SECTION 3

DISPERSED AND RENEWABLE ENERGY SYSTEMS

DISPERSED/RENEWABLE ENERGY SYSTEMS (3.0)

Introduction and Overview (3.1)

In this section, a range of alternatives to centralized energy systems are categorized and discussed. The rapid escalation of fossil fuel use and the development of materials-intensive energy technologies favored the development of economics of scale for centralized energy facilities. Today and in the future, growing energy demands and national vulnerability considerations point to a new potential for exploiting dispersed and renewable energy sources and technologies.

Traditionally, energy needs have been met by adding new capacity to the electrical system, drilling new oil wells, building new energy facilities, importing foreign resources and extending the centralized production and distribution systems. The challenge of developing less centralized energy systems is one which affects all elements of the society, from economic planners in the private sector to government regulators. A recent conference of leading government and industry officials noted that decentralized electric generation systems conferred benefits such as short lead times in construction, reduced capital requirements, greater efficiency, and reduced vulnerability to fuel shortages. Conversely, disadvantages were seen as difficulties with system integration, need for back-up power, and a limited but continued dependence of fossil fuels. The conference proceedings concluded:

> The potential for decentralized technologies as fuel savers or displacers in the electrical sector in the next twenty to thirty years is high—up to 20-25 percent of future generating capacity. These technologies include principally the solar ones (thermal, photoovaltaic, wind machines, hydro); conservation technologies such as heat pumps, new appliances, and insulation; and cogneration and fuel cells using fossil fuels. These technologies, especially the solar ones, are highly capital, materials and energy intensive during the build-up time of their deplayment and so their benefits need to be discounted at least over 20- to 30-year time periods. Also, a production base for decentralized technologies needs to be established and their equitable treatment in the rate structure needs to be formulated.
>
> Current R & D activities funded by the government, not-for-profits and industry provide a spectrum of innovative opportunities. The problem is to demonstrate that these technologies can provide economic and reliable service on the scale needed by users. How to finance these operational demonstrations is an open question: a proper balance of government, private, and ratepayer investments needs to be formulated. The goal should be to provide users with a wide

> range of true economic alternatives from which they can select the technologies of greatest utility to them, subject to governmental policies and regulations on rates, the environment, fuel use, and the health and safety of the public. The process of choice among these technologies, and of their demonstration, is the determinate question, rather than the establishment of specific end results on an a priori basis.[1]

From a strategic perspective, the technologies considered in Section 3 are all capable of contributing to national, regional, and local energy needs. They range from conservation strategies, which will play a major role in reducing oil dependence and vulnerability, to future incorporation of solar, small hydro, wind and other renewable technologies into the nation's energy system.

Within a relatively short time, combinations of these alternative technologies can be integrated with existing systems. Over a longer time frame many of these technologies may replace conventional systems and usher in a less dependent, more secure energy future for the United States.

Energy Conservation (3.2)

Introduction (3.2-1)

At present and for the foreseeable future, attemps to increase national energy conservation and improve the efficiency of energy use will be our major strategic energy "source." Unlike new energy facilities which take years to construct and often entail substantial capital investments, most conservation and efficiency options are available to the U.S. now, at costs below those of imported fuels and new facilities.

Robert Stobaugh and Daniel Yergin recently summarized the significance of moving boldly and rapidly to implement energy conservation:

> The telescoping of the energy emergency in 1979 has greatly increased the urgency of early action. As things stood in 1978, and given the decision now made to decontrol oil prices, we might have hoped to continue with 'business as usual' on energy conservation, allowing higher prices to work through the economy and gradually cause us to increase energy efficiency....
>
> In current circumstance, however, such a course will not be adequate. The gap between energy resources and energy demand would be closed by "unproductive conservation" -- the shutting down of factories, higher unemployment, higher inflation, offices too warm in the summer for efficient work, colder houses, a choice for some between food and fuel....
>
> Far more desirable is the alternative of accelerated energy efficiency. Our whole industrial system is like a vehicle built to operate on $3 oil, puffing along with an inefficient engine and with a body leaking vast amount of energy. Each drop wasted drives higher the price of future oil purchases...[2]

Efforts to accelerate conservation can have a number of strategic effects. In addition to reducing imported energy sources, the following is possible:

- Reduced energy demand decreases pressure on centralized systems and reduces the need for costly new construction of these facilities.
- Reduced energy demand can also reduce strategic material demand.
- Reduced capital requirements for energy facility construction can be channeled to other areas of the economy.
- Inflation can be reduced, affecting the entire economy.

The director of the Joint Economic Committee's energy subcommittee has stated:

> By the end of the decade, conservation savings have the potential of wiping out the majority of our oil imports, while synfuels will be producing no more than a million barrels a day...Why then, has so little been done? For one thing, today's energy supplies are heavily subsidized while conservation is not. Conservation will yield enormous rewards and can do so fairly quickly, but only in modest and multiple increments, after hard decisions frequently best made without fanfare, with political pressure against institutional lethargy and with thousands of public and private investments.[3]

Energy Conservation Targets (3.2-2)

Residences

Residential use of energy accounts for twenty percent of energy consumption in the United States.[4] Increasing energy cost and uncertain future energy supplies have spurred a reassessment of the energy intensive building designs of the 1960s and 1970s. A combination of retrofit, technology change, creative design, and economic incentives will all contribute to the construction of more energy-efficient buildings. Table 3.2-1 provides a percentage breakdown by use of average U.S. residential energy consumption.

Table 3.2-1[5]

RESIDENTIAL ENERGY CONSUMPTION, BY USE

Use	Percent
Space Heating	53
Hot Water	14
Cooling	5
Air Conditioning	7
Other	21
TOTAL	100

Many of the conservation efforts that have been proposed are not in the best interest of long-range effectiveness. The energy vulnerability of the United States is actually increased by "quick-fix" conservation efforts when those efforts perpetuate the use of existing energy intensive technologies and diminish the level of investment in energy-efficient systems and approaches. The most effective energy policy would encourage rapid turnover of inefficient machinery and replacement of high energy consuming buildings and equipment.[6]

Short of structure replacement, many buildings can be "tightened up" or retrofit to ensure more efficient energy utilization. Retrofit alternatives include ceiling and wall insulation, storm windows and doors, heat pumps, weatherstripping, caulking, day-night thermostats, and pilotless natural gas furnaces. New buildings incorporating these features as well as passive solar designs, natural cooling capability, more efficient space conditioning systems and more efficient use of mass and materials offer even greater conservation opportunities.

Additional conservation opportunities also exist in the residential sector by the use of more efficient appliances and machinery including refrigerators, water heaters, and other large energy-consuming devices. Energy savings from such equipment will be realized chiefly through better engineering and construction standards promoted by regulation, although market forces will continue to be a factor as consumer preferences respond to increasing energy costs.

Industry

Industry accounts for 39.5 percent of total U.S. energy consumption.[7] The industrial sector has made the greatest progress in energy conservation. Decreased profits tend to generate interest in searching for cost-effective methods to save energy through improved maintenance procedures, recycling, waste heat recovery, and energy-efficient machinery.

Industrial conservation programs have demonstrated a significant degree of success for major U.S. companies such as Lockheed, which reduce 59 percent of its energy demand between 1972-77 in its Los Angeles factory complex at little or no capital expense. In its U.S. refineries, Exxon reduced energy use 21 percent during this same period—80 percent of this saving was developed with little or no capital invested. The savings are equivalent for this one corporation of 11.3 million barrels of oil per year.[8]

A much-needed increase in industrial conservation programs may occur as a result of new federal laws, such as the ten percent business energy investment tax credit established by the 1978 National Energy Act. Tax credits and faster depreciation schedules are considered to be major inducements for industrial conservation efforts. However, the Internal Revenue Service (IRS) has only recently issued proposed rules for technologies qualifying for the credit. A recent industrial analysis of the rules state, "in a major setback for users IRS failed to expand the list of specifically defined energy property that qualifies for the tax credits, although the 1978 law encouraged such a move by the Secretary of Treasury."[9]

Notwithstanding disincentives, industrial conservation efforts continue to provide a major "source" of energy supply, reducing overall demand and the need for imported energy.

Transportation

Transportation accounts for 26 percent of the total United States energy consumption, with the automobile accounting for over half that amount. The dispersed settlement patterns characteristic of the U.S. indicate that the automobile will remain a focal point for conservation efforts for some time. The most viable conservation targets can be met with reduced driving speeds and increased automobile efficiency. Some conservation might be attained through the development of efficient, flexible mass transit systems and lesser, related efforts such as ride-sharing and variable work schedules.

The major gains in automobile efficiency has been the result of weight reduction and the importation of foreign technology. Yergin points out that "substantial technological innovation is needed in materials, engine and design; and this kind of innovation, as opposed to styling, has not been a major priority for the industry or its suppliers. Massive capital investment is needed over a decade for the four U.S. automotive companies, which will increase vehicle costs."[10]

Such investment might be directed toward the development of radically different smaller cars including two passenger vehicles. Statistics show these would suffice for three-fourths of all trips. The redesign of existing large cars for five-year production runs, to hand on to rapidly dwindling markets, is extremely costly compared to the one-step introduction of extremely efficient cars.[11] The technology to build an 80 mpg auto fleet is nearly ready for commercialization.[12] Table 3.2-2 represents future fleet possibilities available in the near future, with appropriate investment.

Table 3.2-2[13]

FUTURE FLEET POSSIBILITIES

	Vehicle Class	Vehicle Test Weight (lb)	Cruise hp 55 mph	Extra hp, 55 mph, 5% grade	Accerlation power (hp)	Average Engine		Projected mpg
						hp	cylinder	
2 Passenger	Available Now	2250	14.8	—	--	--	—	—
	Available 1982	1500	9.0	11.0	16.9	23	2	110
	Test Demonstration	1050	7.2	7.7	12.2	18	2	140
4 Passenger	Available Now	2000	13.0	—	--	--	--	--
	Available 1982	2000	9.8	14.7	21.4	32.5	3	78
	Test Demonstration	1400	7.8	10.3	15.4	27.1	3	93
5-6 Passenger & light truck	Available Now	2500	13.5	--	--	--	—	—
	Available 1982	2500	10.1	18.3	25.9	43.6	4	58
	Test Demonstration	1750	8.1	12.8	18.6	35.9	3	70

Other possibilities in this area include driver efficiency training programs, automobile registration fees based on efficiency and weight, regulation of fuel prices, and increased fuel taxes.

Conservation Incentives (3.2-3)

The federal government's response to the 1973-1974 oil embargo was to set an objective of achieving energy independence by decreasing oil imports while expanding the development of domestic fuels. National incentives for energy conservation are represented by passage of the following legislative measures:

- Energy Policy and Conservation Act (1975)

  a. set automobile fuel economy standards which established average fleet mileage requirements
  b. set efficiency targets for large appliances
  c. set targets for industrial-energy conservation
  d. provided assistance to states for development of state energy plans

- Energy Conservation and Production Act (1976)

  a. set energy conservation standards for new buildings, Building Efficiency Performance Standards (BEPS)
  b. establish a low-income weatherization programs

- National Energy Extension Service Act (1977)

  Each state is responsible for developing and implementing a comprehensive program for direct, local, and personalized assistance to encourage small energy consumers to adopt techniques and technologies that save energy.

  a. ten pilot states were funded initially for 1978-79 to deliver programs through existing agencies.
  b. all 50 states and trust territories implement programs in 1980-82

- National Energy Conservation Policy Act (1978)

  a. established the Residential Conservation Service (RCS) through which utilities will conduct energy audits and arrange for financing and installation of insulation and other conservation devices or measures.
  b. extended the low-income weatherization program to 1980
  c. established the Schools and Hospitals Program
  d. set appliance efficency standards
  e. established home improvement loans for energy conservation

- Public Utility Regulatory Policies Act (1978)

  a. required that retail regulatory policies for electric utilities be reviewed by state regulatory commissions to consider and determine ratemaking standards (including lifeline rates) that would encourage conservation
  b. allowed for more equitable rates of return for small cogeneration and small hydroelectric facilities' sales to utilities
  c. encouraged conservation of energy supplied by gas utilities, the optimization of the efficiency of use of facilities and resources by gas utility systems, and provided for equitable rates to gas consumers of natural gas

- Windfall Profit Tax Act (1980)

  a. continued price decontrols (which has the effect of increasing conservation as the market adjusts to actual energy costs)
  b. expanded the categories eligible for federal tax credit
  c. established the Energy Investment Tax Credit to encourge commercial conservation investment

- Energy Security Act (Title V) (1980)

  a. established a Federal Solar and Conservation Bank through which approximately 80 percent of the funds allocated were earmarked by increasing incentives for the purchase and installation of conservation equipment through:

     1. principal reduction on loans
     2. direct grants to consumers
     3. payments to banks for pre-paid interest

  b. removed the ban, instituted by previous legislation, on direct utility financing of energy conversation measures and alternative energy equipment

The Energy Management Partnership Act, if enacted, would allocate more federal money to the states for conservation planning with the objective of consolidating existing programs and promoting state and regional planning.

Research, Education and Regulation (3.2-4)

Growth in privately-initiated and federally-sponsored energy conservation research and development has not grown as quickly as research and development programs in energy production.

Government-sponsored research could address obstacles such as consumptive behavioral patterns, structural and institutional barriers, and legal restraints to maximizing conservation. Non-economic factors affecting the final selection of a product also need to be analyzed to determine factors in consumer decisions to effect conservation.

Table 3.2-3 summarizes the opportunities for technological research which could be conducted in support of energy conservation. Clearly the tasks are as demanding as those in any other area of energy development.

Table 3.2-3[14]

OPPORTUNITIES FOR TECHNOLOGICAL RESEARCH AND DEVELOPMENT FOR ENERGY CONSERVATION

	Buildings and Appliances	Transportation	Industry
Basic studies	Properties of materials Automatic control technology	Materials properties, e.g. strength-to weight Thermodynamics of internal/external combustion engines Chemical energy storage Automatic control technology	Materials properties at high temperatures Characteristics of industrial combustion Heat transfer and recovery methods Automatic control technology
Near-term energy-use patterns	Automatic set-back thermostats Pilot/burner retrofit	Specific data on factors that influence fuel economy of existing cars	Improved methods for energy monitoring and housekeeping
Intermediate-term retrofit	Reinsulation methodologies Solar water heating and passive design Metering for time-dependent utility pricing Automatic ventilation control for building and appliances (e.g., clothes dryers)	Improved power-to-weight ratios, as well as interior volume-to-weight ratio Instrumentation to provide driver with real-time data on fuel efficiency Improved intermodal freight and passenger terminals Improved traffic control	Process retrofit technologies Improved methods for scrubbing Cogeneration of heat and electricity Automated monitoring of energy performance Low-temperature heat utilization
Long-term technologies	High-performance electric and heat-driven heat pumps Solar space cooling Sophisticated appliance controls and integrated appliance design More sophisticated design of buildings to provide desired amenities at low energy demand	New motors Improved aerodynamic design for cars, trucks New primary energy sources (liquid, electric) Improved intermodal transfer technology Technology for improved efficiency in air transport	Basic new processes that reduce overall requirements for energy and other resources (e.g., recycling, durability) per unit output Modification of material properties to enable replacement of energy-intensive materials with less energy-intensive material in specific applications

The automobile efficiency standards established after the oil embargo are a good example of a major regulatory program. The Ford Foundation report suggests "...that the standard may reduce long-run gasoline consumption by about 26 percent from what it would have been otherwise. New car efficiency is projected to increase by 47 percent, and vehicle miles by 8.8 percent."[15] In this case the regulations spearheaded market changes that had been traditionally resisted. Since there is a tendency for regulations to become entrenched and solidified after adoption, maintaining flexibility merits close attention by policymakers. Energy efficiency regulations may be best approached incrementally and be modified as technologies and methodologies change.

It has been suggested that rate reform is necessary to eliminate distortion and the restricted pursuits of energy conservation.[16] Current energy prices do not represent the numerous factors affecting actual costs of energy production. For example, if the price charged for using electricity reflected actual production costs, consumer rates would reflect the marginal operating and fuel costs associated with peak capacity generation. Some experts argue that there can be no justification for declining block and discounts to volume users in a period of shrinking energy supplies.

> One relentlessly rising fuel consumption has had an institutional rationale. A dollar invested in facilities to produce more energy makes energy available to the producer, who then sells it for profit. Although the same dollar invested in conserved energy (which would otherwise be wasted) is energy that the energy producer had already counted as sold; the company, for whom a dollar burned is a dollar earned, is generally unenthusiastic about "returned merchandise." If a utility sells a billion kilowatt hours this year, and ten years from now is still selling a billion kilowatt hours, its dividend-conscious stockholders will take little satisfaction in the greater efficiency and benefits of the future billion. Corporate officers cannot relish the prospect of informing stockholders and lending institutions that their company has completed a successful transition into a non-growth economy.[17]

National conservation programs were recently evaluated by the Office of Technology Assessment, which suggests that they are fraught with problems at a time of increasing need and expectation.[18] The report calls for rigorously defined conservation goals to supplement the Committee on Nuclear and Alternative Energy System's (CONAES) scenarios that are currently used to set energy-saving levels:

> It is necessary to define what actually has to happen for the nation to meet the goals and what DOE's role must be to ensure success. National security considerations may make...conservation implementation even more imperative than it appeared at the time that goals were set.[19]

The nation's conservation programs could further detail goals and objectives by identifying:

- materials necessary to achieve the desired results
- anticipated technological changes
- resource projection and location
- estimated time requirements for removal of market barriers
- anticipated time requirements for turnover of capital stock, and
- necessary capital investment

Long-term objectives are also necessary for both program implementation and program evaluation. Evaluation of energy conservation programs allows for continuous assessment of strategies and their degree of coordination relative to national objectives.

State programs vary in scope and intensity. Energy demand growth has been reduced in California by means of a variety of conservation actions. California utility demand forecasts predicted that the electrical peak demand would be in excess of 41,000 MW in 1979; the actual 1979 demand was 6,000 MW less.[20] California has set state conservation standards for appliance efficiency, new residential and non-residential buildings, automobile efficiency, and utility load management. California is carefully monitoring federal policy formation to ensure that the standards adopted at the national level do not conflict with more stringent state standards.[21]

Projections (3.2-5)

Projections can be illustrative of potential trends and relationships within the total energy system. The Committee of Nuclear and Alternative Energy Systems (CONAES) report is based upon assumptions of energy price, GNP growth, population growth, conservation, energy resource/power production, and policy/regulatory conditions. Table 3.2-4 and Figure 3.2-1 represent energy demand projections under five energy conservation policy.[22] These show valuable indicators of the possible range in energy-consumption, by sector, as a result of specific policy direction.[23] Table 3.2-5 summarizes U.S. energy consumption and indicates potential savings across residential, commercial, industrial and transportation sectors.

Table 3.2-4[24]

SCENARIOS OF ENERGY DEMAND: TOTALS

Scenario[a]	Average Delivered Energy Price in 2010 as Multiple of Average 1975 Price (1975 dollars)[b]	Average Annual GNP Growth Rate (percent)	Energy Conservation Policy	Energy Consumption (quads)					
				Buildings	Industry	Transportation	Total	Losses[c]	Primary consumption[d]
Actual 1975	--		--	16	21	17	54	17	71
A* (2010)	4	2	Very aggressive, deliberately arrived at reduced demand requiring some life-style changes	6	26	10	42	16	58
A (2010)	4	2	Aggressive; aimed at maximum efficiency plus minor life-style changes	10	28	14	52	22	74
B (2010	2	2	Moderate; slowly incorporates more measures to increase efficiency	13	33	20	66	28	94
B (2010)	2	3	Same as B, but 3 percent average annual GNP growth	17	46	27	90	44	134
C[e] (2010)	1	2	Unchanged; present policies continue	20	39	26	85	51	130

[a] Scenario D is not included in this table; its price assumption (a one-third decrease by 2010) appears implausible.

[b] Overall average; assumptions by specific fuel type were made reflecting parity and supply; price increases were assumed to occur linearly over time.

[c] Losses include those due to extraction, refining, conversion, transmission, and distribution. Electricity is converted at 10,500 Btu/kWh; coal is converted to synthetic liquids and gases at 68 percent efficiency.

[d] These totals include only marketed energy. Active solar systems provide additional energy to the buildings and industrial sectors in each scenario. Total energy consumption values are 63, 77, 96, and 137 quads in acenarios A, A*, B, and C, respectively.

[e] The Demand and Conservation Panel did not develop a scenario combining the assumptions of unchanging price and 3 percent average GNP growth. If scenario B is used as an approximate indicator, such an assumption would entail a primary energy demand of about 175 quads.

Figure 3.2-1[25]

DEMAND AND CONSERVATION PANEL PROJECTIONS
OF TOTAL PRIMARY ENERGY USE TO THE YEAR 2010 (QUADS)

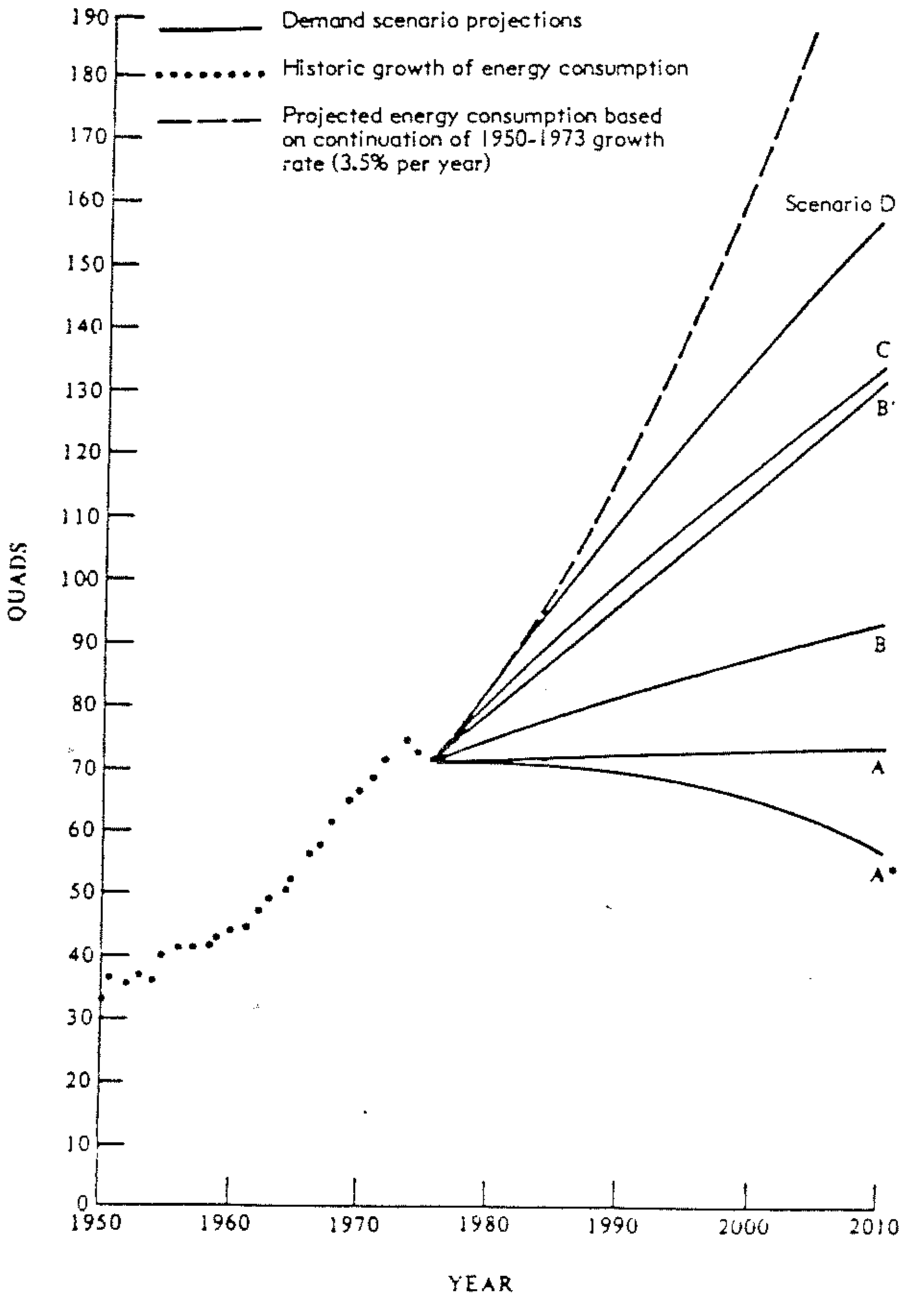


Table 3.2-5[26]

U.S. ENERGY CONSUMPTION (QUADS)

	Residential/ Commercial	Industrial	Transportation	Total
1979 Consumption	29.5	28.9	19.8	78.2
1990 No Change Path (Scenario C)	23.6	69.5	26.9	120
1990 Possible (Scenario B)	18.4	58.6	23.0	100
% Savings	22%	15.7%	14.5%	20%
1990 Possible (Scenario A)	14.1	43.6	16.5	80
% Savings	40.3%	37.3%	38.2%	40%

The Department of Energy has adopted the projections of the CONAES report as the basis for national energy conservation objectives. The energy savings depicted in Scenario A have essentially become the conservation goals for the United States. There is, however, no direct correlation between the goals and the current programs identified in DOE's Energy Conservation Program Summary Document.[27]

End-use estimates of potential energy reduction, costs, and time requirements are difficult to obtain. The historical record does not give insight into ways to reduce energy demand. There is no repository of information on the technological advancements, methodologies, and achievement levels necessary to reduce energy consumption although certain local efforts have produced remarkable results. Energy conservation is a new frontier for which the record is just now being established.

A potential role of government is to eliminate current discentives for implementing the most appropriate conservation technology. The choice of technology is a decision ultimately housed in the private sector. The market is responsive to the needs and desires of millions of individual decision-makers.

> ...in a time in which many Americans did not believe that an energy crisis existed or that, if it did, it was the result of conspiracy among the oil companies and in which polls revealed that more than half of the American public did not know that we imported any oil from abroad, home insulation sales sored. Price was talking to the consumer when administration policy, teleivision programs, and newspaper articles had failed to convince.[28]

As the marginal costs of energy rise in the coming years, it will become more and more profitable to make an investment "to save a Btu than to produce an additional one."[29] The CONAES report projected delivered energy prices to the year 2010. The results indicate a wide range of energy prices, which in turn have a wide range of effects on consumption levels. The report stresses the importance of allowing sufficient market-adjustment time after introduction of increased energy prices or decreased supplies in order to avoid major economic disruption.[30]

Time Requirements (3.2-6)

Estimates of the time required to reach certain levels of energy efficiency vary, yet they share as a common strategy the need for long-term energy conservation planning. The CONAES report projects that following approximations of time required for replacement of non-energy efficient capital stock:

Housing	50+ years
Industrial plants	20-50 years
Automobile	10 years

It is anticipated that the rate of turnover will be expedited by increasing energy prices.

Conclusions: Conservation (3.2-7)

As the arguments and data presented for conservation indicate, strategies for energy conservation have both an immediate gain in reduced imports, economic savings, and reduced vulnerability, and a long-range gain, in laying the foundation for dispersed and decentralized supply development.

Conservation is a legitimate energy source, in some ways superior to the production technologies. Nevertheless, anything more than quickfix efforts will demand a significant commitment of research and development resources. As with the production technologies, meaningful energy conservation, that is, energy management, will entail a good deal of sophistication and innovation.

In line with the need for innovative approaches to the energy problem is the research of Roger Sant at the Mellon Institute. Recognizing that a different perspective on the situation is needed, he and his colleagues at the Energy Productivity Center have developed the "least-cost strategy," a perspective which concentrates on the end result of energy use and how best to provide individual consumers with those benefits at the least possible cost. He explains:

> The conventional import context in which the energy problem has been examined concentrates on the numbers of barrels of oil that can be produced or 'saved' through new production or conservation. Within this framework, the competing elements include various fuels--oil, coal, natural gas, etc. --and various methods of 'saving energy'--lower speeds on the highways, colder homes in the winter and warmer homes

> in the summer, etc. But production and conservation of a given number of barrels of oil or other quantities of energy only partially addresses the function of energy in our economy and lives. A thriving economy and a materially rewarding life are dependent not on the given quantity of energy consumed, but on the services or benefits that are derived from that consumption.[31]

The least-cost energy strategy assumes a traditional free market system in which traditional and alternative energy technologies face stiff competition to be the most energy-efficient technologies. Those that provide the same or better "service" at the least cost would prevail. To test this assumption, several analyses were performed to determine the kind of energy "savings" that could have taken place prior to 1978. The results indicated that the cost of energy services during 1968-1978 could have been reduced by seventeen percent with no curtailment of services.[32]

The study concluded:

> Although the least-cost strategy might not result in the 60 percent improvement is energy efficiency by 2010 that the CONAES study indicated is technically possible, or even the 32 percent that our analysis indicates is economically achievable in a much shorter period, the evidence we have provided demonstrates that there is ample competition to hold consumer costs to manageable levels for the required level of energy services.
>
> ...A wave of optimism--and commitment--is beginning to emerge from many quarters: these changes are possible, desirable and necessary. Perspectives have and will continue to change rapidly. When coupled with ingenuity, new technology and improved management, these changes can be powerful enough to master the energy problem. In fact, seen in this perspective, the problem is transformed into an opportunity—increased employment, new markets, an ehanced environment, a more secure energy future and most important, less onerous levels of energy service costs. We are definitely not stuck with our old attitudes about energy and energy conservation. Our analysis to date shows we can move to higher levels of productivity through a more competitive, consumer-oriented energy policy.[33]

Load Management and Energy Storage (3.3)

At present, the demand for instantaneous energy is met by fuel reserves, the most convenient form of large-scale energy storage. As pointed out by the Electric Power Research Institute (EPRI), "oil and gas stand out as the preferred fuels for storage because of their high energy density and their ease of transport and combustion. Utilities, in particular, have come to rely on them to run the power plants that are started up and shut down each day to meet peaks of demand for electricity."[34]

This reliance on fossil fuels is likely to change as fuel scarcities prevent the use of key fuels, and as the high capital costs of building "peaking" power plants are outweighted by more convenient and less costly options to utilities. These options include conservation, load management practices, fuel storage and energy storage technologies and other measures to reduce costly peak demands. As the EPRI Journal explains:

> Starting with the supply side (of the integrated energy system), direct and indirect storage of electricity from coal and nuclear baseload plants can displace the consumption of oil and gas in peaking and intermediate (cycling) power plants. Present estimates are that fully implemented utility storage systems could supply 1.5-2.5 percent of U.S. electric energy by the year 2000, providing up to 15 percent of peak load demand from stored coal and nuclear in some regions. For each gigawatt (1,000 megawatts is equivalent to the nuclear or coal power plant) of energy storage plant in operation, two to three million barrels a year of petroleum could be saved. The total savings for the United States at the turn of the century could be as high as 150-300 million barrels a year."[35]

Load Management (3.3-1)

Some estimates of the overall potential energy savings for load management and energy storage are considerably higher than that referred to by EPRI. It is theoretically possible to replace one-fourth or more of the existing power plants in the U.S. with "alternative power" in the form of stored energy, and properly managed loads. Although quantified estimates are not available, the theoretical possibilities indicate that millions of kilowatts of potential installed capacity can be deferred, and billions of dollars of investment in electrical and other energy facilities can be channeled into other potential economic areas.

Under the Public Utility Regulatory Policies Act, (PURPA) federal standards were established for the following utility rate and load management practices.

1. Rates charged by electric utilities "shall be designed, to the maximum extent practicable, to reflect the costs of providing electric service to such class..."

2. Declining block rates are discouraged, e.g. rates that encourage excessive use by minimizing unit costs to large consumers in "declining blocks."

3. "Time of Day" rates are encouraged, e.g. rates that discourage consumption during peak demand periods.

4. Seasonal rates are encouraged, to reflect the "costs of providing service to such class of consumers at different seasons of the year to the extent that such costs vary seasonally for such utility."

5. Interruptible rates, e.g. discounted rates for industrial and commercial customers that can be interrupted during peak load periods, are required.

6. Load management techniques to reduce peak demands (under the review of state regulatory commissions) are required, with the determination that they be:

   a. practicable and cost-effective
   b. reliable
   c. provide management advantages to the utility.[36]

The hallmark federal law additionally requires that load management techniques shall be determined by state regulatory commissions or unregulated public utilities, in accordance with these guidelines:

1. The technique must be likely to reduce the utility's maximum kilowatt demand.

2. The long-run cost savings to the utility must be likely to be more with load management, than without the application of load management.[37]

At present much is known about the peak demand periods of the nation's utilities, but little is known about load management approaches in a "real world" sense. How the various technologies for controlling consumer's loads and integration of these techniques with utility management practices remains to be determined.

Time-of-day rates and load management practices are frequently directed towards residential consumers of electricity in order to reduce the use of certain energy-intensive appliances, such as hot water heaters or air conditioners. Hot water heaters are a prime target for peak reduction practices, since their "coincident peak demand" is quite high. A Wisconsin utility survey found that individual water heaters average 4,500 watts in electrical demand.[38] Nationwide surveys have found that the average coincident peak demand falls in the range of .8 to 1.5 kw in a given utility system. This occurs because all hot water heaters are not running at the same time. On the average, about twenty percent are in use during peak periods.

Translated into power plant terms, one household appliance represents about 4.5 kilowatts of inferred capacity. Or in system terms, when twenty percent of these units are operating during peak periods, the capacity value of each unit is about one kilowatt. If the utility were to build new peaking power plants to meet the demand generated by water heaters, the cost per house would be the equivalent of $500 to $1,000 (installed costs, not counting fuel). However, by using commercially available thermal storage technologies in conjunction with load management devices to reduce the use of these appliances during peak periods, the utility would save the capital cost of building a new power plant. In fact, the conservation alternative is only $200 per house, which reflects the total cost of reducing the load and paying for additional heat storage. Translated in terms of thousands of consumers, the savings are potentially enormous. However, in order to credit the customer with a peak-reduction rate (in conjunction with using a timer on a water heater), the utility must be able to verify that the applicance is not capable of being used during a peak period. The central issue then becomes the actual control over energy use within the household.

According to two officials of the Wisconsin Public Service Commission, the answer may be time-of-day rates:

> An appropriate time-to-use rate alternative should be a temperature-sensitive rate. Then, each potential load management customer could achieve the same or regular savings under a time-of-use rate he should achieve under load management (LM) during peak demands. Moreover, he could install storage devices and timers. He would not try to cheat himself, since the conservation strategy would not reside with his imagination, not in some distant utility boardroom. The answer....lies in who owns and activates the LM controls. If the controls are activated by the utility, there is a built-in incentive for the customer to take the benefits and avoid the effects, if that is possible. If the customer activates the controls, the incentive is to maximize his benefits through the control of his appliances. The customer's pattern will depend on the time-differentiated price of electricity.[39]

A first step to load management is load research to determine a more prcise understanding of demand. This is now being conducted by the nation's utilities. The voluminous data developed by utilities can be used to shape load management programs. A recent Tennessee Valley Authority report on load research points out that "most of the nation's 90 million electric customers have their electric meter read once each month and those meter readings comprise an enormous data base which is maintained for many years under most state regulations. As large as that data base may seem, however, it only begins to scratch the surface in terms of telling how people use their electricity.[40]

New techniques for load research such as remote monitoring of customers' use of electricity, and feedback capability through microprocessor-coupled communications systems, offer utilities significant load control information, and potentially, load management options. New technologies for load management include remote monitoring and control of water heaters, air conditioners, and a variety of thermal storage devices to allow for cyclic operation of key appliances, including cooling devices.

Examples of innovative load management programs are actively being pursued by the Southern California Edison Company, a major private utility which serves Los Angeles and Southern California. One program, called "Demand Subscription Service" incorporates elements of load cycling and time-of-day rates. A demand-limiting device is installed at the residence (connected to the meter), which is set to disconnect electrical service if the demand for power is exceeded during a system peak or other period of capacity shortage. Once disconnected, the customer can reduce the residential electrical load under the present limit for service, then manually switch on the device. The system can be operated automatically by the utility's load controllers to reduce peak demands. The utility will place 2,000 of these units on residences during 1980 and 1981.[41]

Southern California Edison (SCE) has also established a new energy co-operative concept for load management for larger commercial customers (with an average of five megawatts of demand).

The first modern co-op was formed in 1979 in Orange County in Southern California. The Irvine Company, Fluor, Pacific Mutual Life Insurance and the South Coast Shopping Plaza formed the Orange County Energy Cooperative Association. For a monthly rebate of $120,000 (i.e., approximately $1.5 million per year) the co-op agrees to shave four MW off peak load whenever SCE requests it to do so. In practice the co-op has 30 minutes to reduce load to a fourteen MW maximum.

The initial capital investment saving to SCE under this arrangement is approximately $4 million (based on an estimated $1,000 per installed capacity). In addition, since peak load power is most often generated from standby reserves of oil and gas, the operating savings are also substantial and becoming more so as fuel costs escalate.

Other co-ops are in the formation stage by California's Pacific Gas and Electric Company (PGE) and in Nebraska. In areas where reserve margins are high, such as Dallas, Texas, co-ops are not being encouraged by the utilities. This situation, however, could change as large capital investments become ever more costly. Load management using electrical co-ops is being promoted and supported by the Department of Energy.[42]

Energy Storage (3.3-2)

A number of energy storage methods currently available or on the horizon would enable electrical energy generated in off-peak hours to be stored for use during high demand periods. The various energy storage technologies could also be utilized to harness the energy produced by alternative energy systems that are often tied to the unpredictable environment. This energy can be stores either as heat, electricity or kinetic energy.

Thermal energy required for storage can be derived from various sources, such as solar heat, winter cold, power plant waste heat, and industrial steam. In the case of solar heat, heat can be captured by collectors in the summer and stored. It can then be extracted for winter use when the demand for space heat peaks. The hot steam that is usually dissipated to the environment by electrical generation facilities can be used for district heating. This winter heating capacity can be increased by storing the heat energy from summer generation. In addition, this would reduce the thermal pollution generated by power plants and reduce the need for peaking units to meet exceptional winter heating demands.[43]

Aquifers are being considered for thermal energy storage. The ground water stored in aquifers is subject to geothermal radiation that usually maintains the aquifers' temperature about equal to the average annual surface temperature. This natural warming action provides a positive temperature differential for heating in the winter when ambient air temperatures are cooler and for cooling in the summer when the surface temperatures are warmer.[44]

This underground storage resource can be exploited by the use of a simple heat pump or heat exchanger. The basis mechanical concept for either heating or cooling is the same. A gaseous fluid with a low boiling temperature like ammonia or freon is cooled by lower pressures to a gaseous state and pumped into a higher temperature aquifer. This cool low pressure fluid absorbs the heat from the environment and then upon condensation it is circulated to warm a cooler environment. To remove the cooler temperatures from the aquifers during the summer, the process is reversed.[45]

The potential for using a heat exchange system to tap the energy storage capacity of aquifers is large. Heat pumps installed in aquifers are operating with a performance co-efficient greater than 4.0. It is estimated by Dr. Jay H. Lehr, of the National Water Well Association, that with a consumption rate of ten gallons per minute for domestic energy demands, that at least 70 percent of the surface of the country can be developed while commercial systems with an output of over ten million Btus can be located over 25 percent of the United States. Studies are now being conducted to determine the actual performance potentials of aquifers and the concept of man-made aquifers.[46]

Energy can also be chemically stores in an electrical system. New battery development offers a non-polluting, compact, and modular unit that can fit the needs of most energy storage interests. Conventional lead-acid batteries cannot withstand the constant cycling between being fully charged and discharged that is essential in either utility or automobile use. The price of heavy-duty design, lead-acid batteries is prohibitively high for general use.

New research efforts are designed to develop high temperature battery technology. High temperature batteries hold the promise of improved performance at a lower cost. Lithium-sulfur and sodium-sulfur high temperature batteries are receiving most attention. The sodium-sulfur cell operates at temperatures near 350°C using molten sodium and sulfur electrodes. The sodium-sulfur battery uses a solid ceramic beta alumina material for its electrolyte. Lithium-sulfur batteries use a molten salt, such as a lithium chloride-potassium chloride eutectic mixture as their electrolyte. The lithium-sulfur battery functions at a temperature range of 357°C to 400°C and theoretically has a greater performance potential than sodium-sulfur cells. In both batteries there are problems with containment of the electrodes, the location of inexpensive and corrosion-resistant construction materials, and sealing at high temperatures.[47] Until these difficulties are mitigated, sodium-sulfur and lithium-sulfur batteries will not be commercial.

Recently, NASA Lewis Research Center in Cleveland, Ohio, conducted a joint Department of Energy and NASA funded project to develop reduction-oxidation battery technology. This battery system, called Redox, promises to provide an inexpensive, long-term, and reliable method of storing electricity. Redox batteries are currently being developed for use in the kilowatt range, but they could eventually be scaled up for use in utility load leveling.

The Redox system consists of a "stack" or combination of cells that takes advantage of the valence change in the reduction-oxidation process. Chromium chloride and iron chloride (reactant fluids) are pumped through the series of cells.

There are numerous advantages to the Redox battery. These include the basic simplicity of the system that allows for extended life and reliability. Also, low operation pressures (ten psi) and its functioning at ambient temperatures, enable the battery to use inexpensive carbon electrodes and other low cost construction materials. NASA also notes that an important advantage of the Redox system is in the flexibility in sizing the stack and reactant fluid storage tanks independently to achieve the most efficient system characteristics.[48]

Companies like Gulf, Western, and General Motors are quickly approaching a point where they and commercially produce a battery that economically facilitates demand load-leveling and will even power electric vehicles in the near future.

Electrical energy can be stored by means other than batteries, for example, superconducting magnets. In a typical electromagnet, the resistance of the magnet's winding causes power losses and power must be constantly applied in order to maintain the field. If this winding lacks resistance (superconducting), then once the desired magnetic field is established, no further energy input is needed and the original energy input is stored in the magnetic field. Up to 95 percent of the original electrical energy can be drawn off the magnet when needed.[49]

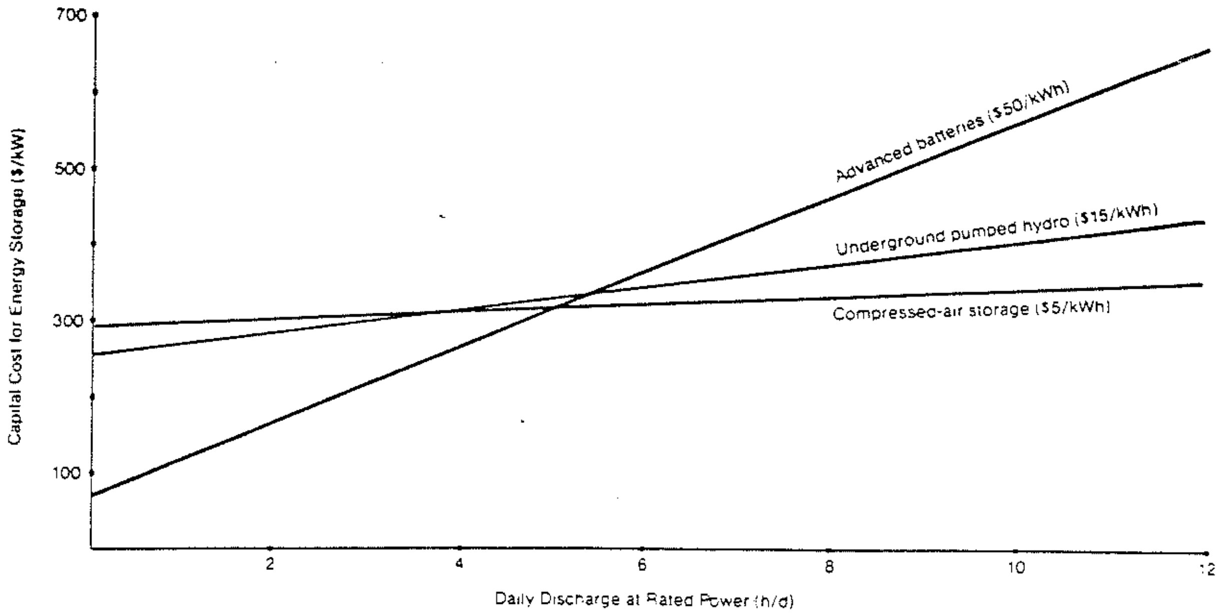
The University of Wisconsin at Madison and the Los Alamos Scientific Laboratory in New Mexico have determined that storing energy for utilities using superconductors, is only economical in the 1,000 to 10,000 megawatt-hour range. Superconducting storage facilities could be more easily located near demand centers if they were located underground. This would also minimize the possible impact of the magnetic field on the immediate environment. Magnetic storage is still in the research and demonstration stage until the technology is further refined.[50]

Compressed-air storage is also promising. In a conventional gas turbine, compressed air is mixed with fuel to generate mechanical power. About 60 percent of the energy produced by the turbine is needed to run the air compressor. To store compressed air, the compressor and turbine can be alternately connected and disconnected from the generator. During off-peak periods, only the compressor could be operated to compress air to be stores for use during times of exceptional demand. This compressed air can then operate a turbine during peak demand periods.[56]

Figure 3.3-1 compares the cost of three alternative utility storage technologies, advanced batteries, underground pumped storage, and compressed-air storage. These systems look increasingly promising when long periods of discharge (from storage) at full power levels are required. Many utilities look for discharge capability of eight to ten hours or more; for discharge periods of less than eight hours duration, battery systems look promising.

Figure 3.3-1[57]

COMPARISON OF ENERGY STORAGE TECHNOLOGIES

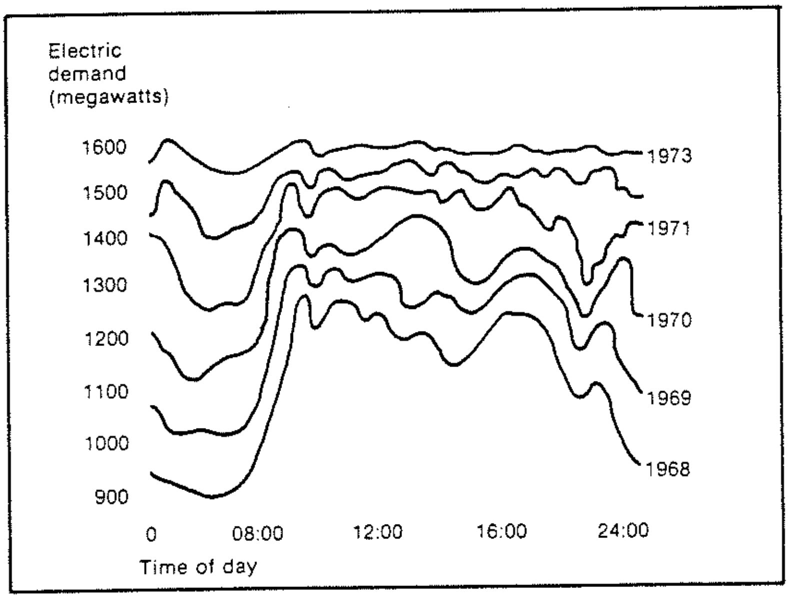


Currently a combination of load management and thermal storage is widely used in Europe. Load management in Germany was originally practiced during the Second World War, when automatic systems were developed to turn off night lighting during air raids. After the war, similar techniques were used to manage utility loads, and automatically turn off appliances during system peaks. In some parts of Germany today, as much as 25 percent of the total demand for electricity is met by electric storage heaters.[58]

The outstanding success of German utilities in perfecting load management technologies, combined with efficient energy-storing appliances, is shown in Figure 3.3-2.

Figure 3.3-2[59]

GERMAN LOAD MANAGEMENT: 1968-1973



The technologies available to European utilities are equally available in the United States, yet a few utilities have taken advantage of these basic energy-saving approaches. As the illustration shows, however, the twenty-four hour demand contour curve for this German utility has essentially been flattened by use of technology and special rates. Enormous capital savings are possible by deferring purchases of peaking power plants to meet demands during brief peak periods.[60]

The combination of load management technology and energy storage techniques is a fundamental element in any future energy policy to reduce overall demand on a major scale. As such, these technologies constitute important strategic energy developments, which can significantly reduce imports, an increase local system reliability.

Cogeneration (3.4)

Cogeneration is the generation of electrical or mechanical power and useful heat from the same primary source of fuel.[61] This can be accomplished by using conventional steam turbines, combustion turbines, diesel engines, or other generation systems in what is known as "topping cycle," or as in the case of industrial waste heat, in a "bottoming cycle."[62] Figure 3.4-1 compares conventional electrical, process steam system , and congeneration systems and illustrates how each operates.

The "topping cycle" uses various boiler-turbine configurations to generate electricity and then makes use of the valuable waste heat from steam for other processes.[63] Figure 3.4-2 illustrates this "topping cycle" in a cogeneration system. Table 3.4-1 describes the various characteristics of "topping cycle" cogeneration systems for gas turbines, diesel engines, and steam turbines.

One basic cogeneration system uses the back-pressure steam turbine. In a conventional steam turbine generator steam is exhausted from the turbine into a condenser at a very low temperature (about 100°F or 37.8°C) and at a pressure of around fifteen pounds per square inch gauged (psig). The waste heat from condensation is released to the environment at near ambient temperatures. Approximately 30 to 40 percent of the primary fuel can be converted to electricity. Unfortunately, the waste heat that is discharged from this system is not of useful quality for industrial processes.[64]

The back pressure turbine, however, facilitates the generation of electricity and useful steam from the same unit. In this boiler configuration fuel is burned to create steam in a high pressure boiler. The steam, typically in the 850 to 1,450 psig range, is used to drive a turbine that in turn produces electricity. Low pressure steam is exhausted from the turbine at a temperature and pressure suitable for industrial applications.[65]

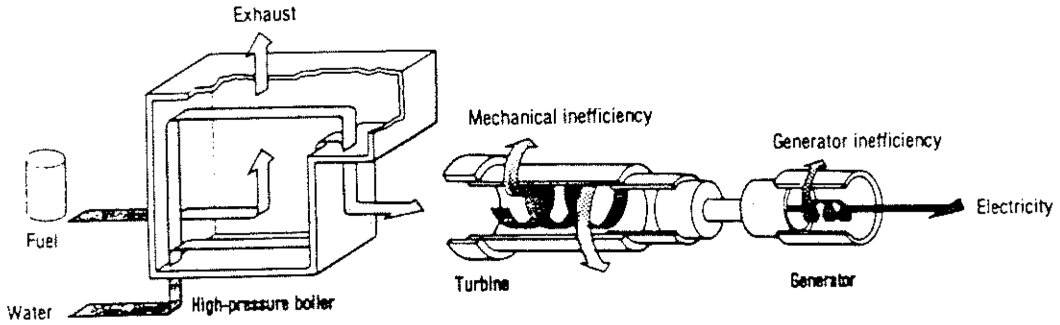
The fuel savings derived from the combination facility are significant. The amount of primary fuel consumed beyond what is used to produce steam for the process use would be an estimated 4,500 Btu/kwh, or less than half the 10,000 Btu/kwh heat rate that is typical of central power facilities. Only ten to fifteen percent of the fuel consumed by a back pressure steam congeneration unit is converted into electricity. Thus, this cogeneration arrangement can only produce a relatively small amount of by-product electricity for a given steam load.[66]

The reduction in effective electrical output characteristic of a back-pressure system can be almost totally mitigated with the use of a gas turbine-waste heat boiler or combined cycle unit. A directly fired gas turbine unit is fueled with a mixture of compressed air and distillate petroleum or compressed air and natural gas.[67] An indirectly fired gas turbine utilizes a heat exchanger between the fuel source and the turbine inlet, permitting the safe use of lower quality fuels without damaging the turbine blades. Both systems use the hot exhaust gas from the turbines to furnish the heat for steam production in a waste boiler. This high pressure steam can also be directly used in various industrial processes. In addition

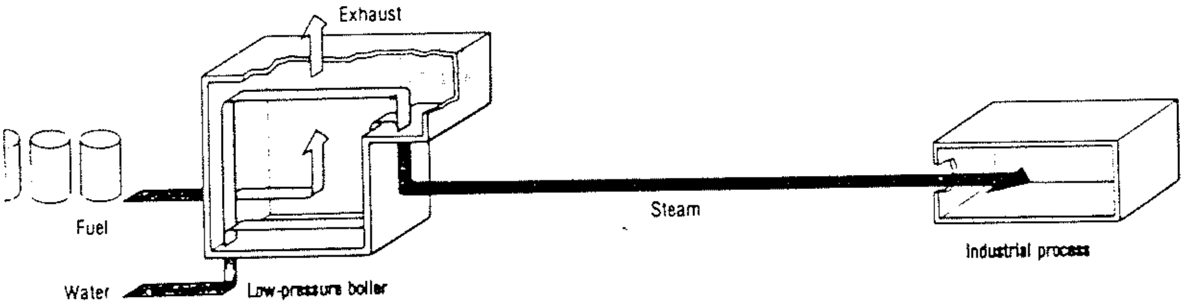
Figure 3.4-1[68]

CONVENTIONAL ELECTRICAL AND PROCESS STEAM SYSTEMS COMPARED TO A COGENERATION SYSTEM

A Conventional electrical-generating system requires the equivalent of 1 barrel of oil to produce 600 kWh electricity.



B Conventional process-steam system requires the equivalent of 2¼ barrels of oil to produce 8,500 lbs of process steam.



C Cogeneration system requires the equivalent of 2¾ barrels of oil to generate the same amount of energy as systems A and B.

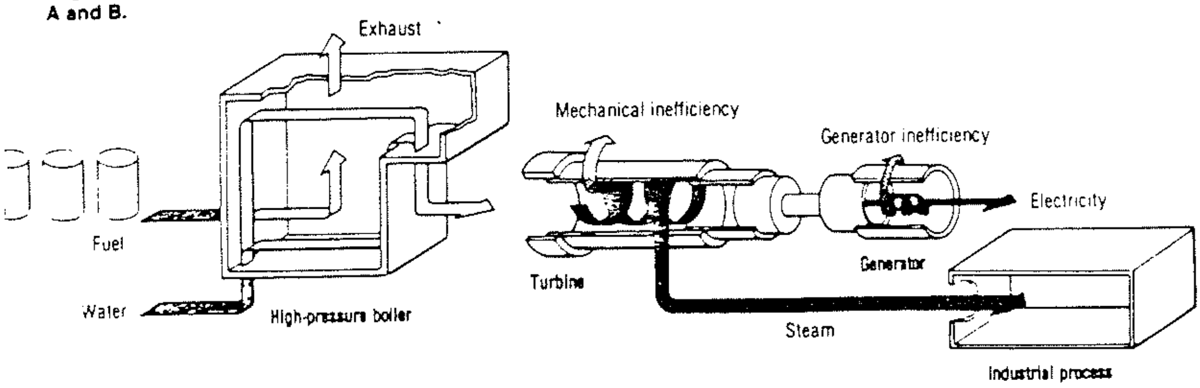
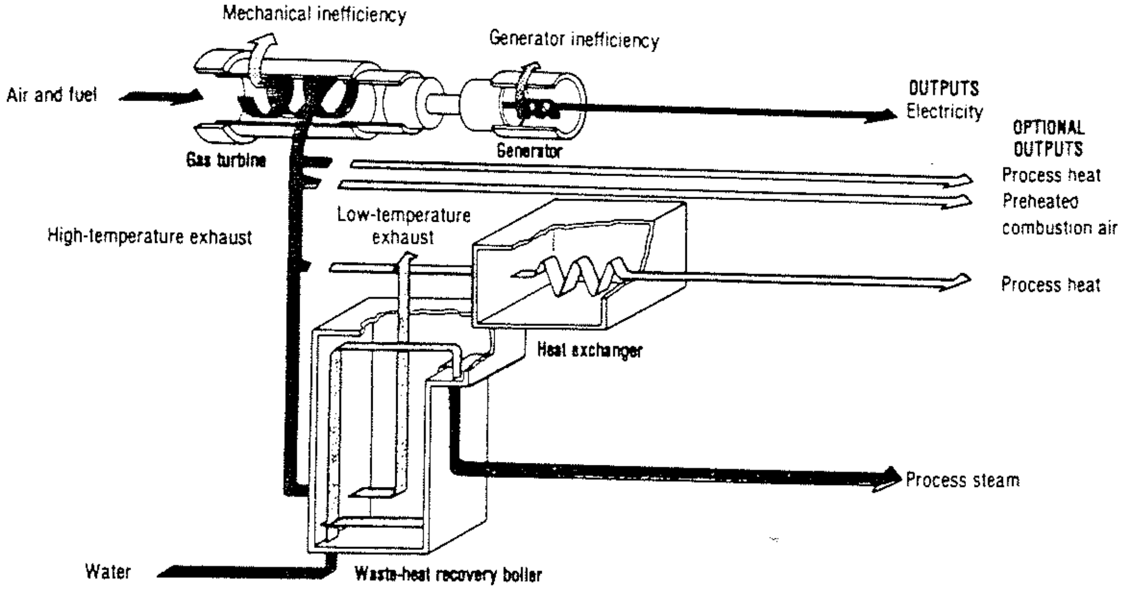


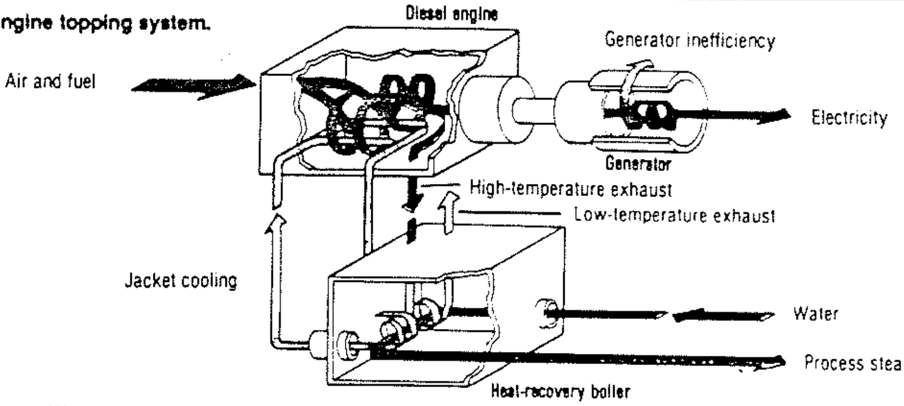
Figure 3.4-2[69]

DIAGRAM ILLUSTRATIONS OF TOPPING CYCLE COGENERATION SYSTEMS

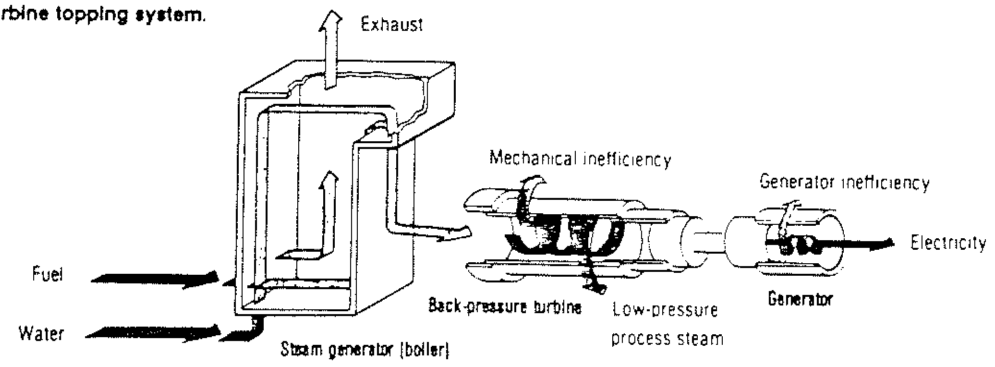
Gas-turbine topping system.



Diesel-engine topping system.



Steam-turbine topping system.



the gas turbine can be fitted with a back pressure steam turbine to make additional electricity and to provide relatively low pressure steam. The gas turbine system can produce an effective heat rate of 5,000 to 6,000 Btu/kwh and produce four to six times the average electricity output of a back pressure steam turbine. The efficiency of gas turbine, or gas turbine with a waste steam boiler compare favorably to central power plants as electrical generators. This cogeneration system utilizes 25 to 35 percent of its fuel, which is well within the range of single mode power plants. The efficiency is even more impressive when the waste heat recovery benefit is included.[70]

There are a number of variations possible, such as liquid metal turbines. These turbines substitute liquid metal in place of water to produce the steam to propel a turbine. Figure 3.4-3 shows a potassium-turbine topping cycle coupled with a gas and steam turbine fueled from coal. Conventional primary fuels such as coal, are burned to boil a liquid metal like potassium and convert it to vapor through a turbine. This hot metal vapor, after leaving the turbine, boils water and superheats steam to drive a conventional turbine. It is estimated that this liquid metal congeneration system could reach efficiencies near 47 percent.[71]

New cogeneration approaches, using fluidized-bed and combined-cycle technology, will be commercially available in the 1980s. With fluidized-bed technology, crushed coal or other fuels are fed into a hot bed of dolomite or limestone that is kept suspended or "fluidized" by a stream of hot air from below. Water piped through coils immersed in the bed is converted to steam for subsequent electricity production. Fluidized-bed technology holds promise for being a clean-burning process for converting coal, as well as other low-grade fuels. The clean-burning nature of fluidized-bed technology will facilitate its acceptance.

Combined-cycle configurations join in one thermodynamic system a gas turbine which generated electricity, a steam generator which produces steam from the waste heat remaining in the gas turbine exhaust, and steam turbine which uses this steam to generate additional electric power. Figure 3.4-4 illustrates a combined-cycle topping system utilizing gas and steam turbines. This cogeneration system is limited by its need for high quality fuel suitable for gas turbine consumption, either natural gas or a light distillate. However, gas turbines can be easily retrofitted to existing genrating facilities. Before the end of the century closed cycle (external combustion) gas turbines, stirling engines, and other technologies are likely to approach commercial status.[73]

At the other end of the cogeneration technology spectrum is the "bottoming cycle" which uses the heat from the lower temperature "bottom" of an industrial process or engine to produce electricity.

Table 3.4-1[72]

DISTINGUISHING FEATURES OF TOPPING CYCLE COGENERATION SYSTEMS

	System		
Distinguishing features	Gas turbine	Diesel engine	Steam turbine
1. Type of fuel used	#2 light distillate oil or natural gas	Oil or gas	All types of fuel including coal
Advantage			Supports NEA conversion to coal objective
Disadvantage	Conflicts with NEA conversion to coal objective	Conflicts with NEA conversion to coal objective	
2. Capital investment required 1/	$500 per kw	$550 per kw	$1,250 per kw for coal 875 per kw for oil
Advantage	Low cost	Low cost	
Disadvantage			High cost
3. Efficiency in converting fuel to electricity 2/	5,500 Btu's per kwh	7,000 Btu's per kwh	4,500 Btu's per kwh
Advantage 3/			
Disadvantage 3/			
4. Electricity produced per unit of steam generated 2/	200 kwh per million Btu's of steam	400 kwh per million Btu's of steam	50 kwh per million Btu's of steam
Advantage 4/			
Disadvantage 4/			
5. Environmental effects	Gas produces little pollution	High nitrogen oxide and carbon monoxide emissions	High sulfur dioxide and particulate pollution with some coals
Advantage	No pollution control equipment needed		
Disadvantage		Exhaust may not meet purity requirements of some process heat applications	Expensive pollution control devices needed

1/ Total installed costs assuming 5 MW capacity.

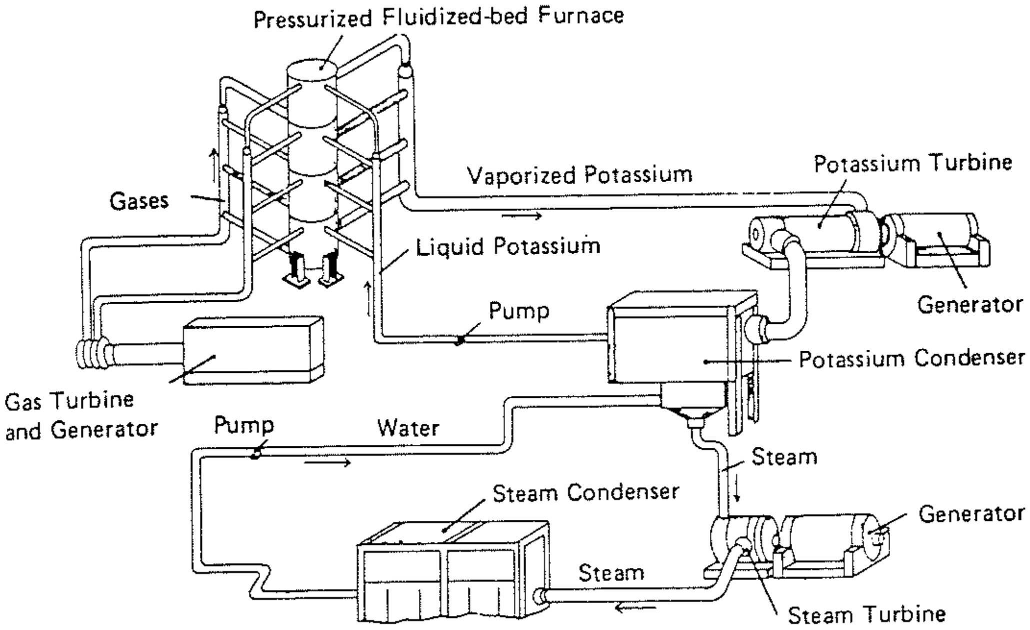
2/ Federal Energy Administration and Thermal Electron Corporation, A Study of Inplant Electric Power Generation in the Chemical, Petroleum Refining and Paper and Pulp Industries. Final Report, 1976. p.2-1.

3/ While steam and gas turbines are more efficient than diesel engines, their fuel efficiency cannot be universally considered an advantage. For example, in situations with large electricity to steam demands, the diesel, although less efficient, would be the most advantageous to the cogenerator.

4/ Whether the amount of electricity produced is an advantage or disadvantage depends on the cogenerator's needs.

Figure 3.4-3[74]

ALTERNATIVE TOPPING CYCLES: POTASSIUM TURBINES



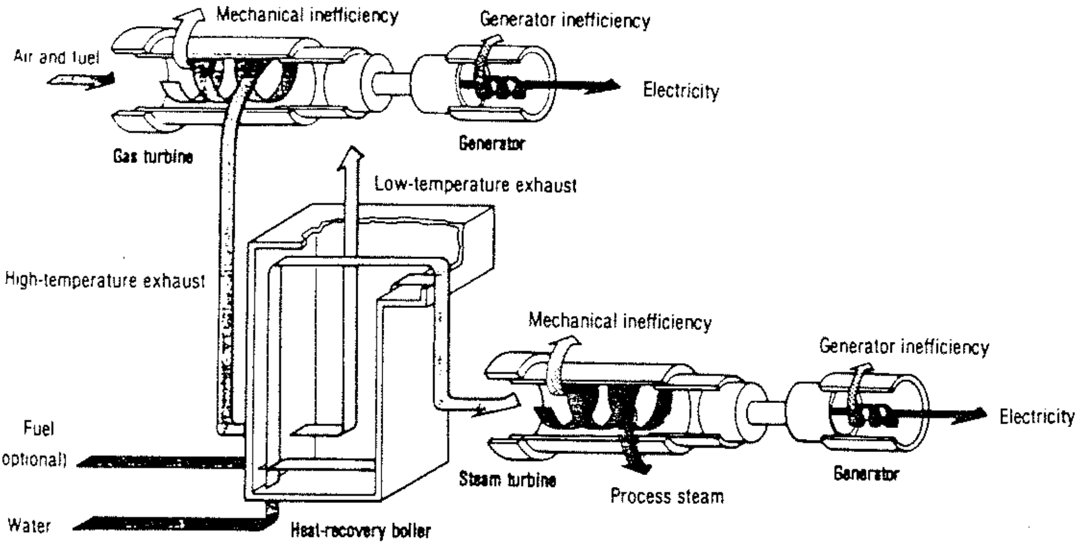
Industrial machinery and processes create large amounts of excess heat. This steam is usually dispensed indirectly to the environment or processed by expensive cooling equipment.[76] The heat can be extracted from industrial processes, such as cement kilns, blast furnaces, and glass manufacturing, to create steam that can be harnessed for additional use. There are a number of industries which require process heat in large amounts including food processing, textiles, pulp and paper, chemicals, and automobile manufacturing. Though the waste steam is not an exact fit in quality or quantity to all industrial uses, the potential for its utilization is great.[77]

The Fiat Auto Corporation of Italy has developed an energy system using an automobile engine linked to a heat exchange unit to utilize waste heat from the exhaust and generator. The prime mover of the system, called TOTEM (Total Energy Module) is a four-cylinder in-line engine that operates on a four-stroke Otto cycle engine linked to an electric generator to produce power. The internal combustion engine has a displacement of 55 cubic inches and can be set up to accommodate various fuels, including natural gas, manufactured gas, biogas, liquified petroleum gas, methanol, and other alcohols.[78]

A synchronous electric motor starts the power generator and serves as a regulator to maintain the module at a constant speed. The combination of technologies provides as energy system that Fiat rates at 90 percent efficiency based on the net value of a gaseous fuel.[79]

Figure 3.4-4[75]

COMBINED-CYCLE TOPPING SYSTEM



The waste heat captured by the heat exchange unit of the TOTEM can be channeled into a variety of specific uses depending upon what is needed. The fifteen kilowatts of electricity and the waste heat energy generated by a TOTEM system can be applied to domestic, industrial, and agricultural sectors for substantial energy savings.

In the domestic sector, TOTEM's size and power generation capacity fit into not only residential units but also any private or community buildings requiring power and heat energy. TOTEM's power generation capacity is typically four or five times the average required for an isolated residential dwelling, thus lending itself to integration into multiple residential dwellings or use as a neighborhood resource. The system's modular nature allows expansion in small increments to keep pace with growing energy demand.[80]

The TOTEM system can be used in the industrial sector to provide power and heat. Heat in the form of hot water or other hot fluids can be provided for production processes. The modular capacity of the system allows it to be expanded quickly, (estimated installation time per unit is eighteen person-hours) to satisfy a multiplicity of industrial uses, such as space heating and water pumping.[81]

The TOTEM system fits into the agricultural sector with the development of technologies for the collection and synthesis of animal excrement and other organic wastes into biogas. Various methods for the fermentation and distillation of vegetable matter into alcohol provide another diverse fuel source for the TOTEM system. On the farm this energy system can be used for drying, irrigation, powering farm machinery, and a host of other applications.[82]

The TOTEM system's benefit go beyond energy efficiency and flexibility. The Fiat Corporation estimates that a TOTEM will provide energy at a retail price of $500 to $600 per kilowatt.[83] This is more than competitive with the price of providing energy with a fossil fuel plant costing nearly $1,000 per kilowatt of installed capacity.[84]

The Thermo Electron Corporation of Massachusetts has developed a total energy system concept similar to Fiat's TOTEM. Thermo Electron's system would use mass-produced Chevrolet automotive engines of the 454, 350, and 305 cubic-inch V-8 class. These engines are derated to operate at 75 percent throttle and 1,800 rpms. They provide continuous generator ratings of 60 kw, 47 kw, and 40 kw respectively.

The Thermo Electron module can provide a minimum of 2,000 hours of service at an operation speed nearly 40 percent lower than Fiat's TOTEM, and will achieve an overall efficiency of 86 percent and a theoretical 36 percent in the conversion of heat energy to work.

The major advantage of such a proposed system over TOTEM is that it utilizes a larger engine, which operates at a lower speed thus allowing for less service problems. The system prime mover contributes only about $15 per kilowatt. This low cost makes it possible to reduce field maintenance expenses to a minimum.[85]

Cogeneration systems offer great potential in terms of efficiency and conservation. The United States Department of Energy determined in 1978 that cogeneration could provide as much as 6.15 quadrillion Btu per year of energy by the year 2000. This significant energy savings takes into account beneficial tax treatment and additional government action beyond the National Energy Act.[86] Dow Chemical Company forecasts that with complete relaxation of governmental and institutional constraints, industrial cogeneration could generate as much as 71,105 megawatts of power by 1985. This amount is 1.45 quadrillion Btu annually, or roughly the equivalent of 680,000 barrels per day of oil. These figures include only the byproduct power feature of cogeneration and not the incremental condensing power for electrical generation.[87] Table 3.4-2 gives the total potential energy savings from cogeneration with an estimate of market penetration.

The energy savings potential of central powerplant cogeneration has not yet been fully exploited, although a number of such plants are in operation today. Gulf States Utilities Company, located in a petrochemical complex near Baton Rouge, Louisiana, has been in operation since 1929. This plant produces electric power and steam for Exxon and Ethyl Corporations. This facility produces about 160 megawatts of electric power and approximately three million pounds per hour of industrial process steam.

Table 3.4-2[88]

TOTAL POTENTIAL ENERGY SAVING FROM COGENERATION AND ESTIMATED MARKET PENETRATION (QUADS)

Scenario Year	1982		1985		1990		2000	
	Energy Saving	Estimated Market Penetration	Energy Saving	Estimated Market Penetration	Energy Saving	Estimated Market Penetration	Energy Saving	Estimated Market Penetration
without additional governmental action	.11	.22	.31	.78	.60	1.53	1.03	1.58
With National Energy Act	.05	.12	.15	.38	.31	.79	.54	1.33
With additional government action beyond national energy act	.035	.11	.14	.67	.42	1.33	.71	2.24
TOTAL	.195	.44	.60	1.83	1.33	3.65	2.28	6.15

Large petrochemical complexes in Texas are also utilizing sophisticated cogeneration systems. American Oil Company, Monsanto Chemical and Union Carbine have tested cogeneration systems linked to utiliites. Their particular cogeneration design uses coal-fired boilers and back-pressure steam turbines. The boilers generate three million pounds per hour steam at 10.3 MPa and 510°C, and the turbines deliver steam at varying pressures and temperatures for process, feedwater, daeration, and heating appliances. This system has total electrical generation capacity of 220 megawatts.

A General Foods Corporation plant in Massachusetts uses a cogeneration bottoming cycle. Oil fired boilers, producing 160,000 pounds per hour of steam at 4.14 MPa and 400°C feed a steam turbine generator that produces electric power. The low-pressure exhaust steam is then used in the manufacturing process for gelatin and chemical products.[89]

The efficient use of a fuel by cogeneration systems not only permits conservation of capital and dwindling fuel supplies, it also reduces the environmental impacts of energy use. Recovery of waste heat by either steam or organic fluid bottoming cycles reduces both thermal and air pollution produced by electricity generation. Heat normally discharged can be converted to useful work energy. The Thermo Electron company has estimated that a large fossil fuel steam plant emits 55 percent more waste heat per unit of electricity than a five megawatt diesel facility equipped with a bottoming cycle. Further, it has been determined that a nuclear power plant emits 130 percent more excess heat per unit then the diesel congenerator. Air pollution per unit of energy produces decreases with cogeneration because recycling waste steam to produce electricity reduces the need for additional use of the primary feedstock.[90]

Bottoming cycle plants have other environmental advantages because of their relatively small size. Conventional power plants cannot match the over 45 percent efficiency projected for diesel generators coupled with various bottoming cycles. The small size of these plants allows them to be located near the site where the power is needed, reducing the environmental impacts of transmission systems.[91]

The economics of cogeneration vary considerably. The U.S. Department of Energy has stated that "in general (the) cost of electricity production from cogeneration compares favorably with the projected cost of purchased electricity." DOE also considers various cogeneration technologies to be more efficient measn of utilizing capital for power generation when compared to conventional plants. But industry notes that this fails to recognize that companies use a different set of criteria for investing capital to generate electricity than do utilities. The generation of power is merely a sideline; it does not represent an expansion of their normal product line.[92]

A Dow Chemical Study prepared several years ago compared four cogeneration combinations to conventional systems of power and steam generation. These indepth case studies and their results can be summarized here as: (1) Industrial generation of power for internal use only; (2) Industry/utility joint venture dual purpose power facility; (3) Industrial generation for internal use and for the scale of excess power to the public, and (4) both industrial power generation facilities and dual-purpose central power stations. Cogeneration's major economic and financial impacts, according to the Dow Study, are (a) general savings in labor, capital, and fuel used; (b) reductions in the amount of capital that utilities must solicit from financial markets; and (c) decreased cost of electricity to consumers. The study noted that the need to generate capital for the electricity sector over the 1976 to 1985 period varied from $2 billion per year in Case 1 to $5 billion per year in Case 4. According to the study, the net savings for the period would be $20 to $50 billion, consumption of electricity could remain constant, and the cost of constructing energy facilities would decrease. The study concluded that the cogeneration alternative would free a sizable piece of the nation's energy resources for other pursuits.[93]

Industry maintains that cogeneration will not reach its full potential without a major impetus from the government. A task force for the National Association of Manufacturers has stated that:

> Investment in cogeneration facilities would not be greatly increased by modest changes to depreciation schedules and/or investment tax credit. Almost certainly, massive doses of either or both would be required to prompt significant

> replacement of existing non-cogeneration installations with technology that can deliver both electricity and useable steam. these firms consider a 50 percent investment tax credit coupled with first-year depreciation as the minimum incentive needed to produce a rate of return higher than 20 percent, a benchmark that companies typically use for discretionary investments.[94]

The cost of standby power is an additional constraint retarding the implementation of cogeneration. Standby power is the rate that utilities charge cogenerators that must occasionally purchase power to supplement their own generation capacity. High standby rates reduce the projects' competitiveness as a capital investment. Utilities commonly regard industrial cogenerators as potential competitors or energy liabilities that they must have the capacity to service.[95]

This is changing with utilities' increasing difficulties in sitting new electrical generation plants and raising large amounts of capital within inflated financial markets. Utilities have begun to view cogeneration plants as a source of energy for their system or as a means to reduce their need for increased generation capacity. Utilities are currently negotiating reduced standby rates or crediting cogenerators for their contributions to the conventional system. Utilities are also attempting to encourage cogeneration with various rate structures such as reduced standby rates for off-peak demand.[96]

The rates that utilities have been willing to pay for the electricity supplemented to their grids by industrial cogenerators have been an additional hindrance to cogeneration. The reason often cited by utilities for not paying reasonable rates is that cogenerators are not predictable and they cannot be depended upon for small additions to the conventional energy system. Some utility regulatory commissions are now mandating that utilities establish equitable rates for the purchase of excess electricity generated by their customers. For example, Southern California Edison developed a formula that pays the cogenerator a time-of-use price as a function of the average system energy cost. This price is adjusted semi-annually to reflect the prevalent energy cost for the cogenerator. Similarly, Pacific Gas and Electric Company has designed a rate structure for the purchase of cogenerated electricity that reflects on-and off-peak period and partial-peak period purchaes of energy. The rates of these California utilities reflect the Public Utility Regulatory Policies Act mandages. As additional contracts are equitably negotiated for the purchase of cogenerated power, industrial firms with high-grade excess steam will take advantage of this incentive and reduce their demand from conventional power plants.[97]

A path to full-scale implementation of cogeneration is being cleared by two sections of the Public Utility Regulatory Policies Act (PURPA), enacted in 1978 and by some alterations in the Natural Gas Policy Act. Section 201 of PURPA requires state Public Service Commissions to set purchase rates for surplus power at rates that reflect the fuel prices in different sections of the country. Utilities must also provide standby power to cogenerators as they would typical electricity customers.

This section also exempts cogenerators from state regulation of utility rates and financial organization, as well as from restrictions mandated under PURPA and the Federal Power Act. Further, PURPA enables cogenerators to take advantage of investment tax credits. These credits, however, cannot be applied to oil or gas-fired systems.

The Federal Economic Regulatory Commission (FERC) (within the Department of Energy) is proposing the elimination of fuel-use restrictions for bottoming cycle cogenerators that produce predominately thermal energy. Potential industrial cogenerators have been wary of cogeneration for fear that the federal government might prohibit the burning of oil and gas in new facilities. Jerry Davis, General Manager of the Energy Systems Division of Thermo Electron Corporation noted that, "The FERC rules move a lot of cogeneration projects from (being) marginal to economic."[98]

There are still a number of regulatory and institutional barriers to cogeneration which must be overcome. It is unclear whether steam and electric sales fall under federal, state or joint regulation. Potential cogenerators have indicated they do not want to get involved with Federal Power Commission regulatory requirements. These include authority to prohibit the issuance of securities for exchange, stability or depreciation schedules, and various regulations, reporting and permit processes which which already overwhelm many companies.[99]

Clarification is needed as to whether waste-heat utilization projects with several partners are covered by the Public Utility Holding Act of 1935. The Act was designed to control abuses believed implicit in holding company structures. Various methods of cogeneration ownership such as having the cogeneration unit of the company as a subsidiary selling the excess power, could fall under this law.[100] This Act and other anti-trust legal tangles are slowing the full-sacle development of cogeneration as an alternative energy resource.

Cogeneration technologies offer a number of advantages over conventional power plant technologies, in addition to their reduced use of primary fuels. Since they can be mass-produced in modular components, they have distinctive economics of scale in costs of individual sub-systems. For a strategic energy perspective, their reliability, energy economy, and flexibility of potential locations increase their value as dispersed, efficient power resources. Micro-cogeneration systems, such as the commercially available TOTEM and the proposed Thermo-Electron system have the added advantage of pre-engineered design which can be mass-produced to suit a variety of end-use needs. Unlike conventional power systems, which are large and site-specific, these micro systems are small and can be readily moved from one site to another. Micro systems can be readily utilized for emergency purposes, and can operate on a variety of fuels, including bio-mass derived gas. The potential for community self-suffiency through the establishment of cogeneration co-ops is great.

Fuel Cells (3.5)

A fuel cell is an electrochemical device that chemically combines hydrogen and oxygen to produce electricity and water. When combined with a fuel processor and power processor to form a fuel cell power plant, fuel cells are a clean, efficient, and flexible means of producing electricity.

Fuel cells so far developed use hydrogen fuel made from fossil fuels, though it is possible to convert biomass into hydrogen fuel as well. Fuel cell power plants work by reacting hydrocarbon fuel (such as naptha or natural gas) in the fuel processor to obtain a hydrogen-rich gas. In the fuel cell itself, the hydrogen reacts in the presence of an electrolyte to produce direct current power. The power processor then converts the direct current to alternating current.

Fuel cells are distinguished from regular batteries by the fact that their electrodes are invariable and catalytically active. Reaction on the electrode surfaces which are in contact with the electrolyte produces current. Generally, fuel and oxidant are not an integral part of the cell; the current load supplies them as needed, and reaction products are continually removed.[101]

Though the electrolyte may be acid or alkaline, solid or liquid, phosphoric acid fuel cells are considered first generation. Phosphoric acid fuel cells are designed to use naptha or natural gas as their primary fuel. Other possible fuel sources include distillate fuel oil, clean coal fuels, methanol, and hydorgen. Another possibility is connection to a wind generator, in which the wind generation system electrolyzes water into hydrogen and oxygen, and stores the hydrogen for later conversion to electricity in the fuel cell.

Generally, the refining process for fossil fuels is so complex that it seems to limit fuel cell applications to those on a large scale. Anhydrous ammonia, methanol, and synthetic fuels such as gasified coal are more easily processed into a hydrogen-rich steam.[102] It is possible that fuel cells will be used in conjunction with coal gasifiers. This second-generation technology would use molten carbonate salt as the electrolyte.[103]

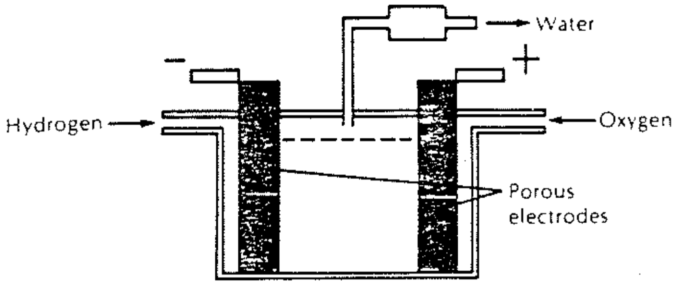
Several different processes are now available for converting hydrocarbon fuel to hydrogen-rich fuel, including steam reforming, partial oxidation, and thermal cracking. The process used most is steam reforming with a nickel catalyst.[104]

The actual fuel cell in a fuel cell power plant is made up of many single cells, each with an anode (-) fed the hydrogen-rich fuel, a cathode (+) fed air (oxygen), and an electrolyte solution to carry the ions between them. Each cell produces about one volt. A series of connected cells forms a "stack."[105] Each individual cell contains the necessary elements for sustained operation.

To illustrate the components and functions of fuel cells, a single type, the hydrogen-air cell with acid electrolyte will be examined. Figure 3.5-1 shows a schematic of such a cell.

Figure 3.5-1[106]

HYDROGEN-AIR FUEL CELL SCHEMATIC



A hydrogen-air cell consists of a pair of porous catalyzed electrodes with an acid electrolyte separating them. Reaction on the anode is the oxidation of hydrogen to hydrated protons with the release of electrons; on the cathode it is the reaction of oxygen with protons to form water vapor with the consumption of electrons. Electrons flow from the anode through the external load to the cathode; ionic current transport through the electrolyte closes the circuit. In an acid cell, protons carry the current.[107]

An advantage of this type of cell is that reactants need not be pure. Hydrogen may come from fuel mixtures and oxygen from air. Oxygen-depleted air removes product moisture from the cathode, facilitated by the cell's operation at sufficiently high temperature to vaporize the water that is formed.

The electrolyte is the center of the fuel cell's operation. In its catalyzed layer, it offers many places where gases and electrolyte can react. Its porosity makes possible fast reactant transport and removal of inert material and product moisture. The electrode also serves as the path for current flowing to the terminals and often contains the electrolyte. The electrolyte, besides providing ionic conduction, assures that reactants remain separate.[108]

According to Earl Cook, fuel cells should be theoretically able to achieve conversion efficiencies of 100 percent.[109] While laboratory tests have achieved efficiencies as high as 75 percent, a more common figure is about 60 percent.[110] An advantage of fuel cells is that their efficiency remains consistent over a wide range of loads.

Practical fuel cells are unable to reach the maximum possible conversion efficiency because of the intrinsic inefficiency of the conversion process rather than from operation losses such as need for auxiliary power. Two basic losses encountered by fuel cells are the ohmic loss in the electrolyte, and the electrode polarization which is the difference between the actual and thermodynamic electrode potential. Electrical resistance in the electrodes and conductors leading to the cell terminals can also be a problem, since fuel cells are a low-voltage device and conduct high currents.[111]

Fuel cells are built in relatively small modules (40 kw to 26 kw) that may be connected to form a larger unit, or operate as equally effectively as discrete units. The U.S. Department of Energy considers 4.8 MW to be the "optimum rating for a power plant building block," and believes that one to two 4.8 MW units could provide the "full requirements of dispersed load centers."[112]

Among the many possible combinations of electrolyte, fuel, electrode configuration, and operating temperatures, several have emerged as the best candidates for power plant building blocks. These include cells with aqueous electrolyte, with fused salt electrolyte, and cells which operate at very high temperatures, in which oxygen ion mobility in the solid state provide ionic conduction. The most advanced of these are phosphoric acid fuel cells which operate below 175°C using aqueous or quasi-aqueous electrolyte.

Aqueous electrolyte cells are favored now because of the high specific conductivity of the electrolyte, higher cell performance at ambient temperatures, and material stability. They can be differentiated by the mode of electrolyte containment.

Some manufacturers use free-flowing electrolyte contained by the electrodes or porous membranes adjacent to the electrode. Others render the electrode hydrophobic, enabling the cell to operate at atmospheric pressure. Matrix-type cells which are compact, and inexpensive to manufacture retain the electrolyte in a microporous mix such as asbestos by auxiliary forces. These cells use hydrophobic electrodes, which can be thinner and more porous than free electrolyte cells because they don't need to contain the electrolyte.

A vital aspect of fuel cell technology is continuous supply of reactants and removal of reaction products and heat generated by conversion losses. A cell's design, particularly for aqueous electrolyte cells, depends a great deal on methods of maintaining the mass and energy balance. Some manufacturers achieve this balance by recirculating the electrolyte. In matrix-type cells the electrolyte is fixed, and there is less of it than in free-electrolyte cells. Balance is maintained by circulating the hydrogen since reactants need not be recirculated in this type of cell.[113]

Fuel cells have many advantages and few drawbacks as an energy generating technology. Being a low-temperature conversion device, their emmissions of sulfur oxides, nitrogen oxides, and particulates are far below the strictest governmental air quality standards. They require no water for cooling or processing; rather, they produce it. They are highly dispersible, requiring less in the way of transmission lines, because their modularity and low environmental impacts allow them to be sited near load centers. Their already high efficiency can be augmented by utilizing the waste heat, for an overall system efficiency as high as 80 or 90 percent. Fuel cell power plants take only two years to construct, and they can use a wide range of fuels. They have no moving parts to replace or maintain. As Cook points out, "Unlike a battery, in which the electrolyte changes composition and the electrodes are consumed, the fuel cell does not need to be recharged or replaced; it can operate as long as fresh fuel is supplied."[114]

The one major limitation of fuel cells is their reliance on noble metals (usually platinum) for the electrolyte catalyst.[115] Fuel cells compete with the environmentally beneficial catalytic converter, used to reduce exhaust emissions in many new cars, for this expensive imported metal.

Like another relatively new energy technology, photovoltaics, fuel cells are a product of the space program. The National Aeronautics and Space Administration adopted the fuel cell principle in the early 1960s as a highly efficient and reliable electrical generator of high energy density, and used it in spacecraft. Soon there were about 50 U.S. companies researching and developing fuel cells. After several years of effort, it was apparent that the first important breakthroughs could not sustain commercialization and that the success of the fuel cell would depend on long-term research and development efforts. By 1975, all but a few companies had abandoned fuel cell research, and only United Technologies Corporation was doing significant work.

Now the Department of Energy has become interested in the fuel cell, particularly the 4.8 MW size. In cooperation with the Electric Power Research Insitutue (EPRI) and United Technologies Corporation, the DOE is building a demonstration plant for Consolidated Edison of New York, to be completed this year. Unfortunately, its performance will not approach that of a commercial power plant; the demonstration is designed to operate for "no more than 10,000 hours;" to be fully commercial such a plant must last 40,000 hours.[116] The Electric Power Research Institute's $9.6 million (FY 1980) Fuel Cell and Chemical Energy Conversion Program is now concentrating on commercializing fuel cell power plants "for dispersed applications in the near-term." EPRI is also constructing a twenty kw "breadboard" molten carbonate fuel cell power plant, to be completed this year. The Institute also plans to test integration of a molten carbonate fuel cell with a coal gasifier.[117]

EPRI expects first-generation (phosphoric acid) fuel cells to be commercially feasible by the mid-1990s. Second-generation technology (molton carbonate) is expected to be commercially feasible sometime after 1990.[118]

Deployment of fuel cells hinges at present on fuel availability and cost. As noted earlier, fuel cells are currently designed to use either natural gas or naptha, both fossil fuels. Coal-derived synthetic fuels, not yet on the market, and methanol from biomass, are other fuel possibilities.[119] According to Rich Lang of the California Energy Commission, total costs are roughly comparable to gas turbine generation technology, though it should be noted that fuel cells will greatly reduce transmission costs.[120] Transmission considerations make home use of fuel cells more efficient than fuel cell power plants, a siting choice few generating technologies can offer.

Small Hydroelectric Power (3.6)

Small hydroelectric power systems are water-electric power systems up to 30,000 kilowatts (30 MW) in size. The hydraulic "head" is comparable in most cases to that found in larger hydro installations, but a smaller water flow restricts electrical capacity. Conventional, but smaller turbines, generators, governors, and control equipment are used in small hydroelectric plants.

Small hydro power facilities are used in many parts of the world with extensive installations in Europe. The People's Republic of China is the world's leader in small and micro hydro power with over 90,000 installations providing more than 5,400 MW. The Chinese small hydro plants are quite decentralized in nature, and are either not grid-connected or feed power to local grids for small industries associated with rural communies.*

Interest in the development of small hydro power has been rekindled in the U.S. in recent years; small hydro was identified as a key source in the National Energy Plan, and major efforts by the Department of Energy (through the Federal Energy Regulatory Commission (FERC)) have placed small hydro development as a high government priority.

In 1975 the U.S. Army Corps of Engineers published a five volume study, A National Program of Inspection of Dams.[122] This study provided the base data on existing hydropower facilities. It contains geographic, physical and ownership data on approximately 50,000 dams in the U.S. Much more limited data has been available on undeveloped sites. Only about 5,000 sites had been identified or previously studied by the Corps and other local, state and federal water resource agencies. In addition, in the 1975 inventory, pumped storage sites and conduit hydro projects, as distinct from dams, were not surveyed.

The data from this inventory is currently being reviewed by the Corps and is the basis for an extensive study of existing and potential hydropower capacity. A Preliminary Inventory of Hydropower Resources,[123] was publised in July, 1979. This study indicates that currently existing hydroelectric power facilities generate 63,702 MW. Of this total, 2,957 MW are produced at small-scale sites (05-15 MW); 1,517 MW are produced at intermediate sites (15-25 MW); and 59,230 MW are produced at facilities larger than 25 MW. Table 3.6-1 outlines the number of sites, capacity and energy produced for total U.S. small, intermediate and large-scale hydroelectric facilities.

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* China treats decentralized sources of energy, such as hydro and other small power plants, as a key ingredient in civil defense planning. Underground shelters and dispersed military installations are served throughout the country by dispersed electric grids fed by small power facilities.[121]

Table 3.6-1[124]

PRELIMINARY INVENTORY OF HYDROELECTRIC POWER RESOURCES NATIONAL TOTAL

Existing,[1] Potential Incremental[2] and Undeveloped[3] Capacity Ranges

	Small-Scale (0.5-15 MW)				Intermediate (15-25 MW)			
	Exist	Incre	Undev	Total	Exist	Incre	Undev	Total
NUMBER OF SITES	842	4,813	2,642	8,297	81	166	387	634
CAPACITY (MW)	2,957	5,455	8,010	16,422	1,517	3,320	7,722	12,599
ENERGY (GWH)	15,048	17,267	28,843	61,158	6,717	7,859	23,503	38,079

	Large-Scale (Greater Than 25 MW)				All Sizes			
	Exist	Incre	Undev	Total	Exist	Incre	Undev	Total
NUMBER OF SITES	238	445	1,503	2,276	1,251	5,424	4,532	11,207
CAPACITY (MW)	59,230	85,859	338,217	483,306	63,702	94,636	353,948	512,286
ENERGY (GWH)	258,239	198,087	883,519	1,339,845	280,004	223,214	935,867	1,439,085

[1] Existing hydroelectric power facilities currently generating power.

[2] Existing dams and/or other water resource projects with the potential for new and/or additional hydroelectric capacity.

: no dam or other engineering structure presently exists.

As this table shows, there are over 5,600 small-scale dams in the U.S. either generating power or with the potential for incremental development to add generating capacity. Annual energy generation at existing small-scale facilities is estimated to exceed 15,000 gigawatt-hours. These value for small-scale capacity and generation represent about five percent of the nation's current installed hydroelectric capacity and energy, according to the Corps. The incremental capacity which could be developed at existing sites could add another 5,400 MW to small hydro's total contribution. The total potential for the U.S., including all three categories of existing, incremental, and undeveloped sites, is given as over 16,000 MW, with a possible total generation of 61,158 gigawatt-hours.[125]

Ongoing studies are being conducted by the Army Corps of Engineers as part of the National Hydroelectric Power Study. These studies include the hydroelectric potential of projects of every size. The final national report will be developed by regions of the National Electric Reliability Council (NERC). The National Report should be completed and sent to Congress in October, 1981.

The distribution of existing small power production facilities is extremely variable and nearly all regions of the country have the potential for incremental energy development. Currently the greatest number and density of small scale hydropower installations are in the Northeast and Lake Central regions of the country. The undeveloped hydroelectric potential at small-scale sites is widely distributed, but appears to be greatest in the Pacific Northwest, Lake Central, and the Northeast regions.[126]

Corps estimates of future potential are only approximate and do not take into account classes of hydro projects such as those associated with canal drops, pipelines, pressure breaks, and other facilities which are part of municipal and district water supply systems. These sites are becoming increasingly attractive as the economics of energy production change dramatically, and many such projects are under study. The federal government has recognized the important of such projects and has written regulations granting exemption from the Federal Energy Regulatory Commission licensing procedures for manmade conduits generating hydroelectric power. For projects up to fifteen MW, exemptions have been given under most circumstances. In states such as California, with extensive water supply and irrigation systems, the potential for small-scale hydro power is considerable. For example, the California Department of Water Resources has recently selected 28 sites for preliminary feasibility studies. Of these 28, sixteen are sited at canals, tunnels, or pipelines; twelve projects have been sited at existing dams. The first estimate of this one round of studies indicates a capacity of 6,615 kw (6.6 MW) at an average of a little over 400 kw (.4 MW) for the sixteen conduits. Projects are also being investigated for hydroelectric production at pressure breaks in the Metropolitan Water District of Southern California and by the water departments of an increasing number of municipalities. The development potential of these small and micro hydro resources has not been surveyed. It can be expected, however, that such conduit rated projects will make an increasing contribution to capacity and energy production.

Hydroelectric technology, on any scale, is designed to exploit the kinetic energy of falling water. The equipment designed to translate the energy of falling water into a useable form is the turbine. A water turbine is the device that converts the energy in falling water into rotating mechanical energy. This energy, available in a rotating shaft, may either be used directly to operate equipment or connected to a generator to produce electricity.

Impulse units are generally the simplest of all common turbine designs and are widely sued in micro-hydro applications. Impulse turbines use the velocity of the water to move the runner rather than pressure as is the case with reaction designs. In general the turbine is a disc with paddles or buckets or sometimes blades attached to the outside edge.

The water passes through a nozzle and strikes the buckets, blades or paddles, one at a time, causing the wheel to spin.[127] In a common type of impulse turbine, the Pelton Wheel, buckets are used for greatest efficiency. Each bucket is split in two so that the water stream is split in half and caused to change direction, heading in the opposite direction to the original water stream. Because the power developed by a Pelton Wheel is largely dependent on the velocity of the water, it is well suited for high head and low flow installations. Operating efficiencies in the 80 percent range are common, and very small units using the Pelton Wheel are produced by several firms in North America.

A variation on the Pelton Wheel uses blades with an outer rim enclosing the fan shape. The water stream is applied to one side, runs across the blades and exits on the other side. Like the Pelton, it is possible to use more than one water jet on a single wheel in situations where relatively lower head and high flow are present. As with the Pelton, the wheel itself is made in relatively few sizes and different nozzle sizes are used to match the equipment to the site conditions. This type of unit, called the Turbo Impulse Wheel, is made exclusively by Gilkes of England.

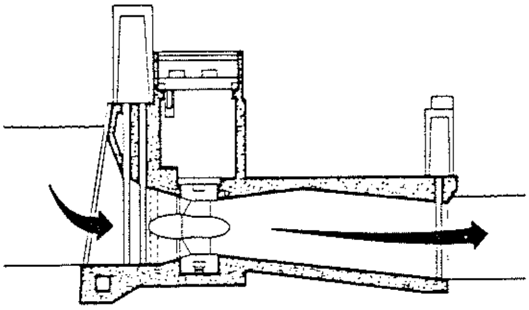
The Crossflow turbine, another type of impulse turbine, is constructed with a drum-shaped runner, the drum having blades fixed radially along the outer edge. Water flows in one side and after having exerted force on one part of the drum, flows across and exits from the other side, having applied force to the blades again as the drum turns. Because of its design, the Crossflow is said to be largely self-cleaning, and it is well suited to low head applications. The major manufacturer of these turbines, Ossberger of West Germany, has installed them successfully in sites with only one meter (39 inches) of head. The Crossflow turbine is used widely around the world, although none have yet been installed in the United States.

Reaction turbines, while functionally the same as impulse design, work, on a different principle. The runner is placed directly in the water stream and power is developed by water flowing over the blades rather than striking each individually. Reaction turbines use pressure rather than velocity.[128] They tend to be very efficient in specific designed-for sites, but their efficiency falls sharply with variation. Reaction units are usually used in very large installation. The Francis turbine in particular is used in the largest of the country's hydroelectric projects.

Other reaction turbines are generally variations on the propeller design. Some of these turbines operate in a tube with fixed propeller blades. If the unit is integrated with a generatgor, and the whole unit is in a case submerged in the stream flow, the mechanism is called a bulb unit. Figure 3.6-1 illustrates a bulb turbine. If the conduit bends just before or after the turbine, then the turbine can be connected to a generator sitting outside the flow itself. A variation of propeller turbines, the Kaplan, allows for greater flexibility in use, with variation in the flow and pressure of the water. Figure 3.6-2 describes a Rim-generator turbine and Figure 3.6-3 describes a Tubular-type turbine.

Figure 3.6-1[129]

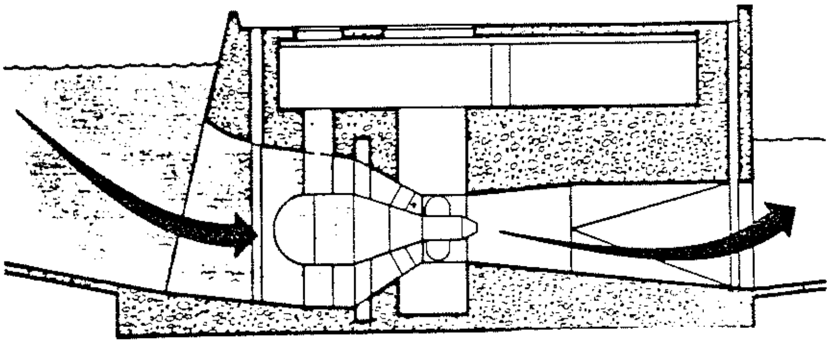
RIM - GENERATOR TURBINE



The energy efficiencies of turbines run generally between 75 and 95 percent. Francis turbines have very high efficiencies of up to 95 percent when operating at designed pressures, but they are generally more expensive than other types and quickly become inefficient as pressure and flows vary from design specifications. Impulse turbines have flatter efficiency curves and generally are less expensive.

Figure 3.6-2[130]

BULB - TYPE TURBINE

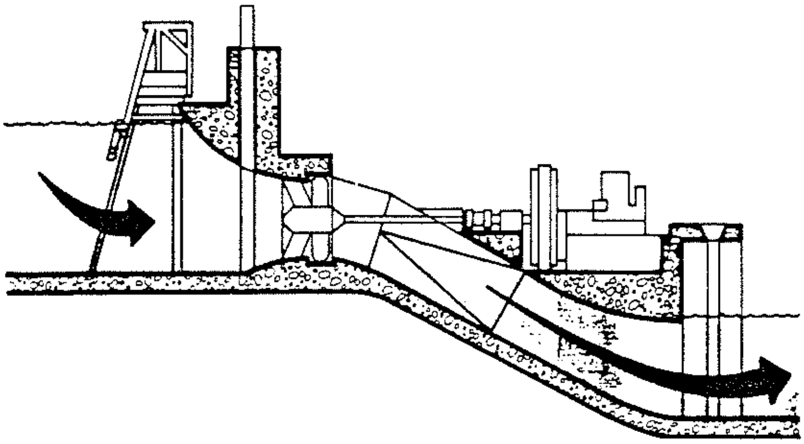


The bulb-type turbine generator is in a bulb-shaped watertight steel housing located in the center of an enlarged water passage.

Transmission of power from the turbine to the generator entails power losses. Belt drives are 95 to 97 percent efficient for each belt. Gear boxes are generally 95 percent efficient. Generators themselves are usually about 80 percent efficient. Thus, overall efficiencies for electrical generation systems can vary from 50 to 75 percent, with the higher overall ratings in the high head, high speed impulse turbines.

Figure 3.6-3[131]

TUBULAR-TYPE TURBINE



The tubular-type turbine uses a conventional horizontal propeller turbine and an attached generator located outside the water passage.

There are basically two types of generators, the synchronous and induction. The induction generator obtains its excitation from the power grid. The general method of getting an induction power plant on line is to start the generator as a motor with the turbine runner spinning "dry" and then opening the wicket gages of the turbine to load the unit. The generator then begins to operate as a generator. By comparison, a synchronous generator is synchronized to the grid system voltage and frequency before the breaker device (which connects the generator to the system) is closed. When connected, the generator continues to operate a synchronous speed. The voltage is determined by the strength of the field; therefore, a voltage regulator is required for a synchronous generator. Because synchronous generator frequency is determined by speed, a governor is required for exact control and a synchronizer is needed to compare the magnitude and displacement of alternative current waves with paralleling generators.

Current costs for induction generators are somewhat less than for snychronous generators of the same output rates. On the other hand there are penalties in the operation of an induction machine amounting to one to two percent loss of efficiency. Generally, induction generators are only suitable in small sizes, generating electrical power into an operating system. There are a number of advantages to a generation system that can start up if there is no possibility of connecting to the grid. The advantages of synchronous generators in times of emergency may become decisive. The DOE publication, Micro-Hydro Power, suggests, "If you intend to be completely independent from the power grid, a synchronous generator is used."[132]

A direct current (DC) generator is another way of generating electricity which will allow for independence from the power grid. This system has several advantages, especially in very small systems (e.g., less than five kilowatts). The excess power generatged by a DC system can be stored in batteries, thereby extending the system's peak capacity. DC generators are not speed-sensitive and no governor is needed. Battery storage systems with hydro generation generally compare more favorably than wind power systems because the hydro generator generally continues to replenish the battery set. This means that a deep discharge condition common with wind systems is very rare. Deep discharge is a common cause of battery failure. However, the storage function limits the size of a DC system as batteries become unwieldly and very costly in systems over six kilowatts.

In times of emergency, particularly if the emergency is short-lived, the availability of DC system equipment could be critical. DC power generation would greatly extend the useability of the equipment.

The ability of a community to use the surviving electrical generating potential of small hydro projects depends upon the type of generating equipment and its independence from the grid, according to the technical conditions described in this section.