundaries of efficiency that economically match a given energy price. Long-term research also provides improved insight into the nature and trends of our energy consuming society -- the choices we make, how and why we adopt or reject technology. Similarly, research yields improved understanding of the social and economic implications of energy conservation: employment, social equity, freedom of choice, resilience in the face of emergencies, international security, environment and health, and urgency for new supply development. One likely outcome of such continuing analysis would be an ability to project energy demand futures with greater confidence. That result alone would justify an enormous research investment. Thus we do need continued federal involvement in energy R&D (and, fortunately, it is not likely to require extravagant sums).

Among the most notable results of public and private R&D related to energy conservation have been high temperature metals, electronic controls, and new chemical processing techniques. Also very important are the increases in understanding of building energy use, lighting, coated glass, and integrated energy systems in buildings. I emphasize the importance of conservation R&D in this discussion because of historic lack of funding in this area, but there also have been some important and notable advances in energy supply R&D. Research into uranium separation technologies and reactor fuel performance has gone a long way toward eliminating our fears of a shortage of uranium and keeping the nuclear option viable. Oil and gas exploration technologies have made remarkable advances in recent years. Advances in flue-gas scrubbing, gasification, and combustion have made it safer to burn coal. Fusion, solar-direct conversion, and biomass conversion are now remarkably advanced technically, compared to a decade ago, but still are far from being economically feasible.

PROSPECTS FOR DOMESTIC OIL AND GAS DISCOVERIES

Advances in supply technologies are very important since energy demand will continue to grow as our economy grows, though not in lock step. And recent disappointing discovery rates of petroleum manifest that it may be the less conventional technologies on which we must rely, sooner than we thought. This leads to my next question, What are our prospects for major new discoveries in domestic oil and gas?

A recent OTA report, Oil and Gas Technologies for the Arctic and Deepwater,(10) found that despite the large oil and gas price increases of the 1970's, with accompanying major increases in exploration, domestic energy production remained virtually level over the past decade. Between 1980-1984, the United States spent $250 billion on domestic petroleum exploration and development, yet oil production remained almost level. The slight increase in domestic oil production since 1980 is due entirely to production from the Prudhoe Bay Field on Alaska's North Slope, and if its contribution is removed, domestic oil production declined more than 18 percent between 1974 and 1983. Domestic oil and gas reserves have declined even more rapidly than production, despite enormous increases in resource exploration and development since 1973, and particularly since 1980. According to the Department of Energy (DOE), proven reserves of economically recoverable oil dropped from 47 billion barrels in 1970 to 35 billion barrels in 1984. And the Minerals Management Services (Department of the Interior) recently revised resource estimates for offshore oil and gas. The new estimate of undiscovered oil resources in the OCS (outer continental shelf) lease sale planning areas are 55 percent lower than the U.S. Geological Survey estimates published in 1981; natural gas resources are 44 percent lower.

A major oil price rise in 1979 and cumulative conservation efforts begun earlier led to declining imports and a record oil import low of 4.9 million barrels per day in 1983. However, in 1984 oil imports increased about 7 percent over 1983, accounting for about one-third of U.S. petroleum requirements. Oil import levels have increased as growth in domestic demand has outpaced domestic oil production.

The DOE and Gas Research Institute (GRI) energy forecasts indicate a continuing decline in the production of domestic oil and natural gas to the year 2000. In both forecasts, oil and gas imports are expected to increase substantially, to between 7.1 and 7.5 million barrels of oil per day and 2.8 and 3.8 trillion cubic feet (Tcf) of natural gas per day. There are indications, however, that even the DOE and GRI projections may be overly optimistic and that imports may reach higher levels. Continued low energy prices may lead to greater fuel usage, reduced conservation efforts, lower exploration efforts, and limited replacement of oil by alternative fuels. There are also great uncertainties about future natural gas supplies.(11)

DOE and GRI projections of year 2000 domestic production of oil are 8.1 million barrels per day and 9.2 million barrels per day, respectively. Studies by OTA and the Congressional Research Service (CRS) forecast even greater declines. OTA, in World Petroleum Availability: 1980-2000, projected that domestic oil and natural gas liquids production would decline to between 4 and