

Energy Situation

Energy/Environment Committee of APS's Panel on Public Affairs

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Energy problems are now being largely ignored, despite their continuing importance. The near-disappearance of energy from the U.S. public agenda is apparent in the scant attention given to energy topics by the media and by public figures. Some suggestions for governmental action were stimulated by the rise in gasoline prices in the Spring of 1996, but the matter was treated as a short-term anomaly -- not as a harbinger of more severe difficulties to come.

This lack of long term concern is perhaps natural, because fuel supplies are generally ample and prices are still relatively low, with the real cost of gasoline in 1994 only one half the cost in 1981. However, we believe that neglect of potential future difficulties is highly imprudent. We summarize below the considerations that lead us to this conclusion. (This Background Paper was prepared by members of the Panel on Public Affairs of the American Physical Society.

It is meant to reflect the considerations that underlie the Statement on "Energy: the Forgotten Crisis" issued by the American Physical Society. This paper has not been reviewed by the Society.)

I. Energy: An Essential for Society

1. Adequate energy supplies are crucial to our pattern of life.

- o Without adequate energy supplies our society cannot function. The transportation sector is particularly vulnerable to energy disruptions and uncertainties. Economic growth, as well as projected population growth of 1%/year for the U.S. and 1.7%/year for the world will create increased energy demands.

2. Coupling between energy and the economy has been reduced, but it is still a reality.

- o Because of the increased efficiency of energy use and because of modal shifts in our economy, the ratio of U.S. energy use to GDP has decreased by 32% from 19,000 BTU/\$ in 1973 to 12,900 BTU/\$ in 1995 (1992 dollars).
- o The rate of improvement in this ratio has fallen sharply since 1986. In the first period since the oil embargo (1973-86), the GDP (in constant dollars) rose by 41%, while energy consumption rose by less than 0.1%. However, in the the next period (1986-1995), the GDP rose by 23%

while energy consumption rose by 17%. On the other hand, energy use on a per capita basis has been relatively constant, dropping by about 14% in the decade following the oil embargo, but by 1995 rising most of the way back toward the 1973 value.

- Since 1975, electricity use has increased almost in lock-step with GDP, rising 72% from 1975 to 1995, while the GDP rose 74% (in constant dollars).

3. The rest of the world has justifiable aspirations that will entail greater energy use.

- Energy consumption is growing much more rapidly in the still developing countries than in the industrialized countries of the Organization for Economic Cooperation and Development (OECD). For example, during 1970-1990 energy consumption increased 178% for non-OECD Asia (5.3% per year) compared to 36% for the OECD (1.6% per year). Within several decades, these and other developing countries are likely to outstrip the OECD countries in total energy consumption.

II. Fossil Fuels, the Main Source of Energy.

4. Fossil fuels continue to be the mainstay of our energy economy.

- Fossil fuels (petroleum, natural gas, and coal) provided 84% of primary energy used in the U.S. in 1995; petroleum contributed about 40% of total primary energy.

Table 1. U.S. energy consumption before the oil embargo (1973) and two decades later (1995) in quads (1015 BTU) per year. Consumption of oil, natural gas, and hydroelectric power have changed little from 1973 to 1995, while coal and nuclear power each grew by about 6 quads/year and renewable energy grew by about 1 quad/year. (*Approximate correction to biofuels to conform to 1990 book-changing.) Data from Annual Energy Review, 1995, p. 9, and Monthly Energy Review, August 1996, p. 9 (Energy Information Administration).

Energy	Fossil Energy			Renewable Energy							Total	%
	oil	ngas	coal	TotalF	nuc	hyd	bio	other				
1973	34.8	22.5	13.0	70.3	0.9	3.0	2.3*	0.04	76.6	92%		
1995	34.6	22.2	19.6	76.5	7.2	3.5	2.9	0.5	90.6	84%		

5. U.S. domestic petroleum supplies are limited.

- U.S. proven reserves of crude oil have declined for 7 consecutive years. Low oil prices and a lack of good petroleum prospects are major factors in the downturn in domestic drilling and the success rates. U.S. proven oil reserves dropped from 32 billion barrels (Bb) to 22.5 Bb between 1977 and 1994. Although the total amount of remaining recoverable oil in the U.S., both discovered and anticipated, is estimated to be significantly greater than the proved reserves alone -- perhaps in the rough neighborhood of 100 Bb -- this total is considerably less than the amount of oil already produced.
- In spite of new Alaskan production, U.S. oil production dropped from 9.6 million barrels per day (Mb/d) in 1970 to 6.5 Mb/d in 1995. Alaskan production dropped from 2.0 Mb/d in 1988 to 1.5 Mb/d in 1995. Production from the lower-48 states dropped from 9.4 Mb/d in 1970 to 5.0 Mb/d in 1995.
- The number of discoveries of large fields in the U.S. has greatly decreased and it seems unlikely that many new large fields of oil and gas will be found in the U.S. Since 1980 no discovered field has more resources (estimated ultimate recovery) than the top 100 previously discovered oil or gas fields.

6. Reliance on oil imports creates problems for the U.S. and other nations.

- The U.S. trade deficit on net petroleum inputs was \$48 billion in 1995, which was about 30% of the total trade deficit and 7% of total imports.

- U.S. net petroleum imports have risen 31% since the oil embargo (6.0 Mb/d in 1973 to 7.9 Mb/d in 1995). The fraction of U.S. oil from imports (in quad/y) was about 50% in 1995, and is projected to rise to about 60% in 2010.
 - The OPEC fraction of the world oil market is projected to rise from 40% in 1990 to 57% in 2015, as a result of the fact that OPEC countries have a large fraction of remaining oil resources.
- 7. World dependence on oil from the Middle East entails military and economic risks.**
- The Middle East continues to be a region of potential political instability. The U.S. fought the 1991 Persian Gulf War in part to defend the unimpeded flow of oil to OECD nations.
 - Dependence on Persian Gulf oil has motivated U.S. arms shipments to that region and increased military involvement.
 - Europe and Japan have partially prepared themselves for future petroleum shortages by using considerably higher gasoline prices (\$4/gallon) to raise revenue and moderate demand.
- 8. Natural gas and coal are considered by some to be the "bridging fuels" of the future.**
- U.S. proven natural gas reserves dropped from 200 trillion cubic feet (TCF) to 164 TCF from 1983 to 1994. (1 TCF is about one quad.) The present rate of consumption is 21 TCF/y. Resources may be as high as 1000 TCF, but it is not clear how much of this can be converted to proven reserves. There are very large resources of coal, but their mining and use entails major environmental problems.

III. Environmental Aspects of Energy.

- 9. Combustion of fossil fuels is harmful to air quality in many cities.**
- 40 urban areas violate at least one of the U.S. ambient air quality standards, adversely affecting human health. Many foreign cities have considerably worse air quality problems. Automobiles contribute about one-half of the cities' air pollution.
- 10. Energy production and use can adversely affect the environment.**
- Energy use and production generally entail adverse environmental impacts. These can arise from both routine and accidental releases of pollutants, the preemption of land (and rivers), and the accumulation of waste products. A more efficient use of energy can contribute to reducing these effects.
- 11. Combustion of fossil fuels and climate change.**
- The atmospheric concentration of greenhouse gases has risen 30% since pre-industrial times, resulting in an increased radiative forcing of the climate system. If current trends in fossil fuel use continue, carbon dioxide concentrations will double in the next century.
 - According to the Intergovernmental Panel on Climate Change (IPCC, 1995), changes in weather and temperature patterns, particularly the spatial pattern of temperature changes, all point to "a discernible human influence on global climate" .
 - IPCC and others estimate that the global average temperature will change by the end of the next century by 2 oC (4 oF) -- although the actual change could easily be twice or half this value. The aggregate impacts of changes in temperature, precipitation, and sea-level, while uncertain, are likely to be harmful to both human and natural systems.

IV. U.S. Energy Demand and the Needs of the Future.

12. **Buildings and appliances consume about 40% of U.S. energy; there are great opportunities to reduce these energy requirements.**
 - o New building diagnostic computer codes allow architects opportunities to use new energy-management techniques. For example, from 1973-1985, the average ceiling insulation in new U.S. single-family houses increased from R14.4 to R26.7 and wall insulation increased from R10 to R12.5. The need for space heating in new large buildings and houses can be decreased by more than 50% on a cost-effective basis. Because of the long lifetime of buildings and the incomplete application of energy standards for buildings, the national transition to more energy efficient buildings will be slow. However, an EIA study found that houses built after 1988 consume only 59% as much natural gas as those built before 1980.
 - o From 1972 to 1990, new refrigerator energy usage dropped from 2000 kwh/year to about 800 kwh/year.
 - o About one-fourth of U.S. electricity is used for lighting. Long-lived compact fluorescent lamps use only 30% as much energy as incandescent bulbs. Considerable improvements in lighting efficiency have been accomplished on an economic basis with high frequency ballasts, and advanced control circuits. The cost effectiveness of these lamps improves as the fraction of the time they are operated increases.

13. **Transportation alternatives are an extremely important challenge.**
 - o Because transportation uses 2/3 of U.S. petroleum and over 1/4 of U.S. energy, it is a very critical target for energy savings.
 - o Since the oil embargo of 1973-74, the number of registered passenger cars has risen from 102 million to 147 million, an increase of 44%. The DOE's Energy Information Administration projects that vehicle miles traveled by light duty vehicles will increase by 1/3 by 2015. The U.S. is saving huge amounts of fuel and billions of dollars a year because the current standard (average) fuel economy for new automobiles of 27.5 miles/gallon is twice the 1973 fleet average of 13.5 miles/gallon.

V. Non-Fossil Energy Sources.

14. **Alternatives to fossil fuels are nuclear (fission and fusion), solar (photovoltaic, biofuels, wind, hydro, and solar thermal), tidal, and geothermal.**
 - o These energy sources are sufficient to sustain the Earth's economy, but in most cases the costs are not now competitive with fossil fuels.

15. **Renewable energy sources are not widely replacing fossil energy sources.**
 - o Hydroelectric power has remained relatively constant over the past two decades. Wind energy has grown considerably, but still contributes relatively little. Geothermal (not strictly renewable) has grown considerably, but is showing signs of depletion.

Table 2. U.S. Production of Renewable Energy (quads/year) (* Approximate correction for reaccounting of biofuels.)

hyd	geo	wind	solar	biofuels	TotRenew	TotEnergyUsed	
1973	2.9	0.04	0	0	2.3*	5.2*	76.6*
1995	3.2	0.34	0.04	0.07	2.9	6.6	90.6

16. **Nuclear fission's role will diminish without new initiatives.**

- In 1995 nuclear energy's share of the electricity generated by utilities was 22% in the United States, 76% in France and 33% in Japan. Nuclear energy has risen from a negligible contributor to U.S. electricity generation in 1970 to the second largest source (after coal, and before natural gas and hydro) in 1995, substantially moderating the need for fossil fuel sources.
- No new reactors have been ordered in the U.S. for more than 20 years. Several versions of improved reactors are expected to be available for pre-licensing shortly, but there are no immediate prospects for U.S. utility purchases. Two such reactors are being completed in Japan.
- No decisions have been reached in the U.S. on the location of either interim or permanent nuclear waste repositories, and it is not clear that a coherent, politically acceptable, nuclear waste disposal program can be established in the near future.
- Little work is continuing toward the design of reactors and fuel cycles that attempt to address simultaneously the problem of long term fuel supply and the danger of the proliferation of nuclear weapons.
- Replacing the present 100-gigawatt nuclear capacity with combined-cycle gas-fired plants would require about 4.5 trillion cubic feet of natural gas, equal to over 20% of the present total U.S. natural gas consumption.

17. Fusion energy, at best, will not be available for several decades.

- In research facilities many parameters critical to commercialization of fusion energy have improved dramatically, but the commercialization date for fusion remains uncertain.

VI. Some Energy Policy Issues

18. Science and technology have had major successes.

- Energy R&D has produced new and improved products and accelerated market penetration, such as: combined-cycle power plants, compact fluorescent bulbs, enhanced nuclear safety, more efficient automobiles, high bypass ratio jet engines for airplanes, improved building designs, catalytic converter mufflers, improved photovoltaic cells, more reliable wind mills, and so forth.
- R&D is necessary to enhance development of future energy sources and to improve end-use energy efficiency.

19. U.S. Government Energy R&D

- Energy R&D is carried out consistent with the DOE mission, although its relative share of the DOE budget has been in steady decline over the past 18 years. While the overall DOE budget has stayed fairly level since 1978, at about 1% of the total federal budget, DOE's energy R&D budget has currently dropped by about 74% (in constant dollars) from the 1978 budget. As a percentage of the DOE budget, energy R&D has gone from 45% of the total DOE budget request in 1980 to 18% in 1995. To place these figures in perspective, in 1995 the total federal investment in energy R&D (expenditures for all agencies) was about 0.5% of total U.S. energy expenditures.

20. The federal government has an essential role in addressing problems with long time horizons?

- When the private sector is not addressing issues that pose threats to the national security and well-being, federal involvement may become necessary. Industry will typically invest in products which have a relatively short payback period. However, energy problems may require several decades of development and success is not assured. Individual private companies may prefer to wait for others to develop a technology, and then modify aspects of that technology for their

purposes. Thus, there is likely to be insufficient industry investment in important long term R&D projects. Federal help is then needed to fill the gap. This should be done with a stability in funding that goes beyond the yearly Congressional budget cycles.

21. National energy policy options.

The APS statement on "Energy: the Forgotten Crisis" concludes that "Low-cost oil resources...are rapidly being depleted," that pollution is a threat to human health and the environment, and that changing climate patterns may be expected from massive reliance on fossil fuels. These conclusions indicate the need for action by the nation. We present the following illustrative policy options that respond to these conclusions. Their presentation does not necessarily signify endorsement, but it illustrates a range of options that we think worthy of consideration and further analysis.

a. Means for establishing national energy priorities and policies.

The long-term decline in general energy research funding, and the severe fluctuations in funding individual energy technologies demonstrate the need for a coherent, long-term, and bi-partisan, U.S. energy policy. One possible step towards this goal could be the establishment of a permanent, bipartisan presidential commission to provide a continuous review of energy policy.

b. Energy education and communications initiatives.

It is desirable to increase efforts, especially within the education programs of the Department of Energy, to educate the public -- particularly students, teachers, and consumers -- about the vital contribution of energy to our national well-being and the fundamental issues and problems surrounding its production and use.

c. Measures to promote efficient and prudent use of energy.

Technological improvements in energy efficiency provide the most readily accepted means for restraining energy consumption. These have had remarkable, although not well-enough noticed, success over the past two decades. Further gains may be achievable through R&D efforts directed toward cost-effective technological improvements. Consideration also should be given to the implications of possible additional measures, such as: (i) gasoline taxes to reduce the use of oil; (ii) higher fuel economy standards for passenger cars, the extension of fuel standards to additional classes of vehicles (e.g. light trucks, minivans), or a revenue-neutral "feebate" system of sales taxes and rebates designed to encourage the purchase of vehicles with good fuel efficiency; and (iii) increased energy standards on buildings and appliances.

d. Measures to encourage non-fossil sources for energy production.

For renewable energy sources that may be approaching competitiveness in some regional markets, such as solar thermal electricity and wind energy, the maintenance or extension of moderate financial incentives could speed the large-scale introduction of the technology. This would permit the evaluation of its economic and environmental merits. For more expensive technologies, such as photovoltaic power, it may be desirable to spur technological development through more direct assistance in research, development, and test deployment.

To maintain and extend the nuclear fission option, it is important to complete the design and the Nuclear Regulatory Commission review of new reactors that may offer safer and more economical nuclear power. It is also crucial to resolve the institutional and technical uncertainties impeding the establishment of interim and permanent nuclear waste storage facilities. Establishing the practicality of the nuclear fusion option requires intensified research and development efforts, including participation in international collaborations.

References

1. Annual Energy Review (1995), Annual Energy Outlook (1996), International Energy Outlook (1995), Largest U.S. Oil and Gas Fields (1993), Monthly Energy Review (August 1996), Commercial Building

Energy Consumption (1992), Household Energy Consumption (1993); all from the Energy Information Administration.

2. Useful data can be easily obtained on the world wide web: U.S. Energy Information Administration (<http://www.eia.doe.gov>), U.S. Geological Service (<http://www.usgs.gov>); American Petroleum Institute (<http://www.api.org>); U.S. Bureau of Transportation Statistics (<http://www.bts.gov>); Energy Efficiency and Renewable Energy Network (<http://www.eren.doe.gov>); EcoNet (<http://www.igc.apc.org/energy>).