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Lawrence Livermore Laboratory

AN ENERGY CONSERVATION AND MANAGEMENT PLAN FOR
PLANT FACILITIES AT THE LIVERMORE SITE

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AN ENERGY CONSERVATION AND MANAGEMENT PLAN FOR PLANT FACILITIES AT THE LIVERMORE SITE

ABSTRACT

An energy conservation and management plan for the Livermore site of the Lawrence Livermore Laboratory is presented. The plan defines the energy-conservation goals for the next 10 years and proposes the ways and means of attaining them.

The main features contained in this plan are as follows:

1. Development of the criteria and underlying assumptions required for long range planning.

- Energy growth rates and the case for using the concept of the technical-fix energy growth rate.
- LLL energy outlook and fuel cost projections.
- Life-cycle-cost criteria.

2. Targets of the long-range plan.

- Between 1975 and 1985, an annual energy usage growth equal to 5.8% of the 1975 energy consumption.
- 1985 and thereafter, zero energy growth.
- A change from the current dependence on natural gas to the use of other fuels for heating.
- A doubling of the 30-day strategic oil storage capacity.

3. Cost schedule for the next 10 years.

INTRODUCTION

The United States is undergoing a long-term transition from an economy based on abundant, low-cost natural gas and petroleum to an economy based on scarcer, high-cost, multiple-source energy. This change will have profound effects on the Lawrence Livermore Laboratory (LLL). The near-term predicament facing LLL is not simply an energy shortage but a mismatch between the changing mix of fuels available and the capability of the existing plant facilities to use them in the proportions and for the durations required.

Since July 1973, in compliance with President's energy message and in response to the notification by the Pacific Gas & Electric Company of predicted curtailments in the supply of natural gas, LLL has undertaken a series of management and conservation actions.* These actions were necessarily of an urgent nature, but they have succeeded in purchasing the time necessary for the long-range plan to evolve.

* See Appendix A for the "Energy Conservation Progress Report--1973 to 1975."

The energy conservation and management plant described here presents no quick and simple panaceas or startling new concepts. It offers only a straightforward application of current technology arranged in a coordinated, 10-year program most suitable for the Livermore site of LLL.

OBJECTIVE OF PLAN

The objective of the plan is to ensure continued operation of the LLL plant facilities at the Livermore site within prescribed energy limits, with minimum disruption to the research and development mission, and, if possible, without changes to the lifestyle of its personnel.

The plan proposes a goal of zero energy growth by the year 1985. This goal will be accomplished through a 10-year (1975-1985) program to fix all new and existing buildings for optimum thermal and energy-using-system efficiencies. During this 10-year period, the energy consumption growth rate would still increase but at a much lower rate than before. In addition, an alternative-fuel strategy is provided to accommodate the changing availability of the various energy sources anticipated for the period up to the year 1985.

The period from 1985 to 2000 is so uncertain that it is considered only in a general way. The plan, however, is adaptable to new developments or technological breakthroughs.

BASIC CRITERIA AND UNDERLYING ASSUMPTIONS

Given the broad objectives outlined in the preceding section, certain basic criteria and the underlying assumptions need to be developed before a program of action can be established. Any strategy devised must be systematically planned and coordinated, with well-thought-out priorities. The setting of these priorities must necessarily be limited by an overall schedule of funding that ultimately depends on an acceptable growth rate for energy consumption, an energy outlook for the LLL Livermore site, fuel-cost projections, and life-cycle-cost criteria.

The tactical options available are limited because it takes time to plan and construct new, energy-efficient buildings or to retrofit existing plant facilities in any major way. In the past, the thermal effectiveness and energy-using-system efficiencies of buildings were sacrificed for lower initial costs because fuel was cheap and thought to be plentiful. These wasteful features will not be permitted in new construction but are firmly fixed in the existing buildings.

Beginning with the Laboratory's 1973 "quick-return" energy-conservation program, most of the energy and cost savings readily attainable with minimum expenditures have been achieved. The further upgrading of the existing plant facilities will require larger engineering efforts and major construction expenditures.

The major thrusts of the energy plan will be to retrofit existing buildings for more efficient fuel use, incorporate energy-efficiency criteria into the design of new buildings, reclaim heat from waste energy streams, and make all preparations necessary to provide a versatile fuel-usage capability to suit the fuel outlook. Current technology, rather than that still in the laboratory or pilot-plant stage, will be used. Meanwhile, a close watch will be kept on technological and scientific developments for promising applications. The present emphasis on energy conservation is causing a virtual revolution in the design, construction, and operation of buildings. Adjusting to this new fact of life will require new attitudes and techniques.

This section describes the basic criteria and assumptions on which the LLL energy plan is based. These factors will be reevaluated each year, and midcourse corrections will be made as required.

Alternatives for Increases in Energy Consumption

The Lawrence Livermore Laboratory started its energy-conservation efforts in July 1973 and succeeded in reducing its energy consumption by 16.8% in FY 1974. At the end of FY 1975, however, the net cumulative reduction since July 1973 amounted to only 11.4%. This apparent relapse is due to the dual effects of expansion in plant facilities and to increases in programmatic energy consumption counteracting conservation efforts. Evidently, energy savings are becoming more difficult to achieve as long as the growth of plant facilities and operations continues unabated.

In the past, performance-reporting instructions included allowances for growth while applying zero energy growth as a base, but this adjustment for growth has since been rescinded. Some other concept--such as the "technical-fix" growth alternative, which accounts for growth while enforcing energy conservation--is now needed. A strict adherence to zero energy growth may be applicable in the short term but becomes unrealistic and unmanageable in the long run for a growing facility.

The Energy Policy Project sponsored by the Ford Foundation outlined three cases in which energy consumption can grow. These are shown in Fig. 1 and are defined as follows:

1. Historical growth: continued growth at the historic rate.
2. Zero energy growth: some change in lifestyles with the goal of zero energy growth by the year 2000.
3. Technical-fix growth: continuation of activities implied by the historical-growth case but with concurrent strenuous efforts to reduce energy consumption.

The equivalent alternatives for increases in energy consumption at LLL are shown in Fig. 2 and are discussed below.

Historical-Growth Case

The trend of LLL energy consumption correlates closely with the long-term growth in the aggregate floor area of the plant facilities. Taking into account the additional

Fig. 1. Various growth scenarios.

Fig. 2. Alternatives to increased energy consumption for LLL.

floor areas to be provided in the new facilities building program, the aggregate floor-area curve was extended to FY 1985 and the energy consumption extrapolated accordingly at the historical rate.

The LLL population data showed little correlation with energy consumption but were included in Fig. 2 as a matter of interest.

Another item of interest is the shape of the energy-consumption curve. Beginning in FY 1963, energy consumption rose steadily with the growth in plant facilities--except in 1973, when plant growth leveled off while energy consumption declined sharply due to the start of the energy-conservation program. This decline, however, has been reversed because of the resumption of growth in plant facilities and increased programmatic requirements. The resurgence in energy consumption despite energy-conservation efforts reflects the overriding effects of plant and program growth. This condition can be accounted for in the so-called technical-fix growth case.

Zero-Energy-Growth Case

In the zero-energy-growth case, there is no increase in energy consumption above the amount consumed in the base year of FY 1975. It should be noted that the target year for the zero-energy-growth scenario used in the Ford Foundation study is the year 2000. The target for the LLL energy plan is zero energy growth for the LLL Livermore site by the year 1985.

Technical-Fix Growth Case

The technical-fix growth case is actually the zero-energy-growth case with a small percentage of the historical growth added. By definition, it falls somewhere between the limits set by the zero-energy and the historical-growth cases. The rationale used for deriving the technical-fix growth rate for LLL can be outlined as follows, using FY 1975 as the base year:

1. If there is no growth in plant facilities or programmatic energy requirements or if there are offsetting energy increases and decreases, the zero-energy-growth case could be in effect. This can be considered to be the practical lower limit of energy consumption.
2. If there is normal growth in plant facilities and programmatic energy requirements, and no energy conservation is practiced, the historical-growth curve can be considered to be the upper limit of energy consumption. By 1985, energy consumption will become 138% larger than the energy consumed in 1975.
3. If the existing facilities maintain a status quo and if all new construction is designed to be energy efficient and consumes 40% less energy per unit area than in the past, the historical growth would be decreased by about 40%.
4. If all existing buildings as of 1975 are retrofitted and made more energy efficient, the 1975 energy consumption could be reduced by about 36%, a little less than what can be achieved for new facilities. Inasmuch as a net 11.4% energy

reduction has already been achieved since 1973, the balance of the reduction achievable is approximately 25%. Therefore a 25% reduction in energy consumption by the existing facilities is a reasonable 1985 target for the 10-year retrofitting program proposed by this energy plan.

The technical-fix energy growth rate can be summed up as follows:

Energy usage by 1985 based on historical growth = 138% (above 1975 base)

Less 40% due to efficiency of new construction,
(0.40)(138%) = -55

Less 25% due to retrofitting existing buildings = -25

Net energy consumption in 1985 due to technical
fixes = 58% (above 1975 base)

Dividing the 58% by 10, one can see that the technical-fix growth rate over the next 10 years averages out to be 5.8% annually (of the 1975 energy consumption). When used in conjunction with the zero-energy-growth case, the technical-fix growth concept provides a target area that is both realistic and attainable without crippling consequences (see Figs. 12 and 13).

Because all growth patterns eventually approach limits, real growth curves are not exponential but S-shaped. The situation at the LLL Livermore site will prove to be no exception, and the physical plant will probably reach maturity at the completion of the 10-year building program in FY 1985. Thereafter, if additional construction is offset by the elimination of obsolete or temporary facilities, zero energy growth at LLL will become a reality.

Energy Outlook

The LLL energy-conservation project is limited to the next 10 years, where the degree of uncertainty does not seriously inhibit the formulation of plans. No attempt was made to forecast the energy scenario beyond 1985 to the year 2000 except to accept the professional consensus with only minor comments.

The outlook for the LLL Livermore site to the year 1985 is for a shift from the current dependence on gaseous fuels (natural gas and propane) to petroleum. Both natural gas and propane will become progressively less available to industrial and commercial users in order to reserve these fuels for households. The situation at LLL would center on the reduction of natural-gas and propane consumption by the substitution of more abundant, regionally available resources like oil or electricity. During this period of transition there would be a continuing effort to conserve energy, recognizing that any persistent gap that develops between the demand for energy and the availability of suitable fuels might affect the prospects for growth at LLL.

LLL Current Status

The current energy-use pattern at the LLL Livermore site is shown in Fig. 3. Of the total energy, 95% is used for buildings and facilities operations, including programmatic research requirements. "Owned equipment" is defined as all ERDA-owned equipment that is not related to transportation but uses vehicular fuels.

Fig. 3. Fiscal year 1975 energy usage.

As shown in Fig. 3, of all the energy used in buildings and facilities operations, 53% is in the form of electricity and 1% is from oil and propane. The balance of the energy used, 46%, is from natural gas.

There are two types of natural-gas service to LLL: noninterruptible (firm) and interruptible. The firm gas supply serves the main computer facilities and adjacent buildings, accounting for 7% of the total natural-gas usage. The interruptible gas supply serves the rest of the LLL facilities but is subject to curtailment at any time. Because of this, the interruptible gas system has been provided with two complementary standby systems, oil and propane, having enough combined storage capacity to operate the LLL plant for about 30 days without refueling, with only limited shutdown of facilities.*

If oil and propane must be used over an extended period, the refueling process will be a formidable logistics problem requiring not only the resupply of propane and oil to make up for consumption but also the transfer of fuels from reserve to live storage tanks.

The propane standby system (actually a propane-air mixture that simulates natural gas and is injected directly into the natural-gas distribution system) was initially installed in the early 1950s. This system currently has a storage capacity of 200,000 gal, consisting of a total of eight 25,000-gal (net capacity) aboveground tanks (three at the LLL Livermore site and five at Camp Parks, a reserve facility approximately 12 miles away). Under winter conditions, the daily firing rate will consume the full load of a 10,000-gal tanker truck and trailer every day.

The oil standby storage system provided since July 1973 now totals 58,000 gal of diesel fuel oil at Livermore and an additional 40,000 gal at Site 300. At Livermore, 33,000 gal of oil are in underground storage tanks. The rest of the oil (65,000 gal) is in 13 mobile tankers of 5000-gal capacity each. All the aboveground tankers must eventually be replaced by permanent facilities, by order of the regional EPA office in San Francisco, California. Under winter conditions, the oil firing rate of approximately 6000 gal per day will consume the full load of a 10,000-gal tanker truck and trailer approximately every one and a half days.

The Transition from Natural Gas to Oil by 1985

The fuel outlook to the year 1985 is essentially predetermined by the present patterns of energy consumption. With the anticipated continuing decline in the availability of gaseous fuels, the only practical "swing" fuel is oil because of the following factors:

1. New technology on alternative energy sources will not become practical in the next 10 years, leaving oil, coal, and electricity as the only practical energy sources available.

*It should be noted that the Pacific Gas & Electric Company (PG & E) has informed LLL that, in the event of another "coldest winter of modern record," such as occurred in 1948-1949, there will be curtailments of interruptible gas service for periods of up to 51 days. Every building in LLL has been ranked according to its critical need for gaseous fuel. This priority system will permit a shutdown response which can be scaled to any eventuality.

2. Conversion of existing plant facilities to permit the dual capability of using either oil or gaseous fuels is more flexible, much easier, more quickly accomplished, and certainly less costly than conversion to coal or electricity. The latter two types of plant conversion involve major capital expenditures instead of modifications to existing equipment.

3. The bulk transportation, storage, handling, and end-point consumption are decidedly simpler for oil than for coal.

4. The use of electricity for the heating function will require major changes to the electric power distribution system.

The Energy Mix by FY 1985

Solar Energy--Barring some unforeseen major scientific, engineering, or cost breakthrough, it appears unlikely at this time that solar energy will be used in large scale before FY 1985 for the heating or cooling of commercial buildings.

The simplest and most natural application of solar energy is for domestic water heating, especially in retrofitting large buildings that already have a large thermal storage capacity and boiler. Furthermore, since the amount of natural gas consumed for domestic water heating is significant (5% of the total gas consumption), a few commercially available modular solar water-heating packages will initially be installed. If successful, this type of solar energy system can be expected to be applied on a large scale. Meanwhile, developments in solar energy research, product development, and demonstration projects will be closely watched and promising situations explored for practical applications at LLL.

Electrical Energy--The Livermore site receives its electric power primarily from the U.S. Bureau of Reclamation (BUREC). However, any power consumed by LLL in excess of the allocation provided by the U.S. Bureau of Reclamation must be supplied by PG & E. These allocations of electric power to LLL are on a decreasing schedule, as shown in Fig. 4. If the consumption of electric power continues to grow as projected, PG & E will become the major supplier by 1985.

The availability of electrical energy is not regarded as a problem at present. The qualification is due to the uncertain outcome of the 1976 California election, in which the Nuclear Initiative is one of the ballot propositions. This proposition is stated as follows:

Nuclear Power Plant Initiative Statute

After one year, prohibits nuclear power plant construction and prohibits operation of existing plants at more than 60 per cent of original licensed core power level unless federal liability limits are removed. After five years requires derating of existing plants ten per cent annually unless Legislature by two-thirds vote has confirmed effectiveness of safety systems and waste disposal methods. Permits small-scale medical or experimental nuclear reactors.

Fig. 4. Electric power consumption and sources of supply.

According to PG & E,* the passage of this initiative means that the existing use of nuclear power would have to be replaced over the short term by increased use of distillate and heavy fuel oil and, over the longer term, by the unprecedented substitution of coal. Oil-fired power plants, which can be built more quickly than coal-fired power plants, would have to be operational by 1979 to prevent power shortages during peak demand loads. This timetable would require that the governor or legislature authorize "emergency" construction to reduce the lead time by expediting the normal licensing and siting procedures.

If the Nuclear Initiative fails, the current expansion program at PG & E is projected to give the power-generation capacity shown below for the year 1985:

<u>Source</u>	<u>Percentage of total</u>
Nuclear	32
Geothermal	10
Hydroelectric and imports	23
Peaking, fossil-fueled	21
Base load, fossil-fueled	14

* Implications of the Nuclear Initiative, Pacific Gas & Electric Company, FYI Report No. 22 (December 1975).

(Note that fossil fuels constitute only a minor part of the energy used for electric power generation. This situation, plus the fact that BUREC power is mainly hydroelectric in origin, makes the use of ERDA standard raw source energy conversion factors* questionable when applied to electricity consumed by LLL.)

Gaseous Fuels (Natural Gas and Propane)--The deregulation of natural gas prices is one of the issues that remains unresolved by the recently enacted Energy Policy and Conservation Act. Meanwhile, the known reserves of natural gas are being depleted, and expert opinion is divided on whether or not decontrol of gas prices would significantly spur the discovery of new sources of natural gas. In the interim, industrial and commercial users of this gaseous fuel are being subjected to increasing curtailments and other pressures to convert to other fuels.

The "firm" and "interruptible" natural-gas categories will not be applicable after May 1976. In their place will be a system of end-use priorities under which PG & E will curtail deliveries of natural gas (see Fig. 6). Propane will not be considered as an alternative fuel to natural gas and will be under allocation controls by the regional Federal Energy Administration (FEA) office.

The new natural-gas priority system imposed by the California Public Utilities Commission affects the LLL Livermore site as follows:

1. The price of natural gas will depend on the usage in each priority. Commercial and industrial users of natural gas will most likely be charged higher prices than residential users.
2. All gas-fired equipment with natural draft or atmospheric burners is expected to be supplied with natural gas without curtailments, at least until 1977-1978. About 22.5% of the LLL gas-fired equipment capacity is in this category. This type of equipment cannot be converted to burn oil. PG & E is noncommittal about the prospects after 1978.
3. Gas-fired equipment that has forced-draft burners and can be converted to fire either oil or natural gas shall be converted or bear the risk of gas-curtailment shutdowns.

Of the LLL gas-fired equipment capacity, 41.1% has already been converted to fire either fuel. This dual-fuel group is in a priority that can expect increasing gaseous fuel curtailments. The remaining 36.4% of LLL gas-fired equipment capacity is forced-draft equipment that has not yet been converted to fire oil. This group must be converted within a limited time or face curtailment along with the other forced-draft equipment, unless waivers are applied for and granted by the California Public Utilities Commission. Due to the conversion costs involved, LLL will file for waivers on this group. It is not known how long the application for waivers will be in the adjudication process, but an abrupt need to convert appears unlikely.

*See Appendix B. See also page 27 for additional comments on ERDA conversion factors.

Since propane will not be allocated by FEA as an alternative fuel to natural gas, no expansion of the existing propane-storage capacity is contemplated. However, if the existing propane tanks can be filled during the off-season, this fuel can be used to fire unconverted forced-draft equipment when natural-gas curtailments occur.

Petroleum--Oil is the most logical replacement for gaseous fuels. All new buildings will be provided with boilers having dual-fuel (oil and gas) firing capabilities, and as many existing boilers as required by the California Public Utilities Commission will be retrofitted accordingly. The existing 30-day oil storage capacity will have to be doubled to provide a reserve against the threat of future oil embargoes and the prospects of increasing curtailments of gaseous fuels.

Coal--Coal may have to be seriously considered regardless of the outcome of the Nuclear Initiative if the oil-supply picture unexpectedly becomes more unfavorable or if there is a catastrophic nuclear reactor accident anywhere in the world. It is, however, the fuel of last resort for LLL within the next 10 years for the following reasons:

1. The nearest commercial source of coal is in the state of Utah.
2. A railroad spur approximately 2 miles long plus coal-hauling trains would be required. One unit car load contains 100 tons of coal. Each day 135 tons of coal would be required.*
3. A large open area (1 acre) must be dedicated for coal storage.*
4. Coal-fired boiler plants are more expensive than oil- or gas-fired boilers by a factor of at least 2.
5. Coal requires high-cost auxiliary systems for coal handling as well as ash removal and disposal (8 tons of fly ash for removal and disposal each day*), high-efficiency stack-gas scrubbers, and precipitators (150 lb of particulates for disposal each day*).
6. Coal-fired plants require more operating and maintenance manpower and resources.
7. Strong opposition is expected from environmental interest groups.

According to the regional EPA office in San Francisco, there are presently no coal-fired boiler plants in California, but several (four) cement-manufacturing plants in southern California do use coal in their cement kilns. The firing rates of these kilns are in the 1.2×10^9 Btu/hr range. (The FEA currently has under consideration the requirement that all oil- and gas-fired-boiler installations with a firing rate of 100×10^6 Btu/hr or more be converted to fire coal. The largest boiler installation at LLL is rated at 28×10^6 Btu/hr.)

*For a hypothetical coal-fired central plant, 2000-boiler-HP (66×10^6 Btu/hr), 2.3 times the size of the existing central steam plant (Building 401). The construction cost of the 2000-boiler-HP coal-fired central plant is estimated at approximately \$4,250,000, including engineering costs and contingency allowances. Distribution costs are not included. The total existing LLL boiler rated capacity is approximately 8000 boiler-HP.

Graphic Summary of Energy Outlook to 1985

Figure 5 is a graphic representation of the fuel outlook to FY 1985 for the LLL Livermore site plant facilities and operations. The energy-consumption pattern for FY 1975 is derived from Fig. 3. The natural-gas usage is shown not in the usual "firm" and "interruptible" categories but in the end-use categories recently imposed by the California Public Utilities Commission. These end-use categories are used to establish

Fig. 5. Energy outlook to 1985 for LLL plant facilities and operations.

gas priorities in accordance with the criteria flow chart shown in Fig. 6. The percentages shown in Fig. 5 indicate the gas-firing capabilities of the LLL Livermore site as of January 1976. Concerning the "heating function" shown in Fig. 5, the bar chart reflects the following situation assumed for 1985:

1. Existing 1975 facilities:

- a. All forced-draft boilers capable of firing oil will be on oil (priority 3--Fig. 6).
- b. Of the existing forced-draft boiler capacity that is not capable of using oil in 1975, 50% will be required to be converted and be on oil (priority 2A-T or 2B-T initially, but relegated to priority 3 by 1985). The remaining forced-draft boilers in this category will be granted waivers for various reasons and will remain on gaseous fuels (priority 2A-T or 2B-T initially, but waived to priority 2A-P or 2B-P by 1985).
- c. All natural-draft equipment will remain on gaseous fuels (priorities 2A-P and 2B-P).

2. New facilities built after 1975: all post-1975 heating equipment will be able to use energy sources other than gaseous fuels. The most likely "swing" fuel is assumed to be oil.

Fig. 6. Gas priority criteria--California Public Utilities Commission.

The Transition from Oil to Other Energy Sources by FY 2000

Two scenarios are possible: "high-nuclear" and "low-nuclear." The "high-nuclear" condition is exemplified by the following table listing the sources of electrical energy projected for 1995 by PG & E for its service area:

<u>Source</u>	<u>Share of total (%)</u>
Fossil fuels (80% oil, 20% coal)	9
Geothermal	8
Hydroelectric and imported electricity	16
Nuclear	<u>67</u>
	100

At the Livermore site, gaseous fuels and/or oil will still be the primary energy sources for heating, whereas electricity will continue to serve its traditional roles in lighting and power. Alaskan oil and natural gas will be important factors in the energy picture as Canadian gas becomes unavailable. Solar energy, synthetic gas from coal, imported liquefied natural gas, and imported oil will make up the rest. The LLL physical plant, mostly convertible to fire either gas or oil, will be ready to switch from one fuel to another as the situation demands.

The "low-nuclear" condition can be translated to mean "no nuclear" energy; that is, a political decision might be made that the risks of nuclear power are too great to continue its growth as planned. Nuclear power would be restricted pending the resolution of safety, political, and environmental issues. New capital investments in nuclear power plants would practically cease. Meanwhile the electrical energy shortfall would have to be made up with coal- and oil-fired power plants. Little relief can be expected from the new technologies because, even with the needed scientific breakthroughs, many years will be required to develop a new technology to the necessary size to substitute for the planned nuclear plants.

Fuel Cost Projections

Projections of the cost of fuels are fraught with uncertainties due to economic, political, regulatory, ecological, special-interest, and other factors. A detailed study of the outlook for the cost of fuels is beyond the scope of this plan. The following premises are therefore accepted with only minor adjustments resulting from some personal judgments of the authors.

Premise 1: The price of oil will escalate between 3 and 8% per year for the next 10 years.

Authority: ERDA Plant Engineers meeting, Bethesda, Maryland, July 1975.

Adjustment: The Energy Policy and Conservation Act enacted in 1976 phases out government oil price controls over a period of 40 months beginning February 1, 1976. It

also temporarily rolls back average domestic oil prices. Assuming that the prices of imported oil will increase by 10% annually during this period and that 50% of the oil consumed in the United States will be imported, the average price of oil should increase by about 5% annually until the middle of 1979, after which time the escalation rate may parallel that of natural gas prices and stabilize at 10% annually.

Since oil is the primary fossil fuel in the transition away from natural gas, its price can serve as a reference point for the price of other fuels. It can be assumed that the relative prices of competing fossil fuels will be inversely proportional to the ease of the fuel's conversion to useful energy and to the relative abundance of the fuel. Accordingly, the cost of gaseous fuels (to commercial users) is projected to be higher than the cost of oil, and the cost of coal is projected to be the lowest of all the fuels considered. The relative cost of electricity could show a downward trend as the proportion of electric power generated by fossil fuels progressively decreases and nuclear power advances. This remains to be seen.

Premise 2: The price of natural gas will reach parity with the price of oil (on a Btu basis) by 1977-1978. In addition, the cost of natural gas to industrial and commercial users will be readjusted to be higher than for residential users.

Authority: Unofficial opinions of local utility staff engineers. It is reported that the Canadian Energy Minister also feels that gas and oil prices should reach parity by 1978.

Adjustment: In Fig. 5 the projected use of natural gas declines from 43.7% in 1975 to 8% in 1985. This is consistent with the need to phase out this fuel in the face of dwindling reserves. Nevertheless, the physical plant can fire either oil or gas and can take advantage of gaseous fuels available from coal gasification and imported liquefied natural gas.

The price of gaseous fuels to LLL is projected to be at a 10% premium above the price of oil, after gas attains price parity with oil in 1977-1978. The prices of Canadian natural gas are based on projections by FEA analysts.

The cost of propane is not considered since the use of propane by LLL for heating purposes will not be allowed by FEA.

Premise 3: The price of coal will escalate at a 4.5% annual rate over the next decade.

Authority: Arthur D. Little, Inc., Study of Base Load Alternatives for Northeast Utilities System (1973), page 63.

Adjustment: The price of coal will follow the same, or slightly higher, percentage increases as those anticipated for oil after the end of oil price controls. The value of coal will increase as coal gasification and liquefaction increase.

Premise 4: The Livermore site receives its electric power primarily from the U.S. Bureau of Reclamation. However, any power consumed by LLL in excess of the allocation

provided by the U.S. Bureau of Reclamation must be supplied by PG & E. This situation is shown in Fig. 4. Prior to FY 1971, LLL's electric power needs were supplied solely by the U.S. Bureau of Reclamation.

Authority: The outlook for the cost of electric power was developed in cooperation with the Bureau of Reclamation and PG & E and takes into account the following factors in sequence:

1975-1977	a. Continuing increases in PG & E rates due to the price of imported oil
	b. Larger proportion of LLL's power supplied by PG & E as BUREC power allocation declines (see Fig. 4)
	c. Increase of 67% in the cost of BUREC power scheduled for January 1977
1977-1980	a. BUREC power rates unchanged until 1981
	b. PG & E power rates increase 20%
	c. PG & E proportion of LLL power usage continues to expand
1980-1981	BUREC power rates decline due to the repayment of BUREC power "loaned" to PG & E, pending completion of PG & E power generation plants in 1980
1981-future	PG & E power rates increase while BUREC power rates stabilize

Since BUREC electric power allocations to LLL are on a declining scale, all new electric power requirements will have to be satisfied with PG & E power. Therefore life-cycle-cost calculations will use PG & E power rates. The 1976 price is \$4.84 per million Btu. The price escalation rate over the next 10 years is projected at 15% per year.

Graphic Summary--Figure 7 shows the cost projections to FY 1985 for the various fuels. Comparative prices for liquefied natural gas, syncrude, synthane, and other fuels are included for reference. These comparative prices are for order-of-magnitude comparisons only. No large-scale plants exist, and pipeline costs are not included.

Life-Cycle-Cost Criteria

All energy-conservation measures that involve capital expenditures must be evaluated and placed on a common basis before investment decisions can be made. These evaluations are to be based on the savings and costs over the life of a project rather than on initial costs alone. The methodology takes into account the investment cost (including the time value of money), net energy cost savings, and other costs such as maintenance and service costs. This type of investment analysis is commonly referred to as "life-cycle costing."

Fig. 7. Fuel-cost projections for LLL.

The life-cycle costing procedure to be used in this plan is essentially the annual cost method modified with payback period constraints* as suggested by ERDA (10-year maximum payback period for retrofit projects, 20-year maximum payback period for new construction). The capital investments are reduced to equivalent uniform annual costs at 10% interest (ERDA), and all other annual costs and savings are tabulated as shown in Fig. 8. The net annual cash flows are then calculated for each year. The cumulative cash flow is finally determined, and the payback period is that point in time at which the cumulative cash flow changes from negative to positive.

A		B	C	DESCRIPTION OF PROJECT
YEAR	BTU SAVINGS PER YEAR (000,000)	PROJECTED COST PER MILLION BTU	ENERGY SAVINGS	
0	1100	\$1.40	\$1540	<p>INSULATING STEAM CONDENSATE RETURN LINE SAVES 1100x10⁶ BTU PER YEAR. INITIAL INVESTMENT IS \$5000, AND MAINTENANCE IS ESTIMATED AT \$50 PER YEAR. ASSUME 10% INTEREST, 20 YEARS ECONOMIC LIFE FOR THE PIPE INSULATION.</p> <p>THIS EXAMPLE SHOWS THAT THE PAYBACK PERIOD IS BETWEEN 2 AND 3 YEARS. (THESE TABLES ARE SIMPLIFIED VERSIONS OF THOSE IN THE FEA TECHNICAL MANUALS.)</p>
1		$1.85 = 1.40 + (.45)^*$	2035	
2		$2.47 = 1.40 + (1.07)$	2717	
3		$2.75 = 1.40 + (1.35)$	3025	
4		$2.85 = 1.40 + (1.45)$	3135	
5		$2.90 = 1.40 + (1.50)$	3190	
6		$3.20 = 1.40 + (1.80)$	3520	
7		$3.35 = 1.40 + (1.95)$	3685	
8		$3.70 = 1.40 + (2.30)$	4070	
9		$4.00 = 1.40 + (2.60)$	4400	
10		$4.30 = 1.40 + (2.90)$	4730	

* DIFFERENTIAL PRICE OF NATURAL GAS ABOVE THE 8% INFLATION LEVEL

LINE NO.	REDUCTION (INCREASE) IN OPERATING EXPENSES	0	1	2	3	4	5	6	7	8	9	10	TOTAL
1	ENERGY SAVINGS (SEE ABOVE)		2035	2717	3025	3135	3190	3520	3685	4070	4400	4730	
2	LABOR SAVINGS (COSTS)		(50)	(50)	(50)	(50)	(50)	(50)	(50)	(50)	(50)	(50)	(500)
3	OTHER												
7	NET INVESTMENT	(5000)											
8	DEBT SERVICE CRF = .11746 @ 10%, 20 YRS		(587)	(587)	(587)	(587)	(587)	(587)	(587)	(587)	(587)	(587)	(5870)
9	CASH FLOW (LINES 1+2+3 -7-8)	(5000)	1398	2080	2388								
10	CUMULATIVE CASH FLOW (CUMULATIVE TOTAL-LINE 9)	(5000)	(3602)	(1522)	866								

Fig. 8. Energy-conservation investment worksheet.

In general, wherever the capital cost of an energy-conservation measure divided by the yearly net energy cost saving is 3 or less, the payback period will usually occur in less than 5 years. In these cases, with projects less than \$5000 the complete life-cycle costing procedure is not necessary.

*See the cost schedule, page 42, for further comments on payback periods.

Where the complete life-cycle costing procedure is necessary, the method to be used is as follows:

1. Convert the capital expenditure (total project cost, including engineering, inspection, and contingencies) into an equivalent uniform annual cost:

$$(\text{capital expenditure}) \times (\text{capital recovery factor}) = \text{equivalent uniform annual cost.}$$

Enter this value on line 8, "debt service," of Fig. 8.

2. Determine the yearly differentials between the price of the fuel involved and the 8% inflation line (see Fig. 7). Enter these values on column B, Fig. 8. Multiply these yearly differentials by the saved each year to get the annual energy savings. Enter these values in column C and line 1, Fig. 8.

3. Enter the annual labor costs or savings in line 2, of Fig. 8.

4. Compute the values for lines 9 and 10, Fig. 8.

5. The payback period is the number of years required before the cumulative cash flow, line 10 of Fig. 8, becomes a positive amount.

In these economic studies, all costs are presented in current-year dollars. The use of current-year dollars in a long-range economic study gives valid results provided that the future price levels of the chief components of the study (e.g., labor, fuel, and interest costs) change at the same pace. Where a component, such as energy costs, is expected to change at a rate different from the rate of inflation, then the differential above or below the inflation rate will have to be factored into the projected energy costs. (Figure 7 has an 8% inflation reference line.)

The main virtue of the payback concept as applied in this plan is its simplicity, but the payback constraint does not take into account the magnitude or timing of cash flows during the life of the project beyond the set payback period. Thus it is possible for a project that has a longer than allowable payback period to produce a higher rate of return than does a project that meets the payback period limitation. Despite this shortcoming, the payback constraints suggested by ERDA seem to be reasonable, considering the approximate nature of the cost estimates, fuel cost projections, interest rates, and level of inflation.

ENERGY MANAGEMENT

Conservation

The future LLL energy condition is in a large measure within the control of LLL. There need not be serious disruptions because of energy shortages if LLL manages its energy consumption prudently. In the energy supply and demand equation, the long lead time required to develop alternative energy sources precludes much relief on the supply

side and places the major burden on reducing demand. Energy conservation is therefore the primary concern and the main hope for achieving an energy supply and demand balance in the next 10 years.

In an earlier part of this plan, it was stated that energy conservation is causing a virtual revolution in the design, construction, and operation of buildings--a revolution that demands new attitudes and techniques. The new attitudes involve the recognition that life-cycle costs are becoming more significant than initial costs as fuel prices increase. The practice in the past of building low-capital, high-energy-consumption facilities must now be reexamined. At the same time, resource-optimization (value-engineering) techniques, long dormant or warped by the availability of cheap and abundant energy, must now be revised and imaginatively applied.

Unfortunately, there is no simple list of rules that can be universally applied to save energy in buildings. Each system must be evaluated on an individual basis. The operational needs of buildings will not be unilaterally changed to suit the needs of energy conservation. System modifications will be made within the legitimate limits imposed by programmatic requirements. This section describes in more detail the various aspects of energy conservation and management.

Existing Buildings

Figure 2 shows that new facilities at LLL will increase at an average annual rate of 5.6%. This means that by FY 1985 new (hence energy-efficient) facilities would still amount to only 56% of the facilities existing today. Obviously, the major part of any energy-conservation program will have to be directed toward existing buildings. It should be noted, however, that though the opportunities for energy conservation in existing buildings are usually as great as those for new construction, the costs are usually much higher.

The engineering aspects for energy conservation in existing buildings will rely on current technology, much of which is expertly detailed in the General Services Administration/Public Buildings Service and the FEA technical manuals. To give an indication of the wide range of engineering applications possible, a schedule of the energy-conservation opportunities discussed in the FEA technical manuals* is listed in Appendix C. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) is currently preparing an energy-conservation standard for existing buildings (ASHRAE Standard 100). The publication date is unknown at this time.

Without going into engineering specifics, the methodology for developing the proper energy-conservation strategies is in outline as follows:

1. A team approach, including the responsible person for the building involved (building coordinator), will be used.

*Energy Conservation Opportunities and Guidelines for Existing Buildings, Dubin-Mindell-Bloome Associates (1975).

2. All the buildings in LLL will be studied. Each of the buildings will be treated as a whole and provided with a prescription formulated to optimize energy conservation within the constraints imposed by life-cycle-cost studies, programmatic requirements, and other factors. This total approach will include both technical and administrative fixes. Goals will be defined, immediate and long-term strategies outlined, and responsibilities assigned.

3. The building coordinator acts on his administrative responsibilities, but the engineering team will perform the technical work, including the preparation of budget data sheets and preliminary proposals for work requiring major capital expenditures.

4. The whole package will then be coordinated and organized into a prescription for management action. The prescription places all the energy-conservation work in the building within the context of that building. This provides a better insight for decision-making, especially when implementation by phases is being considered.

5. Finally, all corrective measures taken will be monitored and judged for effectiveness.

This integrated approach has certain advantages. It immediately gets the building coordinator involved in both the decision-making and the implementation processes. Furthermore, it places all the corrective measures, both near-term and long-term, within the framework of a coordinated program for the building. This, in turn, provides the type of objective that will promote the cooperation of the building occupants and will facilitate the implementation of the program in a logical manner.

New Buildings

All new buildings will be subject to the requirements outlined in Appendix 6301, ERDA Energy Conservation Design Criteria, and to the recently published ASHRAE Standard 90-75, "Design and Evaluation Criteria for Energy Conservation in New Buildings." An excerpt from the "purpose" of this ASHRAE standard is reproduced below:

The purpose of this standard is to provide performance-oriented design and evaluation criteria for energy-efficient buildings.

The performance requirements and criteria are directed toward the design of building envelopes with high thermal resistance; low air leakage; and toward requiring practices in the design of improved mechanical and electrical systems which promote the efficient use of energy.

It is intended that the criteria shall be flexible and designers shall be encouraged to use innovative procedures and techniques to achieve efficient utilization of energy and systems.

Meetings will be conducted within the Plant Engineering Department to revise the design criteria for new buildings in order to incorporate the provisions of ASHRAE 90-75, ERDA Appendix 6301, and any special energy-conservation guidelines that may be developed for the LLL Livermore site. Meanwhile some of the more obvious requirements are being

phased into new projects under design or in construction. These requirements include, but are not limited to, the following items:

1. Fuel-metering systems for natural gas, oil, and electricity.
2. Time-clock controls.
3. Dual-fuel (oil/gas) boilers.
4. Heat-recovery, variable-volume, and airside-economizing systems wherever possible.
5. Lower lighting levels and more flexible switching.
6. Grouping similar activities together to permit zoning the building for different operating modes and conditions.
7. Designing systems in all new buildings to use similar heating and cooling media temperatures. This built-in compatibility provides the option of integrating the individual mechanical systems of several buildings in the future in order to gain the advantages of a central-plant operation.

Energy Audits and Profiles

An energy audit or inventory of energy usage is necessary to determine the energy efficiency of a building and to locate areas where energy conservation can be applied. All energy streams need to be identified and quantified in some manner throughout a complete annual heating and cooling cycle. The initial step in an energy audit of a building will be to conduct a "walk-through" in order to get a general idea of its energy-conservation needs and provide immediate recommendations. If warranted, an in-depth study would subsequently be undertaken. For this purpose, computer programs are now available that calculate the hourly heating and cooling loads in a building over a year's time and simulate the energy requirements of all the mechanical and electrical systems used in the building. The computer can generate monthly profiles of the energy consumed by the equipment and other systems as they follow the heating and cooling load. The differences between these theoretical energy profiles and the metered energy flows are an indication of the potential for conservation.

All new buildings plus a select number (10-15) of the 150 existing buildings at LLL will be provided with permanent, automatic recording fuel-metering stations. The primary candidates will be large buildings with a floor area of more than 40,000 square feet or high-energy-usage buildings with complex heating/ventilation/air-conditioning (HVAC) systems.

It is contemplated that a plant engineer's energy management report will be issued annually. This report will include the metered and theoretical energy profiles of every building studied, with a brief progress report on the energy-conservation efforts in that building. These case histories will be written in conjunction with the building coordinators as a natural continuation of the team approach.

Transportation

The Plant Engineering and Facilities Department is not directly responsible for fuel consumed by LLL transportation, but the energy-conservation efforts in that area are pertinent to the overall LLL energy picture and are included herein as a matter of interest.

The strategies for the conservation of gasoline in motor vehicles will follow the lines of action listed below:

1. Replacement of standard passenger cars with compact sedans, scheduled as shown in the following table for every fiscal year through 1985.

<u>Fiscal year</u>	<u>Number of compacts</u>	<u>Gasoline saved^a (gal)</u>
1976	17	
1977	18	23,000
1978	10	13,000
1979-1980	20	25,000
1980-1985	60	77,000
		<hr/>
		160,000 @ \$0.50/gal = \$80,000

^aOver 6-year life of car.

2. Continued development and training of service personnel in improved preventive maintenance and service procedures. Computerized vehicle testing and maintenance scheduling will be employed where practicable to ensure optimum motor-vehicle operating efficiencies.

3. Conducting a study of the availability of small electric cars and the feasibility of using these vehicles for on-site personnel transport.

4. More efficient employment of existing taxi and shuttle-bus service combined with renewed efforts to reduce the number of individually assigned sedans and increase the use of bicycles.

5. Continuation of employee informational material promoting better driving habits to save fuel.

6. Vigorous endorsement of the 55-mph speed limit, with reminders on all vehicle dashboards.

Central Plant versus Individual Building Systems

The central-plant concept is very complex because there are so many combinations and permutations of subsystems and design parameters to be considered. There are other complicating factors, including (1) funding and (2) the existence of extensive facilities with subsystems that cannot easily be integrated into a central-plant system.

The standard arguments for a central plant are as follows:

1. Reduction in installed equipment horsepower due to load diversity.
2. Savings in operating manpower cost.

3. Energy savings due to increased efficiencies.
4. Space savings in buildings.
5. Increased reliability.

The standard arguments against the central-plant approach are as follows:

1. First cost is very large, especially if the distribution system is extensive. When client buildings are added over a long period of time, the economic justification becomes even more difficult.
2. Energy loss in the distribution system normally ranges from 2 to 5%.
3. Pumping energy is greater for liquids.
4. A central-plant application presupposes a certain pattern of growth or type of load. This necessarily introduces a degree of inflexibility into future plans because radical departures from the original design bases could impair the economic viability of the original central-plant project.

At this point it is not possible to discuss the above arguments in detail because there is so much study that must be done first. In fact, several studies could be undertaken, and several variations of the central-plant concept might prove to be profitable. This plan lists the most likely avenues the central-plant approach could take and proposes that studies be made of the more promising ones.

The possible applications of the central-plant concept are the following:

1. A small central heating and cooling plant for small clusters of three to five buildings having widely differing loads and being closely situated to minimize the distribution systems.
2. For a variation of the above, an integrating loop piping system could be provided for a cluster of buildings that already have individual systems. This, combined with a central control and equipment-surveillance system, results in a "decentralized central plant." One big advantage of this idea is that it is compatible with the normal capital funding process and can be applied retroactively to existing buildings.
3. Central coal-fired steam plant to replace the existing 33-year-old central gas- or oil-fired steam plant.

Although not precisely central plants, two other centralized systems are worthy of mention: (1) a central control and equipment-surveillance system and (2) central oil-storage facilities for closely situated buildings. The former system is under study for LLL by a private consultant; the latter is already being done for a new building complex.

Studies of Other Energy-Conservation Measures

The so-called "quick return" or initial phase energy-conservation efforts have already implemented most of the energy-saving measures readily attainable with relatively small capital expenditures. These are described in Appendix A. Other energy-conservation measures that warrant attention are described in this section (see also Appendix C).

Heat Recovery for Existing Systems--A serious attempt will be made to reclaim the heat (estimated to be 40×10^6 Btu/hr under winter design conditions) that is collected by the central cooling-water system and finally rejected to the atmosphere by central cooling towers. The return-side cooling-water temperature ranges from 62°F in the winter to 95°F in the summer. Hydronic heat pumps using the cooling water as a heat source can produce 105°F water for heating purposes.

Similarly, existing water chillers with reciprocating compressors can be provided with supplementary condensers to convert them to heat-recovery machines producing chilled water and heating water simultaneously. Heat is then rejected to the central cooling-water system only when the building heating requirements are satisfied.

Another heat-recovery scheme is the refrigerant hot-gas desuperheater. Eight percent of the heat normally rejected to the refrigeration machine condenser can be captured between the compressor discharge and the condenser inlet. This is high-quality (100-140°F) heat, and a simple heat exchanger can normally satisfy the domestic hot-water requirements for the building in which the refrigeration machine is located. This technique is not new and has been successfully used.

Heat Recovery for New Buildings--Heat-recovery techniques will be included in the design criteria of all new buildings. Double-bundle condensers on refrigeration equipment and heat-transfer components suitably sized for the reclaimed heat will be the standard initial minimum requirements. Other equivalent methods or heat-recovery proposals by architect-engineer firms under contract to LLL will be considered.

Central-Cooling-System Control Modifications--The central cooling system is rated at 188×10^6 Btu/hr heat rejection and circulates 38,000 gpm. The supply-side cooling-water temperatures vary from 60°F in the winter to 85°F in the summer. The lower temperatures of the cooling water reflect the reduced winter cooling load and the more efficient cooling-tower winter operating characteristics. It could also indicate that the cooling-system controls need to be refined to permit more responsive variable-volume pumping and incremental turndown of the cooling towers to match the cooling load. Ideally, the cooling-water supply temperatures should remain fairly constant throughout the year.

Since the aggregate motor horsepower is over 2000 and the cooling system not only runs continuously but also passes a certain percentage of its water through a demineralization plant, considerable cost and energy savings are possible. This situation will be studied.

Airside Economizers--The use of outside air for cooling purposes will be applied whenever a net benefit can be gained. These airside economizers will be controlled by dry-bulb rather than wet-bulb temperatures as already determined by a study of the most effective control method for airside economizers for the climate at the LLL Livermore site. This same study showed that in some cases, ironically, the cooling energy saved

during summer was offset by the additional heating energy required during the winter season due to control system deficiencies. In these cases, the existing temperature control system will be refined.

Total Energy System (Selective Type)--If the Nuclear Initiative passes in the State of California 1976 elections, there is a possibility of electrical power shortages while PG & E phases out its nuclear power plants and switches to the construction of coal-fired power plants. In this event, a case can be made for on-site supplementary electrical power generation using oil-fired internal combustion turbines. The attraction of the total energy concept is that it recovers the heat energy normally lost in a power plant and puts it to useful work, such as for space heating or cooling with absorption refrigeration. Ideally, the heat recovered and the electric power generated exactly suit the plant needs. This seldom happens, and therefore a total energy plant (one that supplies all of the plant electrical power needs) is never as efficient as the ideal case. A selective energy system, however, is designed to serve only as an extension of the electric utility system and supplies only part of the plant power needs. The electrical output of the selective energy system is so regulated that its heat recovery matches the heat energy needs at all times, with the electric power flowing from the selective energy plant into the utility grid being of secondary importance. The significant difference is that it is the heat demand instead of the electrical demand that regulates the selective energy system. The thermal efficiency of such a system is very high.

Conversion to Alternative Fuels, 1975-1985

For reasons discussed on page 8, natural gas will largely be supplanted by oil within the next 10 years. Figure 5 shows the transition, with natural gas declining from 43.7 to 8% of the total energy consumed while the use of oil increases from 0.5% to 24%. The consumption of electricity increases from 48.4% to 63% due primarily to research and development program requirements.

The use of electricity is heavily penalized by the ERDA standard raw source energy conversion factors, which charge every kilowatt-hour used with generation and line losses. (Fossil fuels, such as natural gas, oil, and propane, are not so charged.) Conversely, savings in electrical energy consumption are given three times the credit that is given equal Btu savings of other energy sources.

The ERDA conversion factors, as currently applied, create distortions in the reporting of actual energy-consumption trends and inhibit the use of heat pumps and other heat-recovery equipment. For example, the initial energy-conservation efforts of most practitioners were concentrated on lowering lighting levels and shutting down buildings during unoccupied hours. The major impact of these efforts was a reduction in electrical energy consumption. The electricity saved, when reported in equivalent British thermal units, becomes three times larger, which gives a distorted picture of the actual energy situation at the user's site. Conversely, another distortion will

result when achieved reductions in fossil-fuel consumption are reported. Comparisons with previous years will be warped since less credit will be given for these British thermal units saved. Moreover, the use of heat-recovery machines (heat pumps), the most advantageous use of electricity for heating, will be discouraged. A heat pump recovers an average of 3 Btu for every electrical Btu expended to power the heat pump. However, since ERDA requires that 3 Btu of raw source energy be charged for every electrical Btu consumed, the net result becomes a tradeoff.

One argument in favor of the ERDA standard conversion factor for electricity is that electrical energy not used in an area of predominantly hydro power generation (as is the case for LLL) can be wheeled to an area of predominantly fossil-fueled power generation. If judiciously applied, it is conceivable that appropriate conversion factors (for all fuels) can channel regional energy usage to effect optimum national utilization of energy resources. The final decision on what conversion factors should be used must be made at the national level, but inputs from the regional level could be very useful.

The realistic assessment of user impacts on raw energy sources is a very complex problem. If the aim is to measure the impact of a user upon the availability and abundance of various fuels, then the fuel situation in the user's locality must be considered. Until these regional impact factors can be determined, fuel use and savings should be reported in tons of coal, Mcf of gas, gallons of oil, kWh of electricity, etc., at the user's site. This problem of determining energy resource consumption impacts on a region is the subject of urgent study by ASHRAE for inclusion into ASHRAE 90-75 (Section 12).

Pending final resolution of the ASHRAE study and pursuant to ERDA Immediate Action Directive 6000-1, LLL will derive, and submit for approval, its own electrical energy conversion factor for internal reporting and planning purposes.

ENERGY FROM UNCONVENTIONAL SOURCES OR METHODS

It is unlikely that any of the unconventional energy sources or methods under study will have a practical impact on the LLL Livermore site in the next decade, although it is tempting to wish into reality the promise of energy from these new technologies. Experience proves, however, that it is easier to perceive the conceptual advantages of a new method than it is to foresee the practical problems involved. A considerable length of time is required to go from the laboratory and pilot-plant stages to commercial production. Even conventional types of facilities require long lead times, as shown in Table 1.

The Institute of Electrical and Electronic Engineers (IEEE) published in May 1975 an energy forecast depicting both optimistic and "worst-case" growth scenarios for the United States. Pertinent parts of these scenarios have been abstracted and are shown in Fig. 9. The new technologies listed in Fig. 9 are very briefly described here for the interested layman.

Table 1. Typical 1973 overall project times (from go-ahead to production).^a

Type of facility	Years
Coal-fired power plant	5-8
Surface coal mine	2-4
Underground coal mine	3-5
Uranium exploration and mine	7-10
Nuclear power plant	9-10
Hydroelectric dam	5-8
Oil and gas production from new fields	3-10
Oil and gas production from retired fields	1-3

^aFrom U.S. Energy Prospects: An Engineering Viewpoint, National Academy of Engineering, Washington, D.C. (1974).

Nuclear Reactors

Two types of nuclear reactor are used. Light-water cooled reactors are the basic type of nuclear reactor currently in service for power generation. They use uranium-235, which is in short supply (estimated to last 25 years at maximum projected demand) and is becoming increasingly costly. Breeder reactors are under study and are scheduled for commercial application in the late 1980s or early 1990s. A breeder reactor produces 20% more plutonium than it consumes, and hence five breeders could provide enough fuel to support themselves as well as one light-water reactor. However, there are waste-disposal and plutonium (bomb material) security problems.

Nuclear Fusion

Nuclear fusion is under study, and a prototype reactor is scheduled to be running by the year 2000. Nuclear fusion reactors produce heat by "squeezing together" atoms of very light elements such as hydrogen. This source of energy is potentially unlimited.

Oil from Shale

Four methods of extracting oil from shale are under study; two of these retort oil shale on the surface of the ground, and two retort oil in situ. The shale preparation for the surface-reporting method is obtained by either underground or open-pit mining. The in situ shale preparation (fracturing) is done by chemical or nuclear explosives. Whatever method is used, the oil shale is heated to about 375°C, at which temperature it decomposes to yield oil and gas. In the in situ process, the oil-shale rubble is retorted in place, using hot gas generated continuously by burning a portion of the oil shale in an air stream forced into the underground cavities.

Fig. 9. Timetable of new-technology applications.

Magnetohydrodynamics

Magnetohydrodynamics studies are being made to obtain electricity directly from a hot conducting gas. The technology developed is to be used in a combined-cycle facility in conjunction with large gas turbines to improve the efficiency of electricity generation from the normal 33 to 60%. This new technology is not expected to be of commercial value until the 1990s.

Solar Energy

Solar energy is dilute and variable but has been used by man since time began. The problems with mating solar energy with modern needs are high capital costs, excessive collector-area requirements, and bulky or inefficient thermal energy storage systems. Nevertheless, solar energy is inexhaustible, and research and development efforts to solve these problems have been going on for some time and are expanding.

Coal Gasification

Coal gasification is a means of converting high-sulfur coal to an essentially sulfur-free gaseous fuel. When the coal comes in contact with high-temperature steam, the hydrogen atoms in the steam combine with the carbon in the coal to produce a hydrocarbon very similar to natural gas. There are both surface and in situ processes under study.

Aboveground high-Btu coal gasification is the conversion of coal (conventionally mined) to high-Btu (950 Btu/ft³) pipeline-quality gas suitable for long-distance transmission lines. Several new processes are under development, including Hygas, Synthane, CO₂ Acceptor, and Bigas. Several processes for accomplishing the gasification step have been commercial for many years (Lurgi, Koppers-Totzek, Winkler).

In situ high-Btu coal gasification is a process wherein chemical explosives are used to fracture deep, thick coal beds. A gas circulation pattern is established through the broken coal. Oxygen and water are introduced, and the coal reacts at high temperature to produce methane or synthesis gas. If synthesis gas is the product, conversion to methane will be carried out in surface processing equipment.

Coal Liquefaction

Coal liquefaction is the conversion of coal to a high-quality fuel oil or to gasoline. In the process hydrogen is added to the coal; sulfur and ash are removed. A number of processes are under development.

Geothermal Energy

Geothermal power generation takes advantage of heat at or near the earth's crust. Two approaches are being used. One involves tapping shallow geothermal deposits like the underground steam reservoirs in Sonoma County, California, for steam to drive electric power generators. The only field development in the United States is in Sonoma; it produces 302,000 kW of electricity, equivalent to about 10% of the electricity demand at LLL.

The other approach is under study at the Los Alamos Scientific Laboratory and seeks to tap deep heat (1000°F) deposits. Two 7500-ft-deep shafts are to be made into the earth's crust. Water will then be admitted into one shaft, subsequently producing steam in the other shaft. The National Science Foundation has high hopes for this project and predicts widespread application of this technology before the year 2000.

Tidal Power

Tidal power is already being used to generate electricity. Several schemes are being applied. In the French facility in Brittany, 24 bulb turbines with reversible Kaplan wheels are used. In the Soviet Union, generating units are being used in floating docks. The governments of Canada, Holland, and the United States are also funding tidal power studies.

This section has presented only a partial listing of the many alternative energy studies under way in the United States. The Lawrence Livermore Laboratory itself is deeply involved.

CONSUMPTION TRENDS AND PERFORMANCE REPORTS

The "Quarterly Energy Conservation Report" (Fig. 10) will continue to serve as the principal reporting document. This report shows the fuel and energy consumption for the quarter being reported and compares it with the corresponding quarter in FY 1975.

ENERGY CONSERVATION PERFORMANCE REPORT^a

Contractor _____

		Use during ____ quarter FY-____	Use during ____ quarter FY-____	Percent reduction (increase)
Building and facilities operations				
Electricity	kWh × 10 ³ Btu × 10 ⁹			
Natural gas	cf × 10 ³ Btu × 10 ⁹			
Fuel oil	gal × 10 ³ Btu × 10 ⁹			
Propane	gal × 10 ³ Btu × 10 ⁹			
Subtotal	Btu × 10 ⁹			
Motor vehicle operations ^b				
Gasoline	gal × 10 ³ Btu × 10 ⁹			
Diesel	gal × 10 ³ Btu × 10 ⁹			
Subtotal	Btu × 10 ⁹			
Owned equipment ^c				
Gasoline	gal × 10 ³ Btu × 10 ⁹			
Diesel	gal × 10 ³ Btu × 10 ⁹			
Aviation fuels:				
Aviation gasoline	gal × 10 ³ Btu × 10 ⁹			
Jet fuel	gal × 10 ³ Btu × 10 ⁹			
Subtotal	Btu × 10 ⁹			
Total	Btu × 10 ⁹			

^aAll conversions are to be made using ERDA conversion factors.

^bOnly ERDA-owned sedans, station wagons, light trucks, and heavy trucks.

^cAll ERDA-owned equipment not included in motor vehicle operations.

Fig. 10. Energy Conservation Performance Report form.

This plan provides two supplementary reports, shown in Figs. 11 and 12, that provide a continuing synopsis of the current-year energy-conservation efforts. Trends and performance relative to the limits imposed by the zero-energy-growth and technical-fix growth rates are clearly defined. Figure 13 is an example of how the concept shown in Fig. 12 has been applied to the latest LLL energy consumption report. Two indices--the growth in building floor space, and the weather conditions for the reporting period--have been included to give information on significant factors affecting energy consumption.

IMPLEMENTATION OPTIONS AND SCHEDULE

Before outlining the implementation schedule, it is proper to restate the objectives of the energy conservation and management plan and to discuss the strategies that should be applied. As already described, the major thrusts of the energy plan will be to retrofit existing buildings to use fuel more efficiently, incorporate energy-efficiency criteria into the design of new buildings, reclaim heat from waste energy streams, and make all preparations necessary to provide a versatile fuel-usage capability to suit the fuel outlook.

The "energy plan" described in the preceding paragraph is a 10-year program. This sustained effort can succeed only if LLL at large is convinced of its need, agrees with its policies, and is committed to its implementation. Though the Plant Engineering and Facilities Department bears the main responsibility for energy conservation, this problem is not strictly technological in nature, but contains strong political, social, and psychological undercurrents. The overall strategy for dealing with these other aspects is beyond the scope of this study. This plan, however, will make a concerted effort to gain the personal commitments of the individual building coordinators and through them win the general support this plan must have.

The approaches to be taken toward the primary technical goals are discussed in this section.

Retrofitting Existing Buildings

The single most significant determinant of energy consumption is the hours of operation of a building. Because of this, the program to provide time-clock controls in all buildings has been accorded a high priority. Another important factor in energy consumption is the level of lighting.

Many of the LLL Livermore site buildings to be retrofitted have been provided with time-clock controls and have had lighting levels reduced as part of the initial energy-conservation program. This plan will continue these efforts and will analyze these buildings again and all others in more detail, applying current technologies and the life-cycle-cost criteria. Energy-conservation measures that meet life-cycle-cost criteria will be submitted for consideration and funding.

CURRENT TRENDS OF ENERGY CONSUMPTION IN BUILDINGS AND FACILITIES

Oil (gal)		First quarter	Second quarter	Third quarter	Fourth quarter
Actual metered usage	1975				
	Current year				
Change (+) from 1975 (%)					

Natural gas (cfh)		First quarter	Second quarter	Third quarter	Fourth quarter
Actual metered usage	1975				
	Current year				
Change (+) from 1975 (%)					

Propane (gal)		First quarter	Second quarter	Third quarter	Fourth quarter
Actual metered usage	1975				
	Current year				
Change (+) from 1975 (%)					

Electricity (kWh)		First quarter	Second quarter	Third quarter	Fourth quarter
Actual metered usage	1975				
	Current year				
Change (+) from 1975 (%)					

Summary of above for current quarter (Btu) ^a					Current-year Accumulated usage (Btu x 10 ⁹)		
					FY 1975 vs FY _____		
Quarter	Energy	FY 1975	Current year	Technical-fix target	To date FY 1975	To date FY _____	Technical fix target
	Oil	(see note 2)		—			
	Natural gas	"		—			
	Propane	"		—			
	Electricity	"		—			
Subtotals		(A)	(B)	(C)			

Notes:

1. Subtotals A, B, and C are shown graphically in Fig. 12.
2. FY 1975 values are from prior records.
3. Subtotal A is from Fig. 2 also.

^a See Appendix B, ERDA Standard Conversion Factors.

Fig. 11. Current-year energy-conservation performance report form.

Fig. 12. Current-year energy-conservation performance.

Fig. 13. Graphic summary of current-year energy consumption at the Livermore site.

Energy Efficiency Criteria for New Buildings

This phase of the plan is already being implemented in advance of the finalization of the energy-conservation standards ASHRAE 90-75 and ERDA Appendix 6301. ASHRAE 90-75 has just been formally adopted, and the completion of ERDA Appendix 6301 is expected in the near future. A seminar on the impact of ASHRAE 90-75 on new construction was held on February 25, 1976. Energy-efficiency criteria now in use will be reviewed.

Energy Audit and Metering

This plan proposes that all significant existing plant facilities be audited monthly for energy consumption. Where necessary, the buildings involved would be analyzed by a computer (Trane Company's TRACE program) to determine their theoretical energy profiles over 1-year periods before and after major building modifications.

Heat Recovery

Attention will be given to the reduction of energy waste as well as the reduction of energy needs. Various heat reclamation techniques will be explored. The first heat-recovery effort will be made on the central low-conductivity water-cooling system, the Laboratory's largest single waste energy stream.

Contingency and Change-of-Lifestyle Options

The contingency and change-of-lifestyle options can be summarized as follows:

1. Shut down the Laboratory the last 2 weeks of every year.
2. Degrade noncritical environmental conditions. This might permit the revival of evaporative cooling, operable windows, less ventilation, lower quality air filtration, higher occupancy densities.
3. Shut down temporary, noncritical buildings that are wasteful of energy.
4. Closely scrutinize the real need for activities to operate beyond normal working hours. Isolate or group such activities together to maximize building shutdowns.
5. Stop growth. Match all occupancies of new buildings with the retirement of existing buildings.

Alternative-Fuel Situation

There are immediate as well as intermediate-term problems in the alternative-fuel situation. The immediate problem is to reduce the vulnerability of LLL to natural-gas curtailments that might extend beyond the 1-month storage capacities of the propane and oil standby systems.

The intermediate-term problem is to adapt to the ramifications of the new end-use natural-gas priority system imposed by the California Public Utilities Commission. AS A RESULT of these priorities, the propane standby system is rendered obsolete because propane is considered to be a "gaseous" fuel subject to the same general

curtailments as natural gas. No further expansion of the propane standby system will be considered. A compensating factor is that all atmospheric (natural-draft) gas-fired equipment will be provided with uninterrupted gas supplies at least until 1978. This removes the need for a propane standby system. At the same time, gas-fired forced-draft boilers will be required to be converted to oil firing unless waivers are granted by the California Public Utilities Commission. This plan estimates that about 50% of the heating load represented by these gas-fired forced-draft boilers will be granted waivers but that the rest will be required to be converted by 1978.

The long-term program to provide underground oil-storage (30-day capacity) tanks to replace the existing aboveground "temporary" mobile oil-storage tankers should be started as soon as possible. These mobile tankers, which will be retained, plus the underground tanks will then constitute the 60-day strategic oil reserve recommended by the Ford Foundation Energy Policy Project and will be consistent with the 1976 Energy Policy and Conservation Act.

Although the completion of the foregoing plans will solve the intermediate-term problems, the immediate problem of prolonged natural-gas curtailments remains. However, since the last two "coldest winters of modern record" (which would, if they recurred, require a 51-day gas curtailment period) occurred in 1948-1949 and in 1829-1830, it is considered that the risk is tolerable and that nothing needs to be done but to proceed with the intermediate-range plans.

Implementation Schedule

The implementation schedule for the next 2 years is listed in Table 2. A much more detailed listing will be provided at a later date.

COST SCHEDULE

The cost schedule (Table 3) is derived from the implementation schedule. This schedule contains a great deal of uncertainty because of the nature and extent of the energy-conservation measures that can be undertaken in the individual buildings.

There are several cost categories:

Costs related to new construction. These costs are funded separately and are not included in this cost schedule. Energy-conservation measures incorporated into the design of new buildings must, however, comply with the life-cycle-cost criteria outlined in this plan.

Costs related to the alternative-fuel program. These costs are due to oil storage and boiler dual fuel conversion projects. The projects are not related to energy savings and hence cannot be subjected to life-cycle costing. The costs will be applied against capital funds.

Table 2. Implementation schedule.

Action	FY 1976T	FY 1977	FY 1978
<u>Retrofitting of existing buildings</u>			
Perform "walk-through" inspections and develop a more detailed plan of action	X		
Prepare standards for fuel-metering systems for gas, electricity, and oil	X		
Design and construct metering installations for selected existing buildings	X	X	X
Input selected existing buildings into the TRACE computer program for theoretical load profiles	X	X	X
Apply life-cycle costing to energy-conservation opportunities; prepare all eligible projects for funding and implementation	X	X	X
<u>Alternative-fuel program</u>			
Design and construct underground oil-storage tanks at Buildings 131, 151, 231, and 321 to replace existing aboveground oil tankers	X	X	X
Convert gas-fired forced-draft boilers to dual-fuel (oil/gas) capability, including underground oil-storage tanks:			
Building 361 without tank	X		
Building 361 tank only		X	
Buildings 241, 331, and 332		X	
Buildings 111, 113, and 194			X

Costs related to the energy audit and metering program. The metering costs will be funded as noncapital (operating fund) projects. The costs related to the TRACE computer analyses will be funded as part of the energy-program overhead costs. Since no energy savings can be directly attributed to these items, life-cycle costing is not applicable.

Costs related to retrofitting existing buildings with energy-conserving devices. These costs can be directly charged to energy conservation measures and must be subjected to life-cycle costing. This is the cost category where the amount of funding is predetermined by the energy cost savings target and the life-cycle-costing criteria. For example, the maximum funding for the 10-year retrofitting program that can be supported by a 25% reduction in energy consumption can be calculated approximately as follows: It is assumed that

1. Fuel costs increase at the same rate as the inflation rate. This assumption is conservative but simplifies the calculations.
2. The annual investments for 10 years are equal and each results in an average annual reduction in energy consumption of 2.5%.
3. The capital recovery factor is 0.13147 based on 10% interest and a 15-year life. The maximum payback period is 10 years.
4. The LLL utility bill for FY 1975 is \$2,294,000 (after adjustments to smooth out the fuel-cost curve).

Given these assumptions, one can say that the 10-year retrofit program is simply the sum of a series of 10 similar projects done consecutively over a 10-year period. It is safe to assume that, if the first such project satisfies the life-cycle-costing criteria, then the program as a whole will also qualify.

First project annual energy cost saving $S = (2.5\%) (\$2,294,000)$

$$S = \$57,350$$

First project equivalent uniform annual cost $C = (\text{initial cost } P) \times (\text{C.R.F.})$

$$C = (P) (0.13147)$$

Net annual savings $B = (\text{savings } S) - (\text{costs } C)$

$$B = 57,350 - P(0.13147)$$

Maximum payback period, 10 = $\frac{(\text{initial cost } P)}{(\text{net savings } B)}$

$$10 = \frac{P}{57,350 - P(0.13147)}$$

Table 3. Cost schedule.

Program	Cost ^a			
	FY 1976T ^b	FY 1977	FY 1978	FY 1979
<u>Capital funds</u>				
1. New construction	N.A. ^c			
2. Alternative-fuel program:				
Oil storage to replace existing tankers (total cost \$275,000)	\$ 65,000	\$ 70,000	\$ 70,000	\$ 70,000
Oil storage for new boiler conversions (total cost \$288,000)	0	180,000	108,000	0
3. Boiler conversions to oil:				
Building 361	\$ 20,000	--	--	--
Buildings 241, 331, 332	--	\$ 85,000	--	--
Buildings 111, 113, 194	--	--	\$ 82,000	--
4. Retrofit existing buildings ^d	<u>0</u>	<u>100,000</u>	<u>100,000</u>	<u>100,000</u>
Subtotals	\$ 85,000	\$435,000	\$360,000	\$170,000
<u>Operating funds</u>				
1. Energy audit and metering:				
Computer analysis (20 buildings @ \$2000 each)	4,000	12,000	12,000	12,000
Metering installations (20 buildings @ \$10,000 each)	10,000	70,000	70,000	50,000
2. Retrofit existing buildings ^d	<u>50,000</u>	<u>150,000</u>	<u>150,000</u>	<u>150,000</u>
Subtotals	\$ 64,000	\$232,000	\$232,000	\$212,000
Grand totals	\$149,000	\$667,000	\$592,000	\$382,000

^aIn 1975 dollars; engineering costs are included.

^bJuly-October.

^cNot applicable.

^dLump sum estimates, subject to change when actual projects are evaluated.

Solving for P, the initial cost or maximum annual funding is found to be \$247,764. Accordingly, the figure of \$250,000 will be used in the following cost schedule for the retrofitting program. Pending more definitive engineering studies, the \$250,000 will be arbitrarily divided, with \$100,000 charged against capital funds and \$150,000 charged against operating funds.

From FY 1980 to FY 1985, the estimated annual cost could be stabilized at \$250,000 or less as the potential for energy savings decreases.

The costs listed herein, especially for the retrofit program, are necessarily very tentative. When the preliminary engineering studies are undertaken, it is possible that existing conditions may be such that few retrofit projects will be able to meet the life-cycle-cost criteria and that these criteria must either be relaxed or the technical-fix growth rate adjusted upward. This plan suggests that regional fuel and construction cost differentials should be factored into the life-cycle-cost criteria. The LLL Livermore site, for example, must add a premium over normal construction costs due to its remote location and security requirements. Other considerations might involve balancing longer payback periods against projects that can effect large energy savings in critical fuels.

If the allocation of ERDA funds for energy-conservation projects is based on payback periods alone, then those facilities that are located in regions where fuel costs are high and construction costs are low will receive a disproportionately larger share of the total funds available. Identical projects in different regions of the United States will have different payback periods. The payback periods must be "normalized" by regional fuel- and construction-cost adjustments before all projects can be evaluated on an equal basis.

CONCLUSIONS

The Lawrence Livermore Laboratory can control its energy future to a large extent if it resolves to formulate and practice prudent energy conservation and management policies. Taking into consideration the LLL growth projections for the next 10 years, it is possible for the LLL Livermore site to achieve zero energy growth by the year 1985. Prior to that, energy consumption will continue to grow but at less than half the historical rate.

The fuel outlook for the next 10 years is significantly influenced by the present patterns of energy consumption. With natural gas as the basic heating fuel at present, the only practical "swing" fuel is oil as the reserves of natural gas dwindle. Coal requires massive changes in the plant facilities; the lead times involved preclude the use of this fuel in the near future.

Concerning the energy supply and demand equation, any gap must be made up on the demand side in the foreseeable future. It is hoped that the retrofitting of existing buildings with energy-conserving devices plus the addition of energy-efficient new facili-

ties will be able to reduce the demand sufficiently. No significant lifestyle changes are anticipated at this time.

The new technologies are not expected to have any significant impact on the LLL energy-supply picture in the next 10 years.

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APPENDIX A

ENERGY CONSERVATION PROGRESS REPORT JULY 1973 TO NOVEMBER 1975 LAWRENCE LIVERMORE LABORATORY

by

WILLIAM H. KERR

BACKGROUND AND PROGRESS TO DATE

In July 1973, the Laboratory was informed of the predicted shortage of natural gas and the expected curtailments of natural gas for large industrial customers of PG & E. At that time, a team was formed by Plant Engineering to study, plan, and implement various means of coping with the curtailments, as well as to study and implement energy-conservation methods and practices. The Energy Conservation Team consisted of a mechanical engineer, an electrical engineer, and an industrial engineer, with a team leader.

Alternative-Fuel Plan

The first order of business was to assess the impact of the expected increasing annual curtailments of natural gas and to prepare for these curtailments in the best way possible with minimum capital investment, while ensuring the continuity of LLL programs. One of the first steps taken was to increase propane storage by the acquisition of six 30,000-gal tanks at Camp Parks. These tanks, added to the existing 30,000-gal Livermore tanks, provided an assured supply of 200,000 gal of propane. Another alternative fuel was D-2 oil, available in three 10,000-gal tanks for the operation of the steam plant, which constitutes approximately 10% of the LLL heating capacity.

Since the available propane supply could furnish fuel for only a limited number of gas curtailment days, a twofold supplementary-fuel plan evolved. First the five boilers of the main steam plant were supplied with gas- or oil-fired convertible burners (12% of the Livermore site load). Next, eight forced-draft boilers in four of the largest buildings, representing about 30% of site load, were supplied with the convertible burners.* In the meanwhile, 13 surplus 5000-gal tankers were acquired from other federal agencies. A separate "firm" gas line and meter were obtained from PG & E to supply the computer building area (7% of the Livermore site load) with noninterruptible gas service.

In addition to the actions to acquire alternative-fuel capabilities, plans were made to improve the existing propane-air plant in order to preclude breakdowns to the plant during a curtailment period, which could cause costly interruptions of critical programs. Furthermore, it is planned to install in FY 1977 several underground tanks to replace the four portable tankers now located at the four large buildings 131, 151, 231, and 321. These tanks will have more capacity than the tankers.

* Completed in FY 1975.

Building Priorities

In order to extend the supplementary fuel for the longest possible time and save expensive oil and propane, a system of building heating priorities was established. Category I buildings (36 buildings) are those that must operate heating systems 24 hours per day for operational or safety reasons. Category II buildings (44 buildings) are those that may be shut down either automatically or manually during nonworking hours, including weekends. Category III buildings (eight buildings) are those that have heating systems shut down 24 hours per day during curtailment periods.

Total Gas Curtailment Capability

By using firm gas, stored oil, and propane, within the strict context of the building priority system, LLL is now able to withstand a maximum curtailment of 4 weeks without significant problems or program disruption.

ENERGY-CONSERVATION PROJECTS

Since 90% of the energy consumed by LLL is related to building and facilities operations, the initial thrust of the energy-conservation program was to improve building operations. This program concentrated on three main projects, as described below.

Time Clocks

The Laboratory is shutting down as many building HVAC systems as possible during nonworking hours, first manually, later by automatic timers and controls. An architect-engineer firm was retained to assist in the design of the time-clock systems. With few exceptions, all of the time clocks installed in buildings will repay the initial investment in less than 4 years, and those in most of the large buildings will have a payback period of 1 year. There are savings in both gas for heating and power for air conditioning. To date, 32 buildings have had automatic time clocks installed, for a total estimated annual savings of over \$290,000 per year in power and natural gas. The program is now virtually completed, but three or four buildings remain candidates for the installation of time clocks.

Reduced Lighting

In the first 9 months of the energy-conservation program light levels in offices, corridors, and laboratories were reduced within accepted standards by the selective removal of fluorescent tubes and ballasts from lighting fixtures throughout the Laboratory. Over 12,000 lamps were removed from 5000 fixtures which is estimated to save 517 kW of instantaneous load. Savings also result from decreased washing and lamp replacement. It is estimated that more than \$22,000 per year is being saved by reduced lighting.

Modification of Building HVAC Control Systems

An outside consultant has been retained to study many building HVAC control systems and optimize the operation. Use has been made of the TRACE computerized system for several buildings to establish building system load profiles. As a result, air-side economizers and boiler bypass loops may be installed in some of these buildings, and more are to be installed later. Concurrent with outside consultant studies, an HVAC "tuneup" program is being implemented throughout the Laboratory by the Facilities Operations Division.

Other Actions--Buildings and Grounds

Other energy-conserving actions that have been implemented are the following:

1. Lights are turned off by building occupants on leaving.
2. Energy-conservation features are being designed into new buildings. Examples are
 - a. Dual sets of light switches to allow office occupants to shut off half their lights on bright days.
 - b. New boilers are now exclusively of the dual-fuel forced-draft type.
 - c. Chiller condenser water is being used for heating purposes instead of being wasted through a cooling tower.
 - d. Exterior lighting is minimized and is controlled by photocells.
 - e. Thermopane glass was used in the new Laser Building to reduce heat loss.
3. Where possible, chillers and air conditioners are completely shut down for the winter season.
4. Thermostats on most domestic hot-water heaters have been reset from 140 to 120°F, saving \$6000 per year in natural gas.
5. Design criteria for new buildings include energy-conservation features.
6. The magnitude of minimum programmatic power requirements during future PG & E "brownouts" were established by Plant Engineering in collaboration with program personnel and PG & E.
7. Automatic photocell switches were installed to improve control of exterior lighting in key locations; more will be installed in the future using a master lighting plan.
8. Insulation is now being installed in the attics and under the floors of 10 of the barracks-type buildings. This is expected to save \$7000 in natural gas per year (330×10^6 Btu), for a payback time of less than 5 years.
9. Thermostat settings recommended by FMC 74-1 were publicized, and thermostats were adjusted where practicable. Buildings with terminal reheat systems were readjusted for optimum energy utilization to suit the individual system.
10. Thirty floodlights were removed from exterior locations.
11. In the Computer Building (113) and Laser Building (381), the laboratory sections were separated from the office wings to permit shutdowns of HVAC systems in the office wings during nonworking hours.

VEHICLE USE AND EQUIPMENT OPERATION

1. All FPMRs regarding vehicle mileage reduction have been implemented. Circulars and memos have been and will continue to be sent to each vehicle assignment area.

2. Preventive maintenance service programs have been updated to implement new requirements. (The latter include steps to ensure that vehicle engines are tuned properly to reduce frequency of oil changes, to upgrade oil to 13-30, and the like.)

3. Shuttle taxi service was instituted from the Livermore site to the Site 300 test area approximately 18 miles away. On-site taxi service, which transports approximately 11,000 passengers per month, has been reestablished.

A privately owned bus line carries 350 passengers in eight buses to eight different towns. Two more buses are to be added. The buses are driven by LLL employees and are parked at the Laboratory during the day.

4. The Laboratory now has 737 bicycles at the Livermore site. These are all available to employees on an unassigned basis. Use of the bicycles in lieu of automobiles for on-site transportation will be actively encouraged. The Laboratory has succeeded in persuading the county and city to provide a protected bikeway from the site to the town (3 miles) to encourage the use of employee bicycles.

5. Reserved parking for carpools resulted in 560 carpool permits for approximately 1700 people.

6. Several vehicles were removed from service, and trips were consolidated whenever possible. Each vehicle user-assigned group will be made aware of vehicle mileage each month and percent of reduction.

APPENDIX B

ERDA STANDARD CONVERSION FACTORS FOR ENERGY-CONSERVATION REPORTING

Form of energy	Btu content	Btu $\times 10^9$ per reporting unit
Electricity ^a	11,600 Btu/kWh	0.0116 per MWh (megawatt-hour)
Fuel oil	138,700 Btu/gal	0.1387 per 100 gal
Natural gas	1,031 Btu/cf	0.001031 per 1000 cf
Liquefied petroleum gas ^b	95,500 Btu/gal	0.0955 per 1000 gal
Coal	24,580,000 Btu/short ton	0.02458 per short ton
Other:		
Steam ^c	1,390 Btu/lb	0.00139 per 1000 lb
Chilled water ^d	24,000 Btu/ton-hr	0.024 per 1000 ton-hr
Methanol	63,500 Btu/gal	0.0635 per 1000 gal
Automotive gasoline	125,000 Btu/gal	0.125 per 1000 gal
Diesel ^e	138,700 Btu/gal	0.1387 per 1000 gal
Aviation gasoline	125,000 Btu/gal	0.125 per 1000 gal
Jet fuel	130,000 Btu/gal	0.130 per 1000 gal

^aElectricity--assumes 10,536 Btu per kWh generated at station and 9% line loss.

^bIncludes propane and butane.

^cAssumes 1000 Btu per pound of steam generated at boiler plant, 80% boiler efficiency, and 11% line loss.

^dAssumes 12,000 Btu per ton-hour and overall efficiency of 50%.

^eIncludes all other petroleum distillate fuels except gasoline and jet fuel.

APPENDIX C

LISTING OF ENERGY-CONSERVATION OPPORTUNITIES IN FEA TECHNICAL MANUALS* FOR RETROFITTING EXISTING BUILDINGS

- ECO 1 Set back indoor temperatures during unoccupied periods
- ECO 2 Reduce indoor temperatures during occupied periods
- ECO 3 Avoid the radiation effects to cold surfaces
- ECO 4 Reduce indoor relative humidity levels
- ECO 5 Shut down ventilation system during unoccupied periods
- ECO 6 Reduce ventilation rates during occupied periods (heating)
- ECO 7 Reduce infiltration rates (heating)
- ECO 8 Increase solar heat gain into the building
- ECO 9 Reduce conductive heat loss transmission through the building envelope
- ECO 10 Improve the burner-boiler furnace efficiency
- ECO 11 Reduce temperature
- ECO 12 Reduce quantity
- ECO 13 Reduce system losses
- ECO 14 Generate hot water more efficiently
- ECO 15 Turn off cooling system during unoccupied hours
- ECO 16 Use outdoor air for cooling
- ECO 17 Increase indoor temperature and relative humidity levels during occupied hours
- ECO 18 Reduce ventilation rates during occupied periods (cooling)
- ECO 19 Reduce infiltration rates (cooling)
- ECO 20 Reduce solar heat gains
- ECO 21 Reduce internal heat gain
- ECO 22 Reduce conductive transmission of heat gain through the building envelope
- ECO 23 Improve the chiller and compressor performance
- ECO 24 Reduce energy consumption through operation and/or maintenance of specific HVAC systems
 - (a) Direct hot water and steam heating systems
 - (b) Single-zone duct systems
 - (c) Terminal reheat systems

*Dubin-Minbell-Bloom Associates, Inc.

- (d) Dual duct systems
- (e) Multizone systems
- (f) Induction systems
- (g) Variable-volume air systems
- (h) Fan coil systems
- (i) Window and through-the-wall air conditioners
- (j) Unitary heat pumps
- ECO 25 Reduce energy consumption for fans
- ECO 26 Reduce energy consumption for pumps
- ECO 27 Reduce distribution piping losses
- ECO 28 Reduce energy consumption for commercial refrigeration
- ECO 29 Reduce illumination levels
- ECO 30 Turn off lights
- ECO 31 Improve the effectiveness of the existing lighting installations
- ECO 32 Utilize daylight for natural illumination
- ECO 33 Use switching and timers to shut off lights
- ECO 34 Remove unnecessary lamps
- ECO 35 Reduce lighting load by relamping
- ECO 36 Reduce power for lighting by replacing ballasts
- ECO 37 Reduce operating time of elevators and escalators
- ECO 38 Reduce energy consumption for equipment and machines
- ECO 39 Reduce peak loads
- ECO 40 Reduce transformer losses
- ECO 41 Improve the efficiency of motors
- ECO 42 Control occupied and unoccupied temperatures
- ECO 43 Reduce transmission heat losses through windows
- ECO 44 Install thermal barriers to further reduce heat losses through windows during unoccupied hours
- ECO 45 Reduce transmission heat losses through walls
- ECO 46 Reduce transmission heat losses through roofs
- ECO 47 Reduce transmission heat losses through floors
- ECO 48 Fit vestibules and/or revolving doors to reduce infiltration

ECO 49 Seal vertical shafts and stairs to reduce infiltration

ECO 50 Install screens to protect external door from prevailing winds

ECO 51 Install new outdoor air dampers

ECO 52 Recirculate exhaust air using activated-carbon filters

ECO 53 Use separate makeup air supply for exhaust hoods to reduce outdoor air ventilation

ECO 54 Reduce air flow rates (heating and ventilation)

ECO 55 Reduce resistance to air flow (heating and ventilation)

ECO 56 Reduce water flow rates

ECO 57 Reduce parasitic loads by insulating pipes

ECO 58 Reduce parasitic loads by insulating ducts

ECO 59 Adjust fuel/air ratios of firing equipment

ECO 60 Install flue gas analyzer

ECO 61 Isolate off-line boilers

ECO 62 Replace existing boilers with modular boilers

ECO 63 Preheat combustion air to increase boiler efficiency

ECO 64 Change steam atomizing burners to air atomizing burners

ECO 65 Reduce blowdown losses

ECO 66 Insulate piping

ECO 67 Insulate storage tanks

ECO 68 Replace central system by local heating units

ECO 69 Install temperature boosters

ECO 70 Install separate boiler for summer generation of domestic hot water

ECO 71 Hot gas heat exchanger

ECO 72 Hot drain heat exchanger

ECO 73 Hot condensate heat exchanger

ECO 74 Reduce solar gains through windows with solar control devices

ECO 75 Reduce heat gains through walls

ECO 76 Reduce transmission gains through floors

ECO 77 Reduce transmission gains through roofs by installing roof sprays

ECO 78 Reduce heat gain through roofs by installing roof sprays

ECO 79 Reduce cooling load due to outdoor air ventilating and infiltration

ECO 80 Use an economizer cycle to reduce cooling load

ECO 81 Reduce internal heat gains from lights

ECO 82 Reduce heat gain from building equipment

ECO 83 Employ evaporative cooling to reduce cooling load

ECO 84 To reduce cooling load use desiccant dehumidification

ECO 85 Insulate pipes and ducts to reduce heat gain

ECO 86 Increase evaporator temperatures

ECO 87 Isolate off-line chillers

ECO 88 Pipe chillers in series

ECO 89 To increase chiller efficiency, use low temperature condenser water

ECO 90 Replace air-cooled condensers by cooling towers

ECO 91 Use piggy-back absorption system

ECO 92 Replace cold cabinet internal lights by external lights

ECO 93 Provide night covers for open cold cabinets

ECO 94 Replace existing open cold cabinets

ECO 95 Move condensers close to compressors

ECO 96 Relocate condensers to recapture waste heat

ECO 97 Replace air-cooled condensers by water-cooled types

ECO 98 Reduce resistance to flow in piping systems

ECO 99 Reduce water flow rates

ECO 100 Reduce resistance to air flow in duct systems (HVAC systems)

ECO 101 Reduce air flow rates (HVAC systems)

ECO 102 Reclaim waste heat to replace or supplement purchased energy

ECO 103 Improve the lighting fixture maintenance factor

ECM 104 Use efficient lenses

ECO 105 Provide switches to turn off unnecessary lights

ECO 106 Modify existing fixtures to accommodate more efficient lamps

ECO 107 Install new efficient fixtures

ECO 108 Increase room interreflectances

ECO 109 Lower the fixture mounting heights

ECO 110 Use nonuniform lighting

ECO 111 Use furniture-mounted task lighting and reduce general illumination

- ECO 112 Use multilevel ballasts
- ECO 113 Install dimmers to reduce light levels
- ECO 114 Make better use of skylights and windows
- ECO 115 Utilize reflectors to maximize daylight for illumination
- ECO 116 Install high-frequency lighting
- ECO 117 Use the waste heat from lights

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