Overview

The energy crisis of the early seventies has evolved into a more complex and subtle national situation that still entails major dangers. Some fuels, gasoline in particular, are actually cheaper now in real terms, and none shows any signs of imminent resource constraints. Energy is used with far greater efficiency than 20 years ago and with less environmental damage per unit of consumption. However, the long-term problems of our growing energy use-accumulating environmental degradation, the national security costs of imported oil supplies, and a worsening trade imbalance from rising levels of oil imports-are as intractable as ever.

Improved technology is a major reason for the present lull in attention to energy. A vast number of options that improved overall energy efficiency allowed the economy to grow 39 percent from 1972 to 1985 with essentially no increase in energy consumption. New technology has also improved the production of oil and natural gas and the combustion of coal. Success in moderating demand and improving supply has led to the present situation of ample supplies at moderate cost. Technology can continue to provide new benefits in the future. Many more technologies for the conversion and use of energy are well along in the development process and can be expected to be cost competitive with further refinement or energy cost increases. Tables 1 and 2 show the technologies that are available or under development for greater efficiency or alternative energy sources.

The three greatest uncertainties facing energy policymakers are: how to assure a long-term supply of reasonably priced, convenient fuels, especially for transportation; how to protect the country against disruptions of petroleum imports; and how to mitigate emissions of carbon dioxide if global warming concerns require it. Just as energy itself is useful only insofar as it enables one to achieve some desired service, energy policy is important only in its contribution to the three fundamental national goals of a clean environment, healthy economy, and security. Some initiatives contribute to all three goals, while others have conflicting results.

Failure to address these uncertainties could have very serious implications eventually. All indications suggest that U.S. oil production is in an irreversible decline. Not only are imports almost certain to rise, but peaking production in petroleum fields in other countries indicates that an increasing share of production will be from the Middle East. If the instability of the last several decades continues in that region, it is likely that major disruptions of supply, possibly exceeding our ability to protect the economy against them, will occur. U.S. production of natural gas, the cleanest conventional fuel, may rise some, but it is likely that within a decade the lowest cost resources will be significantly depleted. Oil and gas supply almost two thirds of our energy demand, so the economic cost of price increases will be great unless alternative modes of production or substitutes are available. Failing to prepare for new environmental concerns could lead to extremely costly impacts if global warming develops into a major threat. Complacency on energy issues entails a major risk for the country on all counts-security, economic, and environmental.

High energy prices in the seventies and early eighties were largely responsible for the rapid development and implementation of energy saving technologies that reduced energy demand and led to today's relatively low energy prices. Conversely, these low prices, while good for the economy, are limiting further efficiency, resource exploration, and alternative fuel investments.

Energy investments, whether supply or demand, typically last for decades. Thus, the energy system is slow to change, and problems that are unlikely to be critical for 20 years or more will be far more difficult to manage then if not addressed now. These critical problems include responding to the threat of global climate change, securing affordable supplies of energy, and protecting against oil import disruptions.

There is not now, and probably never will be, any single energy option that will ideally solve our long-term requirements. All options entail some compromises. Opportunities to improve energy efficiency are closest to the ideal. Many cost-effective opportunities exist, even at today's energy prices. Such investments are generally environmentally beneficial because they reduce energy production and consumption, economically beneficial because they more nearly approach rational distribution of resources, and beneficial to security because they reduce petroleum imports. However, significant structural and behavioral barriers impede their implementation. Alternative energy sources (e.g.,

Table I—Technologies Affecting Demand

Technology	Sector	Availability	Comments
Variable speed heat pump	Residential/commercial	C,N	Improves energy efficiency and provides more flexible control. Widely used in Japan. Increasing market share in United States.
Scroll-type compressors (heat pump/air conditioning)	Residential/commercial	C	Newer scroll-type compressors are 10 to 20 percent more efficient than reciprocating ones. Widely produced in Japan.
Thermally active heat pump	Residential/commercial	R	Could have significant impact in 10 to 20 years.
Low-emissive windows	Residential	C,R	Significant impact on reducing thermal energy loss in homes. Research needed on improving durability, lowering emittance, and reducing condensation.
Heat pump water heaters	Residential/commercial	C	Offers significant reduction in electricity use; premium cost. Commonly used in Scandinavia.
Alternative insulation materials	Residential	R	Needed to counter loss of chlorofluorocarbon-blown insulation. Now being developed and tested.
Refrigerator insulation	Residential	R	Greatest potential for appliance efficiency improvements. New products include vacuum insulation, compact vacuum insulation, and soft vacuum insulation.
Efficient lighting products	Residential/commercial	C,N,R	Combination of lighting options can cut commercial energy use significantly. Improved fluorescents, compact fluorescents, and electronic ballasts commercially available. Research and development continuing on improving phosphors.
Building energy management and control systems	Residential/commercial	C,N	Greatest potential for savings in the commercial sector. Advances in this technology have been continual.
Industrial process changes:			
—Separation	Industrial	C,N,R	Improvements in separation and control, and the use of membrane technology and solvent extraction could reduce energy use considerably.
—Catalytic reaction	Industrial	C,N,R	By increasing reaction rates, lower temperatures and pressures can be used that reduce heating and compression requirements. Discovery and use of new synthetic zeolites have contributed to energy efficiency gain in petroleum refining and chemicals industries.
—Computer control and sensors	Industrial	C,N	Improved monitoring and control optimizes conversion and distribution of energy. Potential savings range from 5 to 20 percent.
Advanced turbine:			
-Steam-injected gas turbine (STIG)	Industrial/utility	C,N	Currently used in cogeneration applications.
—Intercooling (ISTIG)	Industrial/utility	N	Has potential to raise efficiency to about 50 percent. May be better suited for utility applications; pilot-plant stage.
Electric motors	Industrial	C	Adjustable-speed drive and new high-efficiency motors account for about half of the total potential savings in U.S. motors.
2-stroke engine	Transportation	R	Holds promise for long term. Questions remain about ability of engine to comply with emissions standards.
Direct injection/adiabatic diesel	Transportation	C,R	Limited passenger car application in Europe; offers considerable efficiency improvements for both light-duty vehicles and heavy trucks. Questions remain regarding meeting more stringent emission standards.
Ultra-high bypass engines	Transportation	C	Can raise efficiency by about 20 percent but costs two times as much as current generation bypass engines.
Alternative fuels:			
—Alcohol fuels	Transportation	C,N,R	Use of methanol and ethanol should result in greater engine efficiency but costs are higher.
—Electricity	Transportation	R	Big greenhouse advantage if derived from nuclear or solar energy.

KEY: C - commercial; N - nearly commercial; R - research and development needed.

SOURCE: Office of Technology Assessment, 1991.

nuclear, renewable, synthetic fuel) have some advantages, but none will be cheap relative to current fossil fuels. Thus without major policy initiatives, our energy system is likely to maintain its high dependence on conventional fossil fuels for several decades, increasingly interfering with environmental and security goals and using more than the optimal amount of energy.

Table 2—Major Technologies for Energy Supply and Conversion

Technology	Availability	Comments
Oil		
Deepwater/arctic technologies	C,R	Existing technologies that are promising for deepwater areas include guyed and bouyant towers, tension leg platforms, and subsea production units. Advances in material and structural design critical; innovative maintenance and repair technologies important.
Enhanced oil recovery techniques —thermal recovery —miscible flooding -chemical flooding	C,R	Widely adopted over the past two decades.
0il *shale and tar sands* —Surface retorting —Modified in situ	C,N	Uneconomic at present oil prices.
Natural gas		
—Hydraulic fracturing	c	Very complex process; not well understood although successful for some formations. Key to unlocking unconventional gas reserves.
Coal		
—Atmospheric fluidized-bed combustion (AFBC) —Pressurized fluidized-bed combustion (PFBC)	N,R	Small-scale units commercial. Utility-scale AFBC in demonstration stage. PFBC is less well developed; pilot-plant stage.
—Integrated gasification combined cycle (IGCC)	N	Demonstration stage. Primary advantages are its low emissions and high fuel efficiency.
—Flue-gas desulfurization (FGD)	c	Mature technology; considerable environmental advantages.
—Sorbent injection	C,N	Commercially available control technology. Can remove nitrogen oxides up to 90 percent.
-Staged combustion	R	Has potential to remove up to 80 percent of nitrogen oxides.
Nuclear		
—Advanced light water reactor	c	Incorporates safety and reliability features that could solve past problems; public acceptance uncertain.
—Modular high-temperature gas reactor (MHTGR)	N,R	improvements to familiar technology; incorporates passive safety features; design of modular reactor completed.
—Power Reactor inherently Safe Module (PRISM)	R	Conceptual designs expected to be completed this year.
Electricity		
—Combined cycle (CC)	c	Conventional CC is a mature technology; advanced CC is in demonstration stage.
—Intercooilng Steam injected Gas Turbine (ISTIG)	N	Pilot-plant stage. *
—Fuel ceils	R	Several types being developed. Fuels cells that use phosphoric acid as electrolytes are in demonstration stage. Molten carbonate and solid oxide are alternative electrolytes that are less developed. Late 1990s availabiiity, at the earliest.
—Magnetohydrodynamics (MHD)	R	Difficult technical problems remain, especially formal-fired MHD systems.
—Advanced batteries	R	Research and development needed in utility-scale batteries to improve lifetime cycles, operations maintenance costs. Promising batteries are advanced lead, zinc-chloride and high-temperature sodium-sulfur..
-Compressed air energy storage (CAES)	c	First U.S. plant (110-MW)to begin operation in 1991; owned and operated by Alabama Electric Cooperative, Inc.
Biomass		
—Thermal use	c	Use of biomass by utilities is usually uneconomical and impractical.
—Gasification	c	Anaerobic digestion used commercially when biomass costs are low enough. Methane production from biomass not yet competitive with conventional natural gas unless other factors considered.
—Production of biofuels	C,R	Research being done on wood-to-ethanol/methanol conversion processes. Could be demonstrated by 2000.

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Policies to address long-term energy concerns include a wide range of initiatives. Energy taxes can internalize costs, e.g., security or environmental damage otherwise not considered in decisions on appliance, automobile, and industrial process purchases. Financial mechanisms, e.g., subsidies, can target particularly favorable but otherwise uncompetitive (at current energy prices) investments. Regulation can apply standards to raise performance of automobiles, appliances and buildings, and control the conditions under which Federal lands are available for oil and gas exploration. Information programs can improve decisionmaking. Research, development, and demonstration can make available

Table 2—Major Technologies for Energy Supply and Conversion-Continued

Geothermal —Dual flash —Binary cycle	N	Single-flash system used extensively. Little commercial experience with dual flash. Binary cycle system maybe available in 40 to 50 MWerange by 1995.
Solar thermal electric		
—Central receiver	R	Several plants built, including one in California; 30-MW plant in Jordan is major project today.
—Parabolic solar trough	c	several commercial plants built in California;additional capacity planned appears to be marketable.
—Parabolic dishes	R	Testing being conducted in new materials and engines such as free-piston stirling engine.
Photovoltaic —Concentrator system —Fiat-plate collector	N,R	Improvements needed to make photovoltaic cells economic in the bulk power market advances in microelectronics and semiconductors can make photovoltaics competitive with conventional power by 2010.
Wind power	c	Renewable source closest to achieving economic competitiveness in the bulk power market. Current average cost is 8 cents/kWh.
Ocean thermal energy conversion (OTEC)	R	Research focused on dosed and open cycle systems; no commercial plants designed. May be competitive in 10yearsforsmallislandswhere direct-generation power is used. Use of OTEC domestically for electric power is unlikely except for coastal areas around Gulf of Mexico and Hawaii.

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SOURCE: Office of Technology Assessment, 1991.

new options. The Federal Government can contribute directly to ameliorating energy problems by taking advantage of highly cost-effective measures to reduce energy purchases for Federal facilities by at least 25 percent.

Initiatives generally could be aimed at improving the efficiency of use of energy and the supply of energy. This report contrasts a baseline scenario (no major initiatives or surprises) with five variations representing different paths the Nation could follow:

- emphasizing production of conventional fuels,
- improving efficiency of use to the economic optimum,
- minimizing the use of energy as far as is technologically possible,
- emphasizing renewable energy sources, and
- emphasizing nuclear energy.

Any of these scenarios could be the most appropriate path depending on the resolution of uncertainties over climate changes induced by the greenhouse effect, technological developments, and resource discoveries. Each scenario presents risks as well as opportunities. This report describes the choices available to policymakers and the implications of choosing one path versus another.