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LAWRENCE BERKELEY LABORATORY

DRAFT INSTITUTIONAL PLAN - 1978

(FY 78-84)

MAY 1978

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NOTE: This draft submittal consists of Chapters III, V, and Appendix only.

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CHAPTER III

CURRENT AND PROJECTED PROGRAM ACTIVITIES

BASIC ENERGY RESEARCH

DOE: A/S Energy Research (ER)

Research programs in the energy-related basic sciences occupy a major fraction of Laboratory effort. They continue a tradition of excellence for which the Laboratory has been recognized over four decades, and today serve to build a strong base of scientific understanding as a prerequisite to the development of economic energy technologies and efficient use of energy. Basic research done in pursuit of pure knowledge, as in studies of the fundamental particles of matter, is carried out side-by-side with mission-oriented applied research in energy. This complementary association has been characteristic of this multiprogram laboratory since its earliest days.

The Laboratory's basic research programs encompass the fields of high energy physics; nuclear, materials, chemical, mathematical, and geosciences; and the engineering sciences. These programs call forth an array of disciplines and bring together LBL staff and U.C. faculty members, post-doctoral, and graduate researchers.

Basic Energy Sciences (AK 01)

Nuclear Sciences (AK 01 01)

The program supports the operation of the 88-Inch Cyclotron for the acceleration of beams of light ions, including polarized proton and deuteron beams. It also supports the research that is done by LBL groups as well as providing assistance to outside users groups.

Light ion beams are used in a wide variety of ways to study the spectroscopy of nuclei, especially of exotic species far from the line of stability (i.e., having an unusually high or low ratio of protons to neutrons). The masses of these nuclei are measured to provide very sensitive tests of nuclear structure theories.

Polarized beams of protons and deuterons permit experimental research in a variety of fundamental areas, including the study of few-nucleon systems and of parity violation by a weak force component of the strong nuclear force.

In support of its experimental research programs, advanced detector systems and new instrumentation are under constant development at LBL. Research in detector systems focuses on advanced semiconductor detectors and associated electronics, gas ionization and fast time-of-flight detectors. New circuit techniques, instrument modules and systems, computer data acquisition and microprocessor systems are also under development for the LBL nuclear research programs.

The Laboratory applies its experience in the production, isolation, and characterization of the transuranium elements in its actinide and lanthanide chemistry program. Sequestering agents are being designed for actinide ions which can be used in the treatment of spent nuclear reactor fuels. Studies of actinide and fission product speciation in very dilute solution will be pursued in order to further our understanding of radionuclide migration in the biosphere. This research has bearing on the problem of geological isolation of buried nuclear wastes.

Widely used by eperimental and theoretical nuclear scientists the world over, the Table of Isotopes nuclear data compilation has been published since 1940. Subjects covered by the Table include:

- Decay properties of radioisotopes: half-life, decay modes and branching, radiation energies and intensities, angular and time correlations between radiations;

- Properties of nuclear levels: energy, spin, parity, and other quantum assignments, half-lives, transition probabilities, cross-sections for direct reactions.

With the completion of the 7th edition, the LBL effort will be redirected to support the goals of the newly-formed U.S. Nuclear Data Network.

Materials Sciences (AK 01 02)

This interdisciplinary effort addresses basic questions of materials behavior such as factors determining alloy toughness and strength, high temperature stabilities, diffusivities, reaction kinetics, photon and electron interactions with solids and surfaces, and interface reactions. A number of problems of direct application to energy technologies are being attacked. A large array of advanced multi-use facilities has been built up for the preparation, characterization and testing of materials.

Physical Metallurgy. These programs are concerned with the relationship of microstructure to mechanical, electrical and magnetic properties and with the preparation of alloys having predictable characteristics. Control of microstructure is achieved by varying the chemical composition and by thermal and mechanical treatment.

Unusual compositions and structures, in particular high field superconductors in the form of ductile wires and tapes, are obtained by powder-metallurgical techniques. Erosion and corrosion damage to materials for possible use in coal gasification is under systematic study. Major efforts, both theoretical and experimental, are being placed on alloy design, especially in ferrous metallurgy.

A new class of low-alloy silicon steels of increased toughness has been designed for use in the automotive industry, where reduced weight is required for energy conservation. Efforts to produce nickel-free cryogenic steels have been successful and new tough high

strength low alloy steels have been developed for applications in mining and other fields.

Ceramic Science. Historically, ceramic science was focused primarily on the influence of processing variables such as heating and cooling rates and gross chemical composition on the properties of ceramic products. Further advances require ever greater sophistication in identification and control of more subtle material parameters that influence ceramic properties and behavior. The influence of materials parameters on piezoelectricity, on graphitization kinetics, on sintering rates, and on fracture strengths are under study at LBL. The sintering study makes use of a high temperature scanning electron microscope developed at Berkeley, and the strength studies apply ultra-high resolution transmission electron microscopy to identify impurity phases at grain boundaries.

A comprehensive theory of decomposition reactions, developed here, is being used as a basis for systematic identification of the parameters determining decomposition rates and crystallinity and porosity of solid oxide products. By selected combinations of reactant crystallite size, temperature, and gaseous product pressures, either an amorphous or a crystalline CaO can be produced from $CaCO_3$ decomposition. Applications of these and other oxides to sulfur oxide removal, to separation of components of vapor mixtures, and to formation of slags for steel making are under study.

The chemistry of ceramic-metal interactions and the chemistry of attack on refractories by environments encountered in coal gasification are also under study.

Electron Microscopy. Transmission electron microscopy has become widely recognized as an essential technique for materials characterization, principally because of pioneering efforts at Berkeley. Widespread application to new classes of materials, development of new experimental methods, and training of scientists to extend expertise into other national laboratories and universities has been, and continues to be, the goal of electron microscopy research at LBL. Since the acquisition of the first 650-kV microscope, new research in ceramics, crystal structure determination, and defect analysis has been developed that has subsequently led to the recent award of a new 1.5-MeV instrument, scheduled for operation in 1979. In another program, emphasis has been placed on high resolution electron microscopy that has led to important breakthroughs in understanding the fundamental aspects of phase transformations that are necessary in LBL alloy design projects. It is planned to extend this capability, through the addition of a new 500-kV instrument and support facilities (see Section V), to include atomic resolution microscopy of close packed structures used in the energy technologies.

Solid State Physics. This work is concerned with certain advanced materials and their uses. Among these are superconductors and superconducting devices, nonlinear optical materials and processes, semiconductors and far-infrared detectors. A recently-developed superconducting magnetometer can measure changes in magnetic fields as low as 10^{-10} G. It has been incorporated into equipment for locating hydrothermal sources, and is being field tested. Theoretical solid state studies and the far-infrared spectroscopy of solids have been directed to the consideration of surfaces in connection with surface reaction and catalysis programs of interest to fossil fuel conversion. Research in quantum electronics is concerned with the multi-photon dissociation of molecules with lasers. This work is an essential part of studies for new laser isotope separation processes. Electron droplets in semiconductors are being investigated as a novel state of matter.

Surface Science. The purpose of this research is to study the structure and composition of surfaces on the atomic scale, along with atom charge transport and elementary surface reactions, and to correlate this atomic scale information with the macrosocpic surface phenomena of corrosion, mechanical failure, passivation, surface reactions, and electrode processes. Among specific LBL programs are preparation of special materials with high surface areas, study of hot corrosion processes, the structure of internal surfaces, grain boundaries and intergranular surfaces, and the kinetics and mechanisms of elementary surface reactions.

Solid State Chemistry. This research centers on the elucidation of chemical bonding and phase transformations in solids. It includes the prediction of crystal structure and phase diagrams on the basis of electron orbitals, the investigation of phase transformations in liquid crystals by nuclear magnetic resonance and the measurement of physical properties of solids under high pressures, high temperatures as well as in high magnetic fields and at low temperatures. Programs in electrochemistry are concerned with the elucidation of mass and charge transport processes in electrolytic and galvanic cells, dissolution of metals, gas evolution, and non-aqueous solvents.

Chemical Sciences (AK 01 03)

This program addresses basic problems in the structure of chemical compounds and surfaces, atomic and molecular reactions, and chemical theory. Knowledge gained from these efforts is valuable not only in advancing these basic sciences but also in building a scientific base for many energy supply technologies.

Inorganic Chemistry. In this program, new compounds are synthesized and characterized by modern physical-chemical techniques. Of particular interest are unusually high oxidation states of elements, intercalated layer compounds and compounds with new structures and bonding that cannot be explained by present theoretical concepts. New research on the chemistry of sulfur dioxide provides basic understanding for SO_2 removal. The structure and bonding of metal carbonyls that are

of importance in catalytic processes of fossil material are being investigated by photoelectron spectroscopy.

Other research concerns techniques for chemical analysis of trace elements for environmental research. The development of x-ray fluorescence and anodic stripping voltammetry complement other analytical methodologies developed and in use at LBL.

Surface Chemistry. In this research, studies are made of the electronic and atomic structure of surfaces, and studies of catalyzed surface reactions. A major program concerns the correlation of homogeneous and heterogeneous catalysis by studying structure and reactivity of similar systems to bridge the gap between these two important fields. Another program involving several investigations lies in the field of coal gasification and liquefaction. The hydrogenation of carbon monoxide is being investigated to establish the mechanism for this reaction for the purpose of selectively producing organic molecules. Photon-assisted reactions are also being studied at the solid-vapor interface to elucidate the mechanism of thermodynamically uphill chemical reactions.

Chemical Physics. Projects here are concerned with advancement of understanding of chemical reaction mechanisms, molecular collision dynamics and molecular structure. Reactions of ions and molecules in the gas phase are investigated by modern experimental methods using lasers and molecular beams. Results are used for the development of a theoretical chemical foundation for elucidating chemical reactions of interest in combustion and MHD processes. The data derived for photochemical and catalytic reactions have found recent application in stratospheric chemistry. Investigation of wider aspects of the ozone problem in the stratosphere, initially undertaken in connection with the supersonic transport, is now considering the atmospheric effect of all energy-related (particularly combustion) technologies.

Chemical binding energies and electronic structure, that determine the properties of materials, are being studied by photoelectron spectroscopy of metals, semiconductors and insulators. This technique has recently been expanded to the investigation of solid surfaces. Other theoretical and experimental investigations are aimed at more effective prediction of thermodynamic properties, energy transport in molecular solids, and radiation-induced reactions of biologically important organic compounds. Existing strength in surface and catalysis science ranging from the basic to the applied is being consolidated.

Photovoltaic effects within certain micro-organisms are the subject of research. Present work involves gaining an understanding of these processes within the living cell. Future applications of this research include the development of laboratory-scale solar power cells, desalination and concentration cells.

Atomic and Molecular Physics. This effort involves investigation of the validity of relativistic quantum mechanics with highly stripped ions and making precise measurememnts of physical processes on atoms, molecules, and ions by use of optical and radio-frequency spectroscopy. Among these measurements are line widths needed for plasma diagnostics.

National Resource for Computation in Chemistry (NRCC). In 1977, Lawrence Berkeley Laboratory was selected as the host institution for this National Resource by a joint committee of the Division of Basic Energy Sciences (DOE) and NSF. The NRCC was organized as a separate Division of LBL with operations beginning October 1, 1977. The NRCC is to be operated as a user-oriented facility with hardware and personnel dedicated toward serving the needs of the national chemistry community. The staff will document, test, and improve software, develop new computational methods, and conduct original research in computational chemistry. The policy and procedures for the NRCC are determned by a nationally-representative Policy Board. Program decisions within policy guidelines are handled by the Director and a Program Committee.

Engineering, Mathematical, and Geosciences (AK 01 04)

Combustion. Improvement in the efficiency of combustion systems is a recognized national energy goal but the present inability to model and predict the performance of turbulent combustion systems is a serious impediment to the develpment of improved combustion concepts. An LBL, idealized combustion concepts are being studied in order to develop an improved understanding of the interaction between fluid mechanical turbulence and the combustion heat release process. The experimental study of lean combustion in a turbulent boundary layer allows sufficient control of various combustion parameters that several basic phenomenological concepts can be tested. The experiments will be used for testing detailed theoretical models of the turbulent combustion process. The application of recently developed numerical vortex methods to boundary layers and turbulent flow in an internal combustion engine is a new avenue to the numerical modeling of these very complex processes.

Applied Mathematical Sciences. This effort is concentrated on problems of data management and of distributed computing over networks for resource sharing of computational facilities among DOE sites. A Distributed Computing Network (DCN) of minicomputers is being developed to provide a homogeneous network operating system. The possibility of using the DCN as an alternative to use of the ARPANET will be investigated and is expected to provide a modern, cost-effective mechanism for distributed computing.

Research in natural language interfaces to the distributed computing environment will greatly enhance the utility of DOE computing resources. Computer graphics research is aimed at providing powerful analysis and display techniques for multi-dimensional data. High quality graphics output in the form of color microfilm, movies, and holographs are being investigated.

Geosciences. This program emphasizes fundamental research in geological processes that have a bearing both on mission-oriented R&D and promising new techniques in the energy field.

Most of the geoscience effort to date has been in areas relating to hot brine geothermal energy. Major accomplishments in this area include development of techniques to measure and interpret the dynamics of liquid-dominated geothermal reservoirs, characterization of the physical behavior of fluid-dominated geothermal reservoirs, characterization of the physical behavior of fluid-saturated rocks under high temperatures and pressures, and theoretical description of the thermodynamic properties of strong, mixed electrolytes (e.g., geothermal fluids) at elevated temperatures and pressures. A start has been made in characterizing the complex chemical reactions between rocks and ground waters. An information project has undertaken compilation of scientific data of use to engineers and scientists developing geothermal energy.

Of longer-range application is LBL work to determine the thermodynamic and transport properties of magmas from experimental measurement of physical properties of silicate liquids at high temperatures. This work will eventually have applications in the recovery of energy from molten rock.

The influence of rock stress on seismic wave velocities is being investigated as a means of predicting earthquakes. Measurement of artificial seismic waves through controlled volumes of the earth's crust adjacent to the San Andreas fault has been achieved.

In the future, the program will involve greater emphasis on geohydrology, chemical migration and rock mechanics, to provide a basis for solving problems associated with radioactive waste storage in rocks, acid mine drainage, in situ leaching of uranium ores, storage of hot and cold water in aquifers for energy conservation, and problems associated with deep underground excavations, including storage of radioactive waste cannisters, compressed air, and possibly liquified natural gas.

High Energy Physics (HK 02)

The high energy physics research program at LBL is concerned principally with particle physics. Experimental and theoretical work is carried out at the laboratory; experiments lead to advances in theoretical physics and these in turn suggest new directions for experimental research.

The LBL high energy physics research program is closely related to the programs being carried out at other DOE National Laboratories as well as to the research programs of laboratories of other nations. It focuses on experiments with e^+e^- colliding beams using advanced techniques and developments. A balance is maintained by continuing experimentation at FNAL and BNL. LBL has an especially close relationship in the collaboration with SLAC to build PEP, the 20-GeV positron-electron colliding beam facility to be completed in the autumn of 1979.

General Research and Development (HK 02 05)

Physics Research at PEP. Our major effort is the preparation for experiments to be carried out at PEP. We expect that a new spectroscopy of hadrons will be revealed by these experiments and that new and unexpected phenomena will be found as they have been in the past when increased energy has become available.

There are five regions at the PEP facility in which electron-positron collisions can occur and which now can be committed.

Three proposals have been selected by the PEP Experimental Program Committee: 1) The Time Projection Chamber, 2) The Mark II Magnetic Detector, and 3) Search for quarks.

The Time Projection Chamber is a radically new concept for particle identification and measurement. It will have exceptional capabilities for charge particle pattern recognition, momentum analysis and mass identification within high multiplicity jet-like events; neutral reconstruction (Λ^o, K_s, π^o, η^o...); electromagnetic calorimetry and muon identification. This broad range of characteristics results in the detector having an anticipated productive life well beyond the first round of PEP's operation.

In FY 1980 we expect the PEP-4 facility to yield preliminary data in areas such as new particle searches, studies of interference effects between weak neutral and electromagnetic forces, studies of the limits of applicability of quantum electrodynamics, and studies of the details of hadronic production in electron positron annhilation at high energies.

The Mark II Magnetic Detector is an instrument of substantially greater sophistication than Mark I which made numerous discoveries (ψ particles, charmed particles) over a period of four years at the SLAC storage ring SPEAR. Mark II is continuing the annhilation studies

in the 3-8 GeV energy range already initiated by Mark I at SPEAR and will then be moved to PEP in 1980.

Mark II will be the first general purpose facility in operation at PEP and, hopefully, the experience of the previous running at SPEAR should permit rapid initiation of the research program at PEP. Recent results by Lederman and collaborators at Fermilab indicate that there are new structures to be studied in the PEP energy range.

A large part of the results of present day experimental high energy physics can be explained with quarks being the fundamental building blocks of elementary particles; but as yet no quarks have been observed. PEP opens up a completely new domain for the search of charged particles. This experiment offers a simple detector that would be able to detect quarks of mass up to the maximum PEP energy of 15 GeV and enough sensitivity such that a negative result will raise serious doubts about the existence of these hypothetical objects.

Research at FNAL and BNL. Experiments on rare muon-induced reactions are now underway at FNAL. These will continue into FY 1980. Even in the first events seen with the spectrometer; massive dimuon and trimuon final states have been identified.

When the new high energy, high intensity muon beam from the Tevatron is developed the 470-ton spectrometer used in this experiment will be used for new studies there. Among the studies will be measurement of the inverse neutrino scattering process $^{+} + N \quad + X$ (X = anything). This reaction has never been observed except for leptons at rest. At high energies it would provide a unique opportunity for exploring the existence and properties of right-handed weak charged currents.

Neutrino and anti-neutrino interactions with protons and neon are being investigated using the FNAL 15-foot bubble chamber. Several different experiments will be underway to obtain information about 1) the hadronic system in neutral current events, 2) vector meson production and 3) dilepton production by anti-neutrinos. We will be using a dichromatic beam with anti-neutrinos to make precise measurements of the structure functions of the nucleon.

Further experiments using polarized proton and anti-proton beams are planned to study scattering of polarized particle beams from polarized targets.

Construction of a polarized beam facility should begin after the scheduled shutdown of the Meson Laboratory at FNAL in summer of 1978, and with approval of the proposal, the first of the proposed experiments on total cross section differences should be completed during FY 1979. In FY 1980 this experiment should be concluded. In the future, measurement of asymmetries in inclusive production of high momentum pions will be made.

A continuing flow of very interesting and timely physics in the kaon nucleon system is possible by exploiting the new high flux kaon beams at BNL. A new experiment is in the initial discussion stage--the measurement of polarization effect in $K^-p \rightarrow K^0n$ elastic charge exchange. This kind of data will be of value in placing further restrictions upon phase shifts in the kaon-nucleon system.

Magnet Design and Instrumentation. The aim of the LBL program in low temperature research and development and superconducting solenoid magnets is to produce thinner and cheaper magnets for use in detectors for high energy physics. The technique is to develop different schemes of quench protection for superconducting coils and to test the quench protection schemes on specially built instrumented test coils capable of triggered quenching. Techniques resulting from the program are being used in building the superconducting magnet for the PEP-4 detector and are being considered for magnets to be used in detectors at FNAL and CERN.

LBL work in instrumentation for high energy physics is concerned with the development of instrumentation systems having broad and general application in experiments conducted at the Bevalac or at other national high-energy physics laboratories. It includes research and development of particle detectors and detector methods, maintenance and support of previously designed systems, of instruments, computers and peripherals used for data acquisition in nuclear science and high-energy physics experiments.

The future program will be heavily influenced by rapid advances in detector methods and semiconductor technology which accompany the heavy-ion nuclear science experiments and colliding beam high-energy physics experiments. Data busing systems will be developed for fast and efficient readout from large-scale experiments. Microcomputers will be heavily used to make rapid calculations and decisions to sort out data of interest and to improve the efficiency of handling large blocks of data.

The Particle Data Center issues the Review of Particle Properties and other compilations of descriptive and bibliographic information on published articles, preprints, and current experiments. The Berkeley Database Management System is used to maintain and query the various LBL databases, which are also open to outside users.

Astrophysics and Astronomy. In this program, studies are being made of galactal motion by means of measuring directional variations (anisotropies) in cosmic blackbody radiation. Current results, interpreted as motion of the earth relative to the blackbody radiation, indicate that the galaxy is moving at a rate of 600 km/second. A NASA-sponsored satellite version of this experiment is being designed.

The LBL "rubber telescope" project intends to reduce greatly atmospheric distortion in ground-based astronomical telescopes. It uses an optical element called a "rubber mirror" to correct the perturbed

phase front of the incoming light. By this technique, the resolution of a large telescope for objects as dim as 9th magnitude can probably be significantly improved. A large system is being planned, perhaps for use with an existing telescope such as the 120-inch telescope at Lick Observatory, or as a completely independent system.

The astrophysical program is also concerned with the study of compact objects (black holes, neutron stars and white dwarfs) and the phenomena associated with them. The details of their time dependent behavior can shed light on many critical parameters including masses and mass accretion rates.

A group of astronomers of the University of California have begun the design of a 10-meter optical telescope. LBL is involved in this effort. In particular, a system of controlling the surface of the primary mirror (active optics) will be intensively studied at LBL. The preliminary design study will be completed in FY 1980.

Theoretical Physics. LBL theoretical work involves the interactions of fundamental particles, and the interaction of particle beams in the context of advanced and specialized accelerator systems, nuclear science, atomic physics, and mathematical physics. Research in particle theory encompasses the strong, electromagnetic and weak interactions of fundamental particles. Its approaches range from rigorous field theoretic considerations to practical analysis and interpretation of experimental data.

LBL plans to continue a broad program in particle theory. The major areas of activity are expected to be in topological expansion in S-matrix theory, gauge theories and quark confinement, applications of QCD, new particle spectroscopy and dynamics, gauge theories of weak and electromagnetic interactions, and heavy ion beams for fusion.

Facilities Operations. The four main activities in this area are: operation of PEP detectors, computer electronics maintenance, PEP experimental facilities coordination, and operation of the superconducting laboratory.

As the facilities built by LBL at PEP become operational, support is necessary for running, maintaining, improving and making the facilities available to outside users. The completion of all the approved detectors will take place by the middle of FY 1980. Additional new initiatives are expected at this time as the physics discovered at PEP itself leads to new ideas.

Accelerator Theory. At present the major effort is being devoted to the PEP project and to the heavy ion fusion program, anti-proton cooling schemes and the Bevalac improvement program.

Nuclear Physics (HK 03)

Medium Energy Physics (HK 03 01)

The program in Medium Energy Physics includes several research projects. These are done at LASL on LAMPF, on the Bevalac at LBL and at TRIUMF in Vancouver. In addition there are various instrumentation projects associated with the medium energy physics research effort.

The research projects include experiments at LAMPF and TRIUMF on stopped pions and mesons for the purpose of studying their intrinsic properties and using them as probes for nuclei and condensed materials; the use of mesons and light nuclei to study the properties of fundamental interactions and to investigate the details of nuclear structure (this program has been shifted from the 184-Inch cyclotron to the Bevatron with expected experiments at LAMPF and TRIUMF); experiments to measure accurately the mass of pions and kaons to formulate and verify mesonic atomic theory; and investigations of the mechanisms of nuclear reactions induced by medium energy protons and attempts to identify isotopes far from beta stability produced in these reactions. Instrumentation development efforts continue in microchannel plates, with the Large Scale Digitizer (LSD) System, in external muon identifiers (EMI), and other devices.

Heavy Ion Physics (HK 03 02)

As a leading international center for research in heavy-ion science, the Laboratory pursues a varied program that makes use of its unique nuclear-particle accelerators, the SuperHILAC, the Bevalac, and the 88-Inch Cyclotron. The DOE Heavy Ion Physics Program supports the operation of the SuperHILAC, a national facility, and the majority of the operations of the Bevalac and the 88-Inch Cyclotron, as well as the extensive LBL heavy-ion research programs.

The LBL staff and the UCB faculty pioneered the use of heavy ions as a tool in nuclear physics research. They are therefore exceptionally experienced to make use of the unique accelerator facilities at the Laboratory.

The SuperHILAC provides beams of ions up to ^{208}Pb at energies to a maximum of 8.5 MeV per nucleon. It is operated by LBL as a national facility open to all qualified users. Approximately half the available research beam time is used by LBL groups, the remainder by outside users from many U.S. and foreign institutions, universities, and the national laboratories.

The SuperHILAC is coupled to the Bevatron accelerator through a beam transfer line. This combined machine (the Bevalac), accelerates beams of particles that range from protons to ^{56}Fe nuclei to energies from 100 MeV per nucleon to a maximum of 2200 MeV per nucleon (95% of the velocity of light). While the capabilities of SuperHILAC are

unique in the U.S., those of Bevalac are unique in the world. The two machines, under computer control, routinely deliver one type of ion to a SuperHILAC user and a second type of ion, accelerated to much higher energy, to a Bevalac user.

The Bevalac is also operated as a national facility open to all qualified users.

The 88-Inch Cyclotron is capable of accelerating beams of ions from protons (55 MeV) to ^{40}Ca ions at energies up to 35 MeV per nucleon, intermediate between SuperHILAC and Bevalac. It has the important advantage that its beams are continuous rather than pulsed and that beams with very high energy resolution can be accelerated. Although the 88-Inch Cyclotron is not a national facility, it nevertheless supports an outside user program with about as many hours of time per year as the two LBL national facilities. Many of its heavy ion beams are unique in the world.

The research at SuperHILAC and the 88-Inch Cyclotron includes a very wide range of nuclear and atomic physics. Nevertheless, three areas emerge as of especial current importance.

1) The mechanism of nucleus-nucleus collisions. In recent years, a wealth of new phenomena has been uncovered by the study of collisions at low and intermediate energies between heavy ions and target nuclei. Of particular interest is the totally unexpected discovery of "deep inelastic scattering."

In these collision events, the heavy ion projecticle, rather than being absorbed by the target nucleus, goes into a temporary orbit, loses all its kinetic energy, and then separates again. During the orbiting time, the two parts of the system exchange energy, protons and neutrons and angular momentum. The process therefore permits a study of the bulk diffusion properties of nuclear matter which will hopefully be related in the future to a microscopic theory.

2) The study of nuclei under rapid rotation. In traditional nuclear spectroscopy, the properties (energy, angular momentum and other quantum numbers) of individual nuclear states are measured. In many collisions of heavy ions with target nuclei, the colliding partners coalesce to form a compound system that is highly excited in energy and is also in extremely rapid rotation. Much energy--but little angular momentum--is promptly lost by the emission of particles leaving a system that is "cold" but still rapidly rotating. Further decay takes place by emission of γ-rays whose detection provides information about the angular momentum, energy and shape of the nuclear system. The 88-Inch Cyclotron, with its continuous (not pulsed) beam is a particularly appropriate accelerator for this work.

3) The preparation and study of "exotic" nuclei. The initial impetus for the use of heavy ion beams at LBL came from their usefulness in the preparation of "exotic" nuclei, especially those with a large number of protons, i.e., new heavy chemical elements.

The discovery and characterization of new transuranic elements continues to be an important activity at LBL. Two approaches are in use--the stepwise synthesis of one new element after another beyond those currently known and attempts to jump directly into the region of elements 110-114 where some nuclear theories predict that stability will be greater.

So far, attempts to detect the formation of relatively long-lived "superheavy" elements by chemical separation from targets bombarded with heavy ions have been unsuccessful. It is not yet clear whether this is due to failure of the superheavy nuclei to be formed in the first place or--contrary to expectations--to their lack of stability.

At the energies of beams available at the top of the 88-Inch Cyclotron range and on up to the relativistic beams from Bevalac, nuclear physics enters into totally unexplored territory that merges smoothly with High Energy Physics.

At energies of about 20 MeV per nucleon, two important frontiers are crossed--the Fermi energy and the velocity of "sound" in nuclear matter. When a collision occurs at an energy above the Fermi energy the nucleons of one nucleus can penetrate freely into the second without occupying the same quantum states and therefore without any inhibitions arising from the Pauli Exclusion Principle. It is therefore to be expected that nuclear matter at double normal density will be formed. As the collision velocity is increased into the relativistic regime (Bevalac), the Lorentz contraction of the projectile (a factor of 3) should lead to nuclear matter zones up to six times normal density. In the whole history of nuclear physics, it has not previously been possible to study nuclear matter at densities other than those of normal nuclei. The compressibility of nuclear matter is known only at normal density.

Many theoretical studies have suggested that the impact of one nucleus upon another at velocities greater than the "sound" velocity will cause the formation of a shock wave front that will propagate through nuclear matter as a high density wave. The experimental signature of this phenomenon is not yet clear, and no observations are generally accepted to have revealed its existence. However, only fairly crude experiments have thus far been completed at the 88-Inch Cyclotron and Bevalac. The search will continue with far more sophisticated apparatus. It is already known, though, from work at both machines, that a rather abrupt change in the spectra of emitted particles occurs in collisions at about 200 MeV per nucleon.

There have been many theoretical speculations that the equation of state (energy as a function of density) of nuclear matter should show changes of slope corresponding to phase transitions or even minima corresponding to the formation of metastable high density nuclear matter. One theory even predicts the existence of nuclear matter in a high-density form more stable than at normal density. In yet another theory it is predicted that high-energy nucleus-nucleus collisions should lead to the formation of quark matter in which the initial protons and neutrons have completely dissolved. The search for all these exotic phenomena with increasingly sophisticated techniques forms a large part of the research program at Bevalac.

It has already become clear that the collision of one nucleus with another leads to the formation in the overlapping region of an intensely hot cloud of nuclear matter - a "fireball". In some respects, this fireball resembles on a microscopic scale that the state of the Universe at an extremely early stage of the "big bang." Studies of how the fireball expands and cools are in progress, the results will be of much interest to astrophysicists.

In the earliest experiments with relativistic heavy ions, the process "fragmentation" was uncovered. When the projectile heavy ion makes the only peripheral contact with the target nucleus, it usually breaks apart (fragments) into smaller nuclei that continue to move forward with almost no loss of velocity. The process is of enormous importance in cosmic ray physics. Cosmic ray nuclei observed in sattelite experiments have traveled enormous distances through space and have suffered fragmentation by collisions with nuclei in the interstellar gas. It is now possible to correct the observed composition of cosmic rays back to what it must have been at the initial source.

The high energy beams of Bevalac themselves represent an intense and accessible source of artificial cosmic rays. Through special arrangements between DOE and NASA, Bevalac beams are made available at no cost for the test and calibration of instruments that will be flown in sattelites. The performance of these sophisticated and expensive devices has been enormously improved, and so has the probability that they will work properly after launch.

Accelerator Developments. The major planned developments will be:

1) The upgrading of SuperHILAC by provision of a third injector to be funded in FY'79. This will permit the acceleration of ions as heavy as Uranium and substantially increase the intensities for beams of lighter heavy ions. This project forms roughly one-half of the "High Intensity Uranium Beams Capability."

2) The second half of the project will improve the vacuum system of Bevalac so that beams of ions much heavier than those presently available (^{56}Fe) can be accelerated to any desired energy between 30 MeV per nucleon ad 2200 MeV per nucleon.

3) In FY 1978 and '79, the 88-Inch Cyclotron will convert from the present internal ion source to the use of a dual external source. The intensities of high-energy heavy ion beams will be improved and the presently--required frequent down-time for ion source changes will be very substantially reduced.

Nuclear Theory (HK 03 03)

This program supports extremely active research into areas of nuclear theory that guide and interact very strongly with the experimental work. In the description above of the experimental work, the importance of the theory program has been repeatedly emphasized.

With the availability of relativistic heavy ions in recent years, much of the effort has been redirected. Recent major activities include the study of phase changes in compressed nuclear matter and the thermodynamics of the hot substance of the nuclear fireball. In the latter work, it has been shown that relativistic collisions of nuclei should throw light upon the number of new particles and resonances that remain to be discovered by high energy physicists. On any theory the number is enormous--far greater than could conceivably be discovered and counted one by one. Nevertheless, different theories of elementary particles predict very different numbers. Theoretical work at LBL shows that the temperature achieved in a nuclear fireball is sensitive to the number of elementary particles per unit mass interval so that study of the fireball may lead to a result of profound significance to high energy physics. It would also have cosmological importance, for the number of particles per unit mass determines the maximum temperature that the Universe could have reached in the "big bang."

Members of the LBL Nuclear Theory Group also work closely with expermentalists in the study of nucleus-nucleus collisions at lower energies. Extremely elegant calculations provide a frame-by-frame picture of the evolution of a collision and show under what conditions the collision partners amalgamate and under what conditions they go into the temporary orbit described above.

ENVIRONMENT AND HEALTH

DOE: A/S Environment (EV)

The production and use of energy bestows great benefits on society, but has adverse impacts as well. These impacts--to human health and well-being, and to the environment--should be under constant evaluation as our energy system develops in the future. The costs of environmental and health risk mitigation are being internalized increasingly into the production costs of energy. Ultimately, the extent to which society judges such mitigation to be necessary will be an important factor in determining future energy costs.

Lawrence Berkeley Laboratory's program in risk and impact assessment covers these areas:

- Analysis of energy systems and alternative energy futures.
- Study of effects on human health of exposure to energy-related environmental pollutants.
- Study of the chemistry of formation and transport of particulate and gaseous pollutants from fossil fuel combustion.
- Development and assessment of instrumentation for monitoring environmental pollutants with increased accuracy.
- Study of distribution of trace metals in inland water and marine systems.

Environmental Research and Development (GK 01)

Overview and Assessment (GK 01 01)

Energy System Analysis. A major effort is underway to analyze the possibilities for and impacts of decentralized and largely self-sufficient regional energy supply systems making use of local renewable energy sources, including solar, biomass, and geothermal sources.

The Socio-Economic Environmental Demographic Information System (SEEDIS) provides researchers and planners with a comprehensive, computer-based system for data management, analysis and display capabilities. The SEEDIS system presently contains several large databases such as the 1970 Census, air quality data, geographic base files and land use data. A comprehensive set of user-oriented retrieval, analysis and graphical display modules provides tables, charts and maps on both interactive terminals and high-quality hardcopy output.

Other projects are the Endangered Plants Information System (EPIS) of benefit to a number of government agencies, the Information Coordination Focal Point (to store updated data on laboratory programs at Oak Ridge), an Earthquake Safety Guide intended as a handbook for

DOE facilities, and a series of environmental assessments and control studies related to energy production.

Biomedical and Environmental Research (GK 01 02)

Human Health Studies. These studies deal with adverse human health effects resulting from exposure to environmentally related pollutants. They include both laboratory and epidemiological approaches to the problem. The Laboratory has the advantage of being able to collaborate with a large number of trained epidemiological investigators and public health professionals from U. C. Berkeley and the California State Department of Public Health. In FY 1978 a major five-year study has been launched on the health effects of the oil refining and transporting industry. In this study, health effects will be evaluated for both the occupationally and the non-occupationally exposed populations. Support and assistance from the involved workers' unions and industry medical professionals have been solicited and received. It is planned to enlarge the locale of the study to include oil refining districts on the Gulf Coast and in Southern California.

Another study has been initiated to examine retrospectively the health status of workers occupationally exposed for long periods to high magnetic fields. Should nuclear fusion be deployed as an energy source, exposure to high magnetic fields may occur, and early assessments are desirable. The population being studied is principally the accelerator and high energy physics community.

The Laboratory is continuing to explore ways to find new diagnostic and predictive tools for evaluating exposure to polluting environments. Such methods will include low level chemical analytic methods for estimation of the body burden of toxic substances in worker and public communities.

Health Effects Research in Biological Systems. To evaluate systems damage in man from exposure to various toxic agents arising from energy sources--including both chemicals and radiation--the Laboratory studies these effects at several levels: the cell, the organ, and the whole animal. These studies presently emphasize systems for which LBL has been given responsibility: magnetic fields and cosmic radiation. The former is relevant to the fusion, MHD, and energy storage options, the latter to the Space Power Satellite.

Studies are directed at late and long term effects, including carcinogenesis, effects of vision, effects on the nervous and reproductive systems, and mutagenesis. In one program examination continues of a population of primates exposed over the last two decades to plutonium.

The effects of pollutants on lung are being examined, with special emphasis on gases and polycyclic hydrocarbons generated by energy technologies. Carcinogenesis research and mutagenesis research concentrate on further development of methods and test systems for validation of experimental laboratory findings in human beings.

Atmospheric Aerosol Research. The principal goal of this LBL program is understanding the formation and transport of particulate and gaseous pollutants generated by fossil fuel combustion. Effort has concentrated on determining the extent to which primary particulates contribute to the ambient particulate burden, and the role these emissions have in forming secondary aerosol species. Despite the virtual elimination of visible smoke emissions by stack cleaning devices, microscopic soot particles continue to be emitted, and contribute importantly to health-related atmospheric pollution. This research indicates that these particles are chemically active and largely responsible for the formation of sulfates from fossil fuel combustion. In addition to laboratory studies and theoretical modeling, the program uses a mobile sampling laboratory for field studies.

Other atmospheric research concerns indoor air pollution, in conjunction with LBL research on energy-efficient buildings. This program responds to the concern that efforts to conserve energy through decreased ventilation and air infiltration of buildings may carry an increased risk to the health of inhabitants because of buildup of indoor pollutants.

Instrumentation and Technique. The goal of the Laboratory's program is to allow precise characterization of environmental impact of energy technologies to be made, so that effects on human health and ecosystems can be understood and the costs of required control measures accurately assessed. At LBL there is close and fruitful collaboration between instrumentation development and research work in the environmental sciences.

The program includes R&D on components for use in instruments, development of improved or new methods, and the design and demonstration of specific instruments and monitoring systems in the field. Development of instruments and measurement techniques embraces a broad range of physical analytical methods. The x-ray fluorescence and Zeeman-effect atomic absorption methods and instruments developed by this program are now widely used in environmental research studies and in monitoring programs.

Present capabilities include radiation monitoring systems, particulate analysis, and techniques for assessing common gaseous contaminants. Emphasis is expected to shift toward techniques providing information on the chemical state of elements in plumes, combustion chambers, and the environment. This knowledge is essential for developing an understanding of the pollutant sources and chemical transformation processes in the environment. Interest is also developing in techniques for assessing occupational hazards in the energy industry.

An ongoing survey is published to keep other researchers aware of the state of the art of environmental instrumentation.

Trace Metals and Aquatic Environmental Systems. Capabilities for trace metals detection are applied at LBL to several areas related to water quality. One is an assessment of impacts of oil shale technologies, especially the potential for waste water treatment. If large-scale use is made of shale (as much as 1-1.5 million barrels per day is envisaged in some projections) a heavy burden will be placed on the ecology of the arid western regions containing this resource.

A second effort aims at understanding better the biochemical processes involved in trace metal sequestering by certain aquatic plants. The ultimate goal of this research is development of improved bioengineering strategies for waste water treatment.

In another program that utilizes LBL's trace methods detection capability, assessment is being done of impacts on marine ecosystems from ocean thermal electric conversion technologies (OTEC).

The exchange rates of trace gases between aquatic ecosystems and the atmosphere is the focus of another LBL environmental research effort. Making use of refined laser instrumentation, advanced methods of determining the pathways and fate of gas-phase trace substances are being developed. Laboratory ecosystems are being used to model changes occurring in the natural environment and to permit calibration of such new measurement methods for eventual field applications. The microcosm facility is also being employed for study of transient effects on aquatic ecosystems of pollutants from coal conversion facilities.

Life Sciences Research and Biomedical Applications (HK 01)

General Life Sciences (HK 01 01)

General Life Sciences. This research program applies advanced concepts and techniques of chemistry and physics to important problems of biology. The capture, storage, and utilization of energy in biological systems, and their response to environmental agents at both cellular and organismic levels are the development of research methods such as electron defraction and high resolution electron microscopy to investigate complex biological structures at the molecular and atomic level. Among LBL life science projects are a study of blood-cell development and their membrane response to various agents; molecular level DNA repair mechanisms; the structure and function on nucleic acids and their relation to DNA; study of the genetics and biochemistry of yeast toward a more generalized understanding of genetic mapping and recombination, mutagenesis, and x-ray sensitive mutants; an evaluation of human cancer risk from exposure to carcinogens and possible modifications to this risk from such factors as demography, age, time of occurance, and the degree of exposure to carcinogens; and examination of light excitation and photochemical energy transfer in both green-plant and bacterial photosynthesis.

Molecular and Cellular Biology of Cancer. The focus of this research is on the biochemical differences between normal and cancer cells, and how they react to their environments. The fundamental mechanisms are approached by studies involving 1) glucose metabolism in chick embryo and other cells in cultures, 2) biological effects of environmental pollutants by testing in cultures, 3) regulation of growth in cultured cells, 4) the properties of cell membranes in culture, and 5) characterization of human mammary epithelial cells in culture.

Molecular Biology of Nerve Cell Function. The focus of this research is on the response of the nervous system to environmental and chemical stimuli. The four principal tasks undertaken are 1) studies using selected toxins as probes (particularly in the mammalian central nervous system), 2) the influence of drugs on brain chemistry (with emphasis on the neurochemical steps of long-term memory function in the brain), 3) brain changes associated with brain stimulation, and 4) the recovery of function after brain damage.

Biophysical Chemistry. This program utilizes biophysical techniques, including magnetic resonance, optical studies, x-ray spectroscopy, theoretical modeling, and chemical synthesis to study fundamental processes of membrane cells, nucleic acids, proteins, and nerves. Emphasis is placed on 1) the role of biological structure on the process of energy transduction in photosynthesis, 2) the way in which nucleic acid structure and organization influences its role as a repository and transmitter of cellular information, 3) the role of membranes in energy transduction, and 4) specific steric requirements related to the action of enzymes and other controlling factors in cellular

regulation. The results are applicable to problems of solar energy, carcinogenesis, drug-membrane interactions, DNA replication, and damaging effects of pollutants produced from fossil fuel combustion and from nuclear energy production.

Elucidation of the mechanism of photosynthesis at the molecular level will facilitate improvement of crop and energy yields in agriculture. It will also provide the understanding necessary to design light-to-energy transducers based on the biological model. This work could lead to production of energy in a directly usable form from sunlight by using such devices on a large scale. These would have the additional advantage of promising to achieve these ends with fewer complications from pollution, disposal of byproducts, or exhaustion of natural resources.

Biochemical Studies, One study seeks to understand the processes involved in initiation and propagation of environmental damage to mammalian cell membranes. The investigation focuses on how damage is spread intracellurarly and which metabolic activities are most affected. Research is proceeding on the effects of several oxidants, namely oxygen species produced by visible light activation of endogenous membrane photosensitizers and ozone, which is believed to be the most damaging pollutant in the urban environment.

Another biochemical investigation addresses the goal of improving the bioproductivity of large-scale culture systems of bluegreen bacteria, to enhance ammonia and food production. Several species of algae are being examined in studies of the functional relationship between hydrogen consumption, nitrogen, fixation, and photosynthesis in these organisms.

Bio-Organic Chemistry. In this area are studies of the paths by which kerogen is formed in the earth's crust from decaying green plant material subjected to geologic forces (forming fossil fuels); the origin of biopolymers, relating to the probable biochemistry of the prebiological earth by which the first living cell came into being; the study of energetic carbon chemistry with ^{14}C beams as tracers; and improved tritium labeling for biomolecules through study of the mechanics of triton uptake.

Biomedical Applications (HK 01 02)

Medical applications of nuclear technology continue to be a significant part of the Laboratory program. Emphasis is on development of new diagnostic techniques for detection and quantification of disease. Methods with potential application in the diagnosis and treatment of disease arising from exposure to environmental pollutants are a particular concern. Primary diseases under study include cancer, cardiovascular and pulmonary disease.

A major constituent of LBL biomedical programs is the Bevatron/Bevalac, the only facility in the world where heavy ion beams are produced and investigated for therapeutic applications. The Bevatron/Bevalac Biomedical Operations Project is currently directing its principal focus on initiation of full-scale patient therapy trials. In support of this objective are ongoing radiobiology and dosimetry studies to provide precise evaluation of the physical and chemical interactions of heavy ions with biological systems. The advancement of heavy ion radiodiagnostic techniques is an associated goal served by the project, as are space biology studies aimed at characterizing the potential hazards of heavy cosmic rays.

The Research Medicine Clinic is continuing its long-term follow-up of patients exposed to or treated with ionizing radiation, as well as developing instrumentation and research techniques by use of animals. These techniques will be applicable to the study of environmental agents as they affect man. The LBL Metabolic Ward provides a safe, controlled environment for the performance of investigative endocrine and matabolic testing on tumor patients. The acute and long-term effects of localized heavy ions on normal tissue as well as pituitary tumor tissue will be derived from this population. High energy 910-MeV alpha particles are used successfully to control pituitary hormone secretion and reduce the morality and morbidity of acromegaly, Cushing's disease, Nelson's syndrome, and more recently, prolactin-secreting tumors.

Development of radionuclides and radiopharmaceuticals for scintigraphic and dynamic quantitative physiological studies continues. Three-dimensional reconstruction of the organ distribution of injected or inhaled material is facilitated by new instrumentation and computer applications. Specific applications include the study of flow and metabolism in the brain, heart, lungs, kidneys, and bone marrow.

The project involving irradiation of pituitary tumors with heavy ion particles is the parent program for the use of heavy ions in the treatment of cancer. With the use of helium ions or other heavy particles, it has been possible to overcome the relative insensitivity of the pituitary to externally delivered radiation, without irradiating the hypothalamus and large volumes of surrounding brain tissue. This project has provided data on acute and long-term effects of heavy particles on normal and tumorous tissues and has made significant contributions to the understanding of the endocrinopathies associated with the pituitary.

The feasibility of using high-energy radioactive beam particles for diagnostic procedures is being investigated. Even though human patients will not be involved in these studies, various types of phantoms (similating bone, tissue, air, fat, etc.) will be used for practical demonstration. The technique uses high-energy radioactive beams and a gamma-ray coincidence detector device. The immediate problem of interest is the localization of a Bragg ionization peak in a heterogeneous medium such as human tissue. Later, this method can be easily extended

to diagnostic procedures such as local blood circulation rate in a microregion, or to examine heart valve action.

New knowledge of human biochemistry in disease and health is being sought that directly bears on our understanding the effects of the environment of man, in particular a method for assessing the biological impact of increased use of fossil fuels and other methods of energy production including the effects of magnetic fields, as well as new methods for nuclear medicine. The methods employed involve three-dimensional reconstruction of the organ distribution of injected or inhaled material at various times after administration.

As the major site of damage from gaseous pollutants, the lung is being studied with respect to immune system response, effects on lung pathology, and blood-borne effects on other organs. These studies will not only advance understanding of the basic growth and regenerative processes in the normal and damaged lung, but an immunologic method for assessing the magnitude and type of pulmonary damage in the human population may derived.

Another study suggests that atherosclerosis may have a mutational origin, with environmental chemical pollutants being a possible cause.

ENERGY SUPPLY TECHNOLOGY RESEARCH AND DEVELOPMENT

DOE: A/S Energy Technology (ET)

COAL

Coal is the nation's most abundant and versatile fossil energy resource, from which virtually every means of delivering energy can in principle be derived. Before coal can fulfill its potential to be one of the nation's principal energy resources, however, economically sound ways must be found to convert solid coal to more convenient and environmentally cleaner liquid and gaseous fuels, as well as to use solid coal in a manner consistent with acceptable levels of environmental and health risks. Research at LBL focuses on both of these areas.

Mines Research and Development (AA 01)

Coal Desulfurization. Coal combustion is the largest single source of sulfur dioxide pollution. To the extent that efficient and economic methods can be developed for removing sulfur from coal, the need for post-combustion stack gas cleaning will be lessened. The LBL coal desulfurization project applies basic physical and chemical methods to the study of coal desulfurization to help build an adequate scientific base for technology development.

Liquefaction (AA 02)

The goal of this activity is the development of new processes and supporting technology for the conversion of coal into liquid fuels. Projects are: (1) identification of new liquefaction catalysts and processing conditions, (2) characterization of chemical changes occurring during coal processing, (3) evaluation of the erosion-corrosion behavior of materials used for liquefaction processes; and (4) the separation of pyritic and organic sulfur prior to liquefaction.

Gasification (AA 03)

De-ashing of Solvent Refined Coal. The objective is to develop basic process and bench-scale equipment for solids removal from solvent-refined coal/unfiltered oil, by means of agglomeration in electrical fields and electrostatic deposition.

Waste Water Purification. The objective is to develop, evaluate and compare methods for processing and treating process condensate and related waters from coal-conversion processes, with the goals of (1) devising feasible processes, (2) reducing process cost, (3) minimizing net plant water consumption, (4) minimizing pollutant loadings of waters released to the environment, and (5) recovering valuable chemicals, such as ammonia and phenol, economically and in the most marketable form.

Removal of H_2S from Low-Btu Gas Streams. This project will deal with development of economic processes to prepare low-Btu gas with H_2S removed before combustion.

Interfacial Properties of Coal. This project deals with surface chemistry and physical properties with respect to coal cleaning and combustion.

Direct Combustion (AA 05)

Exploratory studies on the mechanisms of coal burning have been initiated at LBL, with the objective of allowing direct combustion with fewer pollutant emissions. Study is being undertaken of the spouted fluidized bed combustion system which has the unique capability of providing for the combustion of fuels over extreme ranges of mixtures, well beyond the normal lean and rich limits of flammability.

Advanced Research and Supporting Technology (AA 06)

Coal Liquefaction Alloy Test Program. In this project the behavior of materials used in the flow passages of coal liquefaction systems will be studied under simulated operating conditions.

NMR Determination of Coal Structure. Nuclear magnetic resonance (NMR) is being applied to the analysis of solid coal. This technique provides a non-destructive method for identifying chemical changes in the coal structure produced by processing.

PETROLEUM

Through the next several decades, oil-based fuels will be essentially the only source of energy for transportation; therefore liquid fuel demand will probably continue to increase. The supply of fluid fuels will be essentially critical between 1985 and 2000. The national energy R&D program should assist in maintaining domestic oil production by developing techniques for advanced recovery and by accelerating exploration of new sources; by developing economically sound methods for deriving synthetic fluid fuels from coal; by investigating production of liquid fuels from oil shale; and by developing programs for the understanding and mitigation of the ecological and health impacts of these technologies. LBL research programs cover all these areas.

Enhanced Oil Recovery (AB 01)

Enhanced Recovery with Mobility and Reactive Tension Agents. This project is concerned with chemical processes for enhancing oil recovery from underground sources by flooding these sources with emulsion-producing chemicals that lower interfacial tension and improve mobility.

Oil from Oil Shale (AB 02)

Partitioning of Trace Elements During In-Situ Oil Shale Retorting. Extraction of oil from shale deposits will create heavy demands for water in arid regions, and will severely stress water quality. This program addresses the water problem by: 1) determining the distribution of major and minor elements in shale oil, process water, offgas and spent shale as a function of retort operating conditions, and 2) identifying and quantifying the organo-metallic species of Hg, As, Se and Sb released to retort waters and offgases during gaseous emissions from an in-situ retort. The data developed will be used to assess the environmental impacts of a field in-situ operation.

SOLAR ENERGY FOR FUELS AND POWER

Solar energy will eventually be able to provide each of our needed energy forms: heat (plus cooling), fuels, and electricity. A major objective of the national solar energy R&D program should be assessment of the potential of solar energy in each of these areas so that it can be realistically compared with other long-term sources as these comparisons become necessary.

This assessment requires research of three kinds: (1) basic research to build a solid scientific base for economic solar technology, (2) development and assessment of a variety of solar-based technologies, and (3) assessment of the environmental, health, and socio-political impacts of solar energy development.

The Laboratory's programs encompass all of these elements, and are being carried out in these subject areas: (1) ocean thermal electricity generation, (2) central tower solar electricity generation, (3) photovoltaic electricity generation, (4) cooling of buildings, (5) control systems for solar installations, (6) solid-state engines for converting heat to work, (7) evaluation of passive solar systems for heating and cooling buildings.

Technology Support and Utilization (AD 02)

Environmental and Resource Assessment (AD 02 01)

Ocean Thermal Energy Conversion. This project addresses the environmental impacts of Ocean Thermal Energy Conversion (OTEC). The principal work thus far has been the development of a bioecological program plan for the Environment and Resource Assessments Branch of DOE's Division of Solar Technology. When complete, the plan will summarize existing bio-ecological knowledge, integrate data from ongoing OTEC projects, identify topics for future research, and provide engineers with bio-ecological criteria by which to judge if a plant can be operated within environmental regulations. Future efforts include participation in a program to evaluate potential OTEC sites, and technical monitoring of similar work of other institutions.

Solar Electric Applications (AD 03)

Circumsolar Radiation. The objective of this project is to provide measurement of the circumsolar (around-the-sun) radiation as input to considerations of the performance of solar energy systems employing concentrating collectors (mirrors or lenses). Four instrument systems have been constructed and are obtaining data at various locations of interest to DOE's concentrating collector program. In the future these data will be incorporated into detailed computer simulation models of specific concentrating designs. Correlations will be established between the circumsolar radiation and other solar and meteorological parameters.

Photovoltaic Conversion. Study is being made of the Cu_xS - (Cd,Zn)S heterojunction for the purpose of providing insight for its possible development as a practical solar photovoltaic converter. Analysis of the current-voltage characteristics of this heterojunction will be carried out with mathematical modeling techniques. Single crystal heterojunctions will be fabricated to obtain data on the behavior of the junction without the complications introduced by the effects of grain boundaries in polycrystalline materials. Future efforts include the development of device fabrication procedures and the comparison of single crystal and poly-crystal cell characteristics.

GEOTHERMAL ENERGY

Engineering Research and Development (AE 01)

LBL strategy is to assist in the commercial utilization of hydrothermal (liquid dominated) geothermal resources through earth sciences and engineering, engineering design and development of wellhead systems, program management for various joint projects, technical liaison with the geothermal industry, and development of a geothermal data base.

The major technical programs arising from this strategy are geothermal energy utilization, exploration technology, reservoir dynamics, geochemical engineering, and environmental impact studies as described below. LBL has been assigned lead responsibilities in the areas of binary systems development, hydrothermal reservoir engineering, and subsidence mitigation investigations.

Utilization Technology (AE 01 02)

The LBL program in binary cycle studies is to develop a general thermodynamic cycle simulator for the analysis of energy conversion processes, develop design and economic information on direct-contact heat exchange, conduct field tests of conventional heat exchangers, and develop basic heat transfer data on binary cycle working fluids.

LBL's reservoir engineering and power plant engineering personnel will work with DOE and DOE's contractor for the Geothermal Demonstration Plant to enhance the chances for success of the demonstration. LBL personnel will take part in the Geothermal Loop Experimental Facility (GLEF) project and other DOE projects as requested. Data reduction and management for the GLEF will be continued. A reservoir and plant performance program for the Demonstration Plant will begin in FY 1980.

Resource Exploration and Assessment (AE 02)

Magnetotelluric Investigations. This project is to develop new instrumentation, data acquisition, data processing, and interpretation techniques for the magnetotelluric method; applying these developments specifically to geothermal exploration problems, and transferring the technology to industry.

Electrical and Electromagnetic Modeling. The main objective is to develop, test, and disseminate to industry and other researchers more efficient, more accurate, and more generalized computer programs for the analysis and interpretation of electrical and electromagnetic survey data. These programs are needed for geothermal reservoir exploration and assessment involving the use of surface electrical and electromagnetic techniques, and must therefore be capable of dealing with numerical analogs of the complex geologic settings typical of many geothermal reservoirs.

Passive Seismic System Development. This project is to design, fabricate, and test a passive seismic system with the capability of accepting and processing, in the field, seismic signals from a large number of geophones. The desired system would be a cost-efficient means for geothermal reservoir exploration and assessment.

Controlled-Source EM System. This project is to design, fabricate, and test a controlled-source electromagnetic surveying system useful to the geothermal industry, particularly where existing natural field and galvanic resistivity techniques are not feasible for technical or economic reasons. The system would provide a basis for a rapid technique for exploring from the surface to large depth in areas of rugged terrain, high surface resistivities, and/or high cultural noise.

Reservoir Analysis (AE 02 02)

Coso Hot Springs. A geothermal well was completed with well casing cemented to about 3400 ft. The hot portion of the well will be tested and the analysis of the recompletion and well test results will be used to assess further the reservoir potential.

Niland. It is anticipated that LBL will continue to assist DOE/DGE in acquiring and analyzing temperature and heat flow data bearing on definition of the SSKGRA in the offshore area. LBL will assist in writing a pass-through contract for such work in the event that LLL elects not to pursue this task. Furthermore, LBL expects to continue efforts to encourage the application of LLL's expertise in scaling and corrosion, acquired from experience at Niland, to other areas.

East Mesa. LBL will assist Magma Power Company, Republic Geothermal Company, and others in well testing and analysis. Work will be performed on developing techniques and hardware for conducting hot geothermal measurements such as: flow measurements in two-phase optimum use of tubing fluids, fluid sampling, and analysis. Computer calculations will be used to examine the hydrological behavior of the reservoir during production and injection of fluids. Chemical sampling will be used to determine the stratification and compatibility of fluids in different portions of the reservoir.

Cerro Prieto. Well tests and geophysical surveys will be continued to define the preliminary models of the field and to monitor the reservoir behavior as the exploitation of the production area progresses and new areas are developed. Studies will begin on methods to ameliorate silica precipitation from the separated brines and reduce scaling in the surface installations. The reinjection of brines will be analyzed from the chemistry and reservoir-engineering points of view. Data collection, data interpretation, model development of the field, and coordination of DOE activities in the area will continue.

ENEL/DOE. In FY 1978 the effects of solution-gas chemistry will be studied by expanding the computer program capability to include these effects. This is very important for geothermal analyses since many geothermal systems have high CO_2 contents in the early life of the reservoir. The Serrazzano and Castelnuovo simulation problems will be rerun, and the physical effects of gas liberation in geothermal systems will be studied.

Raft River. In order to develop the Raft River geothermal reservoir, improved understanding of the reservoir parameters and geometry through injection, production, and interference tests on existing as well as planned wells is necessary. This is to be achieved by giving top priority to hydrodynamic tests conducted in parallel with the drilling program. The tests and the interpretation are to be carried out by INEL. LBL will provide technical quidance to DOE in the design, contract, and interpretation.

Hydrothermal Technology Applications (AE 03)

Well Test Analysis

LBL is applying its multiple-well variable-flow well testing analysis method to data from one or more observation wells as influenced by one or more production wells. Parts of this project are analysis of variable-flow production wells as influenced by vertical fractures that intersect the well, and gathering data from geothermal resevoirs by test well methods.

A study will be made of the fluid flow in wells, which is important in the model of a geothermal reservoir. The transient response of the fluid, including compressibility, friction and heat losses, will be modeled.

Further work on the coupling of mass thermal transfer in a geothermal reservoir with simplified chemical precipitation phenomena will be done to understand their role in reinjection.

Reinjection and Optimization of Heat Recovery. Various schemes for injection and production well distributions and flow rates will be studied including applications of the screening concept wherein some wells may be screened from the reinjected colder water by selected well arrangements. We will also study the possibility of maintaining constant production temperature by mixing water from several production wells.

Geochemical Engineering. Because of economic and technological factors, it is possible that the first hot brine resource to be commercially exploited in the United States will be of the high temperature, low to moderate salinity type and that a flash steam cycle will be employed. Such a development would very likely utilize brine whose chemistry resembles that of the brine at Cerro Prieto and would employ

power plants of the surface condenser configuration that has been developed at The Geysers.

We propose to anticipate such a development's need for detailed chemical information by studying the brine chemistry of Cerro Prieto and the power plant chemistry of Geysers Unit 15 (the first of the surface condenser-equipped power plants). This work would be in support of the ongoing chemical research projects of CFE, IIE, and PG&E.

Subsidence Research. The ultimate goal of geothermal subsidence research is to control or mitigate potential displacements within predictable limits, as they relate to naturally occurring and man-made movement. Successful subsidence research will assist in 1) the means to develop and operate a geothermal facility within predicted degrees of subsidence related to the geothermal energy utilization, and 2) the basis for judgment as to project feasibility. The methods developed will be useful for monitoring geothermal subsidence.

FUSION

As a potential source of electricity, nuclear fusion has a resource base probably greater than that for fission with breeder reactors. However, fusion is much further from technological or economic feasibility than either the breeder or solar electricity generation, and scientific feasibility must first be demonstrated.

The LBL program in fusion has three components:

- Development of systems for large experimental fusion devices, to initiate the hot plasmas by injection of neutral particle beams.
- Exploration of a new concept in magnetic confinement, the toroidal magnetic cusp (TORMAC).
- Theoretical studies on magnetic confinement and heating, and on relevant atomic processes.

Magnetic Fusion (AF 01)

Confinement Systems (AF 01 01)

LBL is engaged in the design, fabrication and mechanical check out of the Doublet III Neutral Beam Injector System in support of the magnetic fusion reactor program of the General Atomic Corporation. The three major goals are 1) to provide initial heating on Doublet III in late 1979, 2) to add sufficient injector systems to allow significant heating (hopefully to Lawson conditions) in 1980-81, and 3) to effect transfer of neutral beam technology to industry for fabrication of follow-on injector systems. The project is concentrated on engineering, procurement, fabrication and assembly of hardware for the first neutral beam unit. By FY 1979, final assembly and checkout of this unit will be accomplished. Fabrication of other units (two through six) is expected to commence after bids are solicited by General Atomic. LBL may continue to support General Atomic in a technical liaison capacity beyond FY 1980.

Development and Technology (AF 01 02)

The ductile superconducting wire project is developing a high field superconductor with useful plastic ductility in liquid helium. This project is complementary to LBL research on the cryogenic mechanical properties of structural materials.

Applied Plasma Physics (AF 01 03)

The Applied Plasma Physics project will continue theoretical and experimental studies of atomic and plasma physics which will provide a basic underpinning to the neutral beam and Tormac projects.

The Tormac concept, if successful, will lead to fusion reactors that are smaller and less expensive than Tokamak reactors.

It is assumed that scaling tests will be successful so that the Tormac concept can be reclassified as an accepted Magnetic Confinement System in FY 1981. This would lead to a reduction in the support for Tormac under the Applied Plasma Physics projects, and an initiation of support under the Confinement Systems subprogram. the major portion of the Tormac program after FY 1980 will consist of the construction and operation of Tormac VI. This device will be designed to produce and confine a reactor-grade plasma ($n = 10^{14}$, $T = 10$ keV) for a meaningful time as a test of Tormac scaling, and thus permit the design of a test reactor experiment.

LBL is also working on basic plasma theory for application to MFE in the related areas of stochasticity, wave interactions, and lie transforms.

The major part of the MFE effort at LBL is concerned with the development and application of high-energy neutral beams for heating and fueling plasmas in fusion experiments, to meet specific needs of users such as MFTF, TMX, and TNS. Primary goals in the neutral beam program are achievement of long, multisecond pulses, and eventually, DC operation; the improvement of electrical efficiency and gas utilization; and extension to higher energies, possibly into the MeV range.

Reactor Projects (AF 01 04)

LBL is developing the neutral beam system to be utilized on the TFTR at Princeton Plasma Physics Laboratory. The TFTR (Tokamak Fusion Test Reactor) is the major fusion research reactor project funded by DOE. The TFTR is to demonstrate fusion equilibrium per the Lawson criteria in the early 1980's, and TFTR relies on four of LBL's neutral beam systems for energy injection.

The four neutral-beam lines will introduce high-energy deuterium atoms into the torus at a major radius which can be varied from approximately 2.1 to 2.7 meters (6.9 to 8.9 feet). Two beams will inject the atoms in the direction of the plasma current and the other two in the opposite direction. Space is available for two additional beam lines.

The total length of each of the four beam lines is about 9 meters (29.5 feet); the height is 6.5 meters (21.3 feet) and the width 2 to 4 meters (6.6 to 13 feet). The beam is only slightly divergent as it enters the vacuum vessel through an opening 0.7 meter (2.3 feet) by 0.4 meter (1.3 feet).

The high-energy deuterium atoms begin their flight at three separate ion sources per beam line. Here the deuterium is ionized and accelerated by a voltage of 120,000 volts to full energy (120 keV). The ions (D^+) are then neutralized by "charge exchange" as they pass through a chamber containing neutral deuterium (D^o) at low energy. This process is represented by:

$$D^+(\text{high energy}) + D^o(\text{low energy}) \rightarrow D^o(\text{high energy}) + D^+(\text{low energy})$$

The high energy neutral atoms formed are injected into the plasma, where they are subsequently ionized, and the low-energy ions are removed by a magnetic field into an "ion dump."

An accompanying beam of half-energy 60-keV and third-energy 40-kev atoms also enters the plasma. This beam originates at the ion source where some of the deuterium is ionized in molecular form (D_2^+). These ions are also accelerated to 120 keV, but during neutralization the molecular forms produce neutral atoms, each with only 40 or 60 keV of energy.

The prototype beamline is designated the Neutral Beam System Test Facility (NBSTF) because of the development character of the prototype, which will operate at higher power levels (up to 5 megawatts) than any previous neutral beam. The neutral beam design goals are 120 kV, 65 A, 0.5-sec pulse every 5 minutes, and 20 percent of accelerator grid power to be delivered to the plasma as deuterium neutrals. Neutral beam development work at LBL in FY 1978 indicates that these values will be attained with the NBSTF.

Design and fabrication of the NBSTF will be completed in FY 1978, and assembly, checkout and initial operation of the prototype beamline will be accomplished in the first half of FY 1979. The second half of FY 1979 and all of FY 1980 will be devoted to the operating phase of the NBSTF. This will consist of comprehensive testing of the prototype beamline in addition to demonstration of the source capabilities. Concurrent with the prototype beamline operations will be an extensive training program for the Princeton personnel who will operate the four TFTR beamlines. LBL will also utilize the highly instrumented NBSTF to "condition" and acceptance test the ion sources which will be used on the TFTR beamlines.

The major subsystems and support systems which are parts of the NBSFT are the vacuum enclose (52 m^3), the cryopumping systems (2.5×10^6 ls^{-1}), the sweep magnet (0.25 T), the beam dump and neutral beam calorimeter (1.8 $kW\text{-}cm^{-2}$), the ion sources (120 kV, 65 A, 0.5-sec pulse every 5 min), cryogen supply and recovery system (helium, 80 lh^{-1} 400 W maximum), shielding (824,000 kg), controls and diagnostic systems to provide automatic beamline control, and site support systems consisting of a control room, a roughing vacuum system and a cooling water system. The NBSTF will utilize a cryopumped target tank to simulate the toroidal plasma containment vessel of the TFTR.

The NBSTF power supply arrangement differs from that being planned for TFTR. The NBSTF power supply is a low risk option chosen because 1) it uses existing tubes in the regulator; 2) it is a straightforward extension of similar successful techniques now in service at LBL, and has a demonstrated capability for long-pulse, multi-megawatt operation at 120 kV.

LBL will also provide design and purchase information to Princeton to facilitate the procurement of the "production" beamlines for the TFTR. LBL is working with industrial suppliers to ensure that there is sufficient transfer of technology to industry to permit competitive bidding for the "production" equipment to be installed at Princeton.

The NBSTF will be a highly significant development advice for the high energy neutral beam technology, and also a significant contribution to the national fusion energy program. Furthermore, most of the NBSTF support systems and all of the knowledge gained in design, fabrication and testing of this major facility will remain available to LBL for application to future neutral beam and fusion energy research and development programs.

Inertial Confinement Fusion (JF 01)

The basic objective of this program is to establish the most suitable design of a heavy-ion accelerator system as a driver for inertial-confinement targets on a power plant scale. In addition, in pursuit of that goal an orderly sequence of intermediate steps needed to demonstrate convincingly the feasibility and the value of accelerator technology must be identified and carried out. Some of these steps are part of the ongoing and proposed R&D program, but ultimately a large-scale Heavy Ion Demonstration Experiment (HIDE) will be required in the early 1980s to provide a test-bed for a later pilot-plant with net energy gain.

There is a high degree of confidence that a heavy-ion accelerator system will satisfy the scientific needs of a power-plant driver. The suitability of the energy-deposition profile of the ions in the target is in little doubt, and achievement of a large stand-off distance and the proper propagation of the beam in the reactor vessel seems quite tractable. There are, however, missing pieces of design information which must be fitted in to arrive at a credible design and cost estimate.

The accelerator systems under study can be broadly categorized into three classes according to the device that supplies most of the energy to the beam, viz., radio-frequency (rf) linac, synchrotron, and induction linac. The first two will require a combination of rf linacs arranged in a tree-like structure as a front-end low velocity injector. While the induction linac might employ a similar system of rf linacs feeding a low-energy accumulator ring, an injector based on pulsed power technology (e.g., pulse drift-tubes) would be a simpler solution and would be a much better match to the properties of the induction linac.

The program at LBL, in close coordination with the programs at ANL and BNL, follows these areas.

- Conceptual design, systems, and cost studies
- Subsystem hardware development
- Generation, acceleration, and transport of high-current heavy-ion beams
- Theory in support of above areas

FISSION

Nuclear Research Applications (AG 04)

Waste Storage.* The waste storage program is designed to assist in the development of a safe, licensable, and publicly acceptable underground nuclear waste repository through determination of rock response, property measurement, instrumentation and technique development, and through assistance in planning and problem identification. Long term plans include further assistance through the development of field survey and testing techniques and equipment, actinide migration studies, systems analysis, expanded in-situ programs, and the development of major new laboratory measurement programs.

The major current technical programs consist of two projects; one at the Stripa mine in Sweden and one at the Hanford Waste Isolation Project. The program at the Stripa mine is an attempt to measure the response of a large in-situ rock mass to the anticipated high thermal loading. Hydrological, geophysical, laboratory and in-situ stress measurements will be made before, during, and after the experiment.

The project at Hanford is essentially a duplicate of the Swedish experiment, differing only in that the location is in basalt instead of granite.

As the basic in-situ heater experiments develop the necessary data, new research efforts will be required to apply these results and to investigate areas not considered to date. As an example of the work required for application, it will not be feasible to repeat the whole in-situ experiment for every repository site under consideration. An area of interest for both the repository development and the geoscience community in general will be the development of techniques that can test the rock response from the surface.

Other examples of areas to be investigated are actinide migration and rock properties. Techniques need to be developed and results obtained with regard to actual in-situ migration and absorption of actinide isotopes in the event of a failure of other barriers. Attempts to measure basic rock properties during the waste storage projects have made clear the need for more advanced property measurement techniques. Both the Swedish and Hanford projects require development of new instruments and field testing techniques. As the basic in-situ experiment techniques are perfected, it is anticipated that more effort will be devoted to such research. Such research will eventually be important for repository monitoring. Similarly, new types of rock-property measurement are being made at LBL, and this work should expand in the future.

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*This project is funded by DOE reconciling transfer, see work for others. See also Chapter V.

Advanced Isotope Separation (AG 04 08)

Resource availability poses a potential major constraint on the expanded U. S. use of nuclear power. Therefore it is important to investigate ways to increase the efficiency of fuel use in all parts of the nuclear fuel cycle. The development of advanced techniques for isotope separation could make possible more efficient use of uranium ore, by increasing the efficiency and economy of uranium isotope enrichment.

Selective photochemistry research at LBL is aimed at the demonstration of new laser isotopes separation (LIS) methods and the development of the fundamental research base required for the use of new and existing laser isotope separation techniques.

Isotope separation techniques under study at LBL include:

- Multiphoton dissociation of polyatomic molecules.
- Selective dissociation of van der Waals molecules.
- Chemical reactions of selectively excited molecules.
- Selective condensation of molecules.

The LBL program uses unique crossed molecular and laser beams to study isotope separation. This approach avoids molecular collision and chemical reactions which often confuse the experimental results.

The LBL LIS Group has recently made important contributions to the understanding of multiphoton dissociation of polyatomic molecules.

BIOMASS

Fuels from Biomass (AJ 01)

Agricultural and wood wastes constitute a potentially significant national energy resource. Were all the nation's municipal waste and one third of its agricultural waste to be processed for this energy, about 5 quads per year would be obtained (about one third of present coal production). Toward this end LBL is studying the feasibility of cultivating plants for their hydrocarbon yield, the possibility of genetic engineering for increased yield, and biological process development for conversion of plant cellulose to liquid fuels. The laboratory is also assisting DOE in assessment of a pilot biomass liquifaction facility.

Hydrocarbons from Plants. This project involves cultivation of hydrocarbon-rich crops to determine the feasibility of producing fuels and chemical feedstocks. Since many such plants have never been cultivated or studied with these ends in view, various kinds of basic information and methods must be sought, such as (1) crop yields and the effects of various growing conditions, (2) cultivation and harvesting techniques, analytic methods for selecting suitable plants and analyzing their constituents, chemical processes for conversion of the hydrocarbons to useful forms, and the economics of each of the alternatives resulting from such development.

Biological Process Development. This project is directed to production of liquid fuels (mainly ethanol) by enzymatic conversion of the carbohydrate content of plant cellulose, especially from agricultural and forest-product residues. As the product of photosynthesis, this carbohydrate is a form of stored solar energy. Research into relevant basic problems is being conducted, as well as investigation of a number of processing concepts for production of cellulose enzyme and ethanol fermentation.

Major new objectives include development of an economic method for removing lignin from cellulosic materials to enhance enzymatic hydrolysis, development of methods to increase cellulose accessibility without lignin removal, development of more powerful mixed-enzyme systems, development of an effective xylose fermentation, and optimization of ethanol production processes.

Albany Biomass Liquefaction Facility. The purpose of this Bechtel-operated facility is to obtain definitive process information, sufficient for commercial design purposes, on the conversion of biomass to syncrude. Tasks to be performed by LBL are: (1) formulation of experimental program, (2) evaluation of experimental results, (3) evaluation of plant configurations and process flowsheets, (4) economic feasibility review, (5) evaluation of supporting research and analytical activities, (6) review of related programs on biomass conversion, and technical assistance to DOE in the preparation of RFPs.

ENERGY STORAGE

Achieving widespread and economic application of energy-supply technologies based on intermittent resources (such as solar electric systems) requires the development of inexpensive and efficient energy storage technologies.

Energy Storage (C8 01)

At LBL, chemical methods of storing energy are being studied. One investigation deals with an SO_3/SO_2 system which absorbs heat at a high temperature and releases the heat at a lower temperature. Design work has concentrated on optimizing flowsheet patterns for this process. Comparisons are being used with other chemical systems and with conventional methods of storing sensible or latent heat.

A technical program has been initiated to provide basic engineering-science background for the development of economical electrochemical processes, not limited by the efficiency of a Carnot cycle, for electrochemical energy storage and conversion.

ENERGY DEMAND AND END-USE

DOE: A/S Conservation and Solar Applications (CSA)

BUILDINGS

The buildings sector consumes about 30% of U. S. primary energy, or about 23 quads in 1976. Many opportunities exist for increasing the efficiency of primary energy-resource use in this sector. These include a wide variety of design improvements as well as passive and active solar heating and cooling systems. LBL is involved in R&D activities of both kinds.

SOLAR ENERGY

The LBL solar-energy program for buildings encompasses varying application-oriented research, development of innovative devices, and technical support of the DOE Solar R&D Program.

The evolution of LBL's solar energy program over the next five years will include ending some projects as the results of technological development are transferred to the emerging solar industry. New efforts will also be initiated that will respond to and, in turn, influence the direction of the national program. The Laboratory also expects to play a continuing technical support role.

Thermal Applications (AD 01)

This project involves designing, fabricating and testing absorption chillers suitable for solar cooling applications. The effort to date has involved the use of ammonia-water absorption cycles. The program is directed toward developing advanced versions suitable for production by the air-conditioner industry.

Heating and Cooling of Buildings (AD 01 01)

Electronic Controller Development and Testing. The performance of multi-component solar heating and cooling systems can be improved by controlling their operation with inexpensive but sophisticated micro-electronics. At LBL an experimental system (collectors, storage tank, space and hot water heater, air-conditioner) has been constructed to simulate a variety of loads and weather conditions. This system will be used to test an electronic controller developed at LBL, and to evaluate commercially available controllers.

Nitinol Engine Development. This project is investigating the feasibility of using a "shape-memory" alloy (Nitinol) for conversion of heat energy to work by means of solid-state heat engines. Prototype engines have already demonstrated the principle and at present, several experimental testing efforts are proceeding. A primary milestone is the development of a Nitinol engine capable of driving a moderate-sized residential air conditioner with solar heated hot water. Other

promising applications for such engines include irrigation pumping, ocean thermal energy conversion, and utilization of waste heat.

Passive Systems Analysis. In the "passive" approach to solar heating and cooling, architectural design, construction materials, and the environment are used to moderate the interior climate of buildings. In collaboration with Los Alamos Scientific Laboratory (LASL), LBL is developing computer programs to evaluate new passive designs, and for determining applicability of existing designs to various climates.

Radiative and Passive Cooling. A process is being studied whereby heat storage materials would be cooled by radiation to the night sky, then provide "coolness" to the building the next day. Its efficacy depends upon the transmission properties of the atmosphere in the infrared region, which depends in turn upon atmospheric variables such as precipitable water content and aerosols. This is being studied by computer techniques as well as by measurements involving infrared sky radiometers. The program will allow the performance of candidate systems utilizing radiative, convective, and evaporative cooling to be predicted.

Heating and Cooling Demonstration Program (BD 01)

LBL provides technical support to DOE's Solar Heating and Cooling Demonstration Programs in: (1) design review, project liaison and monitoring for commercial, hotel and motel demonstration projects; (2) design and engineering for LBL Solar Demonstration projects; and (3) technical review of proposals for DOE Solar Research and Demonstration programs.

Buildings and Commercial Systems (C3 01)

Performance Standards (C3 01 02)

Building Envelopes and Ventilation (BEV) Program. This LBL program is identifying areas in the physical structure of buildings as well as the heating, ventilating, and air-conditioning systems where modification in construction and/or operation will result in cost-effective energy savings while not interfering with the design use of the building. In buildings alone comfort levels can be maintained while energy consumption is reduced by 40-60%, at little or no increase in first cost.

It is generally understood that conduction losses in building envelopes can be greatly decreased with insulation; therefore, the next major areas to address are conduction losses through windows and the energy required to heat fresh air. In residences, fresh air typically comes as "infiltration" through cracks in the building envelope (including windows and doors). The infiltratrion rate averages 0.5 to 1.5 air changes per hour and accounts for one third of the energy use of an insulated home. There is great interest in building (even requiring) tighter residences, and goals of 0.3 air changes per hour are frequently stated. However, combustion products from gas stoves are already often above tolerance levels in existing homes, therefore reduced fresh air may lead to problems with moisture, mold, odors, chemicals outgassed from building materials and plastic, and radioactivity from radon in concrete and water.

The LBL BEV program conducts experiments with tighter homes, and also studies the mechanical introduction of fresh air and recouping of heat from exhaust air streams. In order to make optimum tradeoffs between energy conservation and indoor air quality, studies are also being carried out on indoor pollutants and their control.

The LBL BEV program is examining specific building retrofits as well as new design, construction and operating features that are cost-effective and can be implemented by the building community. As cost-effectiveness and energy-saving potential of program results are verified, they are compiled in an updatable computer-based center. Reports, tailored to best strategies for different U.S. regions, will be issued regularly and results will be conveyed to the design and building community by seminars and other media. The data and experience collected by the program will enable governmental agencies to establish and update energy-conserving standards for buildings and appliances.

DOE-1. The Laboratory has developed a cost-effective computer program in which a variety of building types are modeled so that energy use of buildings can be analyzed or predicted. Building designers can use this program as a tool in adjusting parameters to determine the building configuration of minimum energy usage while satisfying design requirements. The program is in the public domain and is currently being implemented on a nationwide time-sharing network.

DOE-1 already treats solar collectors and thermal storage in water-tank and rock beds on the same basis as conventional building components. Passive solar features are now being added. DOE-1 will then be a unique program in that trade-offs among improved thermal integrity, active solar collectors, passive solar designs, and increased thermal mass can all be made without prejudice, based entirely on economics.

National Program on Windows and Lighting. Under this national program, the Laboratory will plan, arrange and conduct a research, development, and demonstration effort to complement and accelerate the efforts of private industry in fostering the use of energy-efficient windows and lighting. Ten percent of total annual U.S. energy consumption, and much more peak power, is attributable to the use of windows and lighting in buildings. Strategies and programs are being developed that would, if implemented, lead to reductions of energy consumption of 20-60% in existing buildings and 40-90% in new buildings. Analytical and testing capabilities have been developed at LBL to provide neutral third-party judgements on complex technical questions.

The energy-efficient windows program is developing innovative window designs, materials, and accessories and also taking steps to ensure that they are recognized, accepted, and utilized by design professionals and the public. The LBL role encompasses overall program planning and assessment of research priorities, technical management of sub-contracted research activities, and support of in-house windows research.

Lighting consumes about 8% of total U.S. electricity. About 40% of this could be saved by concerted near-term conservation efforts. These results can be expected from a program based upon 1) cost-efficient design practices and products in place of less efficient choices; 2) operation and maintenance of lighting systems consistent with sound energy conservation and economic practices; 3) providing the technology and knowledge for increased use of natural lighting where applicable; and 4) rapid commercialization of new energy efficient products now entering the marketplace. The LBL lighting research program, as part of the national effort, is designed to generate options in all of these areas.

Industry (C4 01)

Engineering Analysis of Gas Evolution in Electrolysis. This project is a study of the effects of free- and forced convection on gas bubble dynamics on electrode surfaces, electrolyte surface coverage, and of velocity profiles in the gas-electrolyte emulsion. An experimental technique will be developed for the detection of surface charge (if any) on bubbles. An experimental program will be initiated to correlate surface morphological features and the chemical nature of the electrode and product gas, with the bubble number density, surface coverage and size at separation, in steady state gas evolution. The

effect of surface charge on coalescence will be further explored. A theoretical model will be advanced for the prediction of the velocity field in gas-liquid emulsions resulting from electrolytic gas evolution.

TRANSPORTATION

Transportation Energy Conservation (C5 01)

LBL is studying catalytic and lean internal combustion as two promising methods of obtaining higher efficiency in transportation prime movers. Results on important aspects of chemical kinetics, fluid mechanics, and surface reactions which relate to the development and use of these types of power systems have been obtained. These results can be used both in assessing the potential of the prepared combustion system technique and in the engineering development of such systems. Work on catalytic combustion should be extended, as there is a serious lack of knowledge of the influence of surface reactions on gas phase reactions in the boundary layer. Ignition, quenching, and heat transfer studies on lean internal combustion engines have yielded valuable information on these processes. To extend these studies, design has started on an improved single cycle engine which will more realistically reproduce the conditions of automobile engines.

The Laboratory is applying to transportation problems its own expertise in electro-magnetic systems and the capabilities of U. C. campus in systems analysis. An integral part of the program is developing participation of industry and state/regional government, and forging a more direct link to the DOE conservation mission.

A program in the transportation area is the development of a dual-mode all electric transportation system (DMET) that uses a combination of roadway pickup and onboard energy storage for personal urban/suburban vehicles. The dual modes of this system are operation using propulsion power provided from the roadway while on high speed arterials and operation using stored energy while on other roads.

Appropriate Technology (C8 08)

LBL has undertaken a role in managing and monitoring the award of grants under the DOE Appropriate Technology program for Arizona, Hawaii, California, and the Pacific Trust Territories.

The objective of this project is to encourage and foster the development and demonstration of small-scale (appropriate) energy technologies. The means of accomplishing this objective is by awarding numerous small grants for those projects judged to be the best proposals received in response to DOE solicitation. Program guidelines encourage projects which: make the best use of available renewable energy resources, are labor intensive, utilize locally available materials, emphasize decentralized technologies, are environmentally sound, and increase community energy self-reliance.

ENERGY POLICY, MANAGEMENT, AND INFORMATION

DOE: Other Activities

Collection and Dissemination (FK 01)

Data Collection and Validation (FK 01 01)

During 1978, the Energy Information Administration (EIA) commissioned validation studies on a small number of selected energy information systems. This work by ORNL, Kindle Corporation and LBL will provide validation reports on approximately 15 data systems out of over 200 such systems for which EIA is responsible. A major component of such validation studies consists of checking the data against comparable information collected from other sources.

We propose to carry out a validation study of a major segment of either the oil or coal fuel cycle of the U.S. The results of relevant validation studies completed in FY 1978 will be utilized in this work. A validation study will also be carried out on a model of the same fuel cycle. This combination of related data bases with already validated data and a model of the same fuel cycle should permit a powerful and coherent validation analysis.

Policy and Program Analysis (KK 01)

Conservation Policy (KK 01 02)

While the current literature on energy policy is replete with references to institutional barriers to energy conservation, there has been surprisingly little systematic work on this problem. The Council on Environmental Quality (CEQ), recognizing this deficiency, has funded a one year project at LBL to begin the development of the needed framework by conducting a review and evaluation of recent work concerning conservation barriers. A number of needs for continuing work have been identified, e.g., a need to maintain an up-to-date bibliography, a need for analysis of specific problems and policies in a broader context, and a need for continuing interactions between a variety of disciplines. Each of these needs is addressed in the proposed work.

Program Direction - Management Support (KN 01)

LBL has proposed a computer program for energy analysis of buildings called DOE-1 (formerly Cal-ERDA). It is expected that DOE-1 will receive wide use at DOE facilities beginning early in 1978.

Institutional Relations (KN 02)

Technical Information Services (KN 02 10)

Methodology of Information Generation. The Information Methodology Research Project (IMRP) has the goal of finding improved methods for collecting, analyzing, indexing, storing, retrieving, and presenting information. Improved methods would ensure that data are useful, and that the data-handling process is efficient. Presently, the specific concern is the structural analysis of bibliographic databases, i.e., thesaurus generation and analysis, and automatic database mapping. A new research plan is being developed that will report on the state of the art of specific methodologies.

Methodology of Information Retrieval and Use. Improving present computerized information storage and retrieval techniques and providing a variety of information services is the main emphasis of this subject. In addition, LBL is developing federal Energy Information Centers for DOE in the western states, training new searchers on the DOE/RECON retrieval system, and keeping RECON clients informed with a monthly DOE/RECON newsletter.

LBL interaction through these activities provides a means of feedback to Oak Ridge Technical Information Center and to the RECON system developers at ORNL.

WORK FOR OTHERS

Work for others during FY 1978 includes reimbursable work for other federal agencies and work for other Department of Energy programs funded through other contractors in which LBL is involved as a partner.

Among reimbursable work-for-others projects are work for the National Science Foundation (NSF), the National Institutes of Health (NIH), the Department of Defense (DOD), and the Department of Labor (DOL). This work is briefly characterized below.

NSF - Joint funding with DOE for the National Resource for Computation in Chemistry (NRCC).

NIH - Biomedical applications, primarily under PHS grants and contracts. This work will continue, and probably increase.

DOD - Primarily computer time purchases.

DOL - Information systems and data bases. Large computer system acquisitions for DOL.

Other - Primarily computer time. This work should decrease due to increased in-house demand for computer time.

Major undertakings are the Swedish-American Cooperative Work Program on Radioactive Waste Storage in Mined Caverns in Crystalline Rock, which is jointly supported by DOE and the Swedish State Power Board and an equivalent radioactive waste storage program in basalt at Hanford Laboratory, joint programs with the Lawrence Livermore Laboratory (LLL) and participation in construction for the proton-electron project (PEP) at the Stanford Linear Accelerator Center (SLAC).

CHAPTER V

NEW INITIATIVES

The research and development programs of Lawrence Berkeley Laboratory address a wide range of national energy requirements and goals. Constantly in a state of evolution, LBL programs have grown when the need for them increased, and have diminished when the need lessened. A period of substantial growth has taken place in the last few years, during which the mission of the sponsoring agency broadened and many new challenges and responsibilities came within the Laboratory's purview.

The present size and character of the LBL program came about as the result of many initiatives taken, for the most part, by the Laboratory as it perceived important problems that it could help solve, but also, from time to time, from initiatives taken by the agency. Most of the programs described in Chapter 3 already embody new initiatives suggested as part of normal program development. These vary from minor changes, not involving growth, to requests for major expansion. The initiatives have in common that they arise from ongoing programs, and that they are taken for the purpose of increasing the relevance of the programs to the Laboratory's and agency's goals, or the ability of the Laboratory to solve the problems on which it is working.

Some of these new initiatives are substantial in size, scope, or in the increase of Laboratory responsibility. The recent creation at LBL of the National Resource for Computation in Chemistry is an example of a major initiative. Discussions are presently underway between the Laboratory and the agency concerning several other evolutionary program changes.

Four of these new initiatives are described in this chapter.

1. Center for Research in Energy Information

The value and importance of information about energy has been widely recognized in recent years. Before 1974, little emphasis was placed on this broad area although specialized topics within the field of energy information were studied in depth. With the establishment of the Department of Energy, the primary statistical data gathering, data analysis, and energy information functions of the Department were consolidated in the Energy Information Administration. Because of the recent and rapid growth of this field, there does not exist a widespread network of research directly related to the activities of the Energy Information Administration.

Effective research and development of new techniques for energy information studies requires the integration of expertise from a wide range of disciplines including the technical energy fields, economics, statistics, operations research, computer science, and survey research. LBL's experience with many scientific data projects has demonstrated

the value of close association between data activities and researchers in the corresponding subject matter.

We propose to establish, at LBL, a center for research in energy information. The nucleus for the center will be provided by ongoing projects on energy end-use data and energy data validation. The center will draw upon the wide diversity of expertise available through LBL staff and the faculty of the University of California at Berkeley. The activities of this center will benefit from close association with the thriving energy research program at LBL and the academic environment of U.C. Berkeley.

Research will concentrate on the following major topics:

Improved methods for data collection. Because of the large expense involved in extensive data collection, improvements in the effectiveness of data collection techniques can be of great value. Topics suggested for study include various field survey techniques, statistical sampling techniques, and data processing methods.

Data validation studies. Efforts to ascertain and improve the quality of energy data are crucial to effective use of the information. This area will include validation studies of specific energy information systems as well as the development of validation techniques.

Analytical techniques. Studies will include the development, construction, and testing of new energy models; scenario development; and other analytical techniques.

Application of energy data. Work in this area consists of abstraction, compilation and integration of data from existing data sources to make the data suitable for use in analysis, policy studies and regulatory activities.

Specialized data compilations. New techniques will be tested and applied to data compilations maintained for specialized areas of energy information in which LBL has particular expertise. Such topics include energy end use data, geothermal resource data, and other information used for construction of national energy scenarios.

2. Nuclear Waste Management Program

Radioactive wastes have been generated for over three decades and will continue to be produced as long as nuclear fission is used as an energy source. Even in the absence of civilian nuclear power, there would remain a substantial inventory from military programs. Inadequate, temporary near-surface sites are now being used to store large and increasing quantities of waste. Therefore, the highest priority should be given to developing and implementing a workable waste-management strategy at the earliest possible date.

A number of important questions must be addressed before a specific waste management program can be implemented:

- an acceptable repository must be found;
- an adequate and safe means for emplacement must be developed;
- the desirability of retrievability must be evaluated;
- acceptable methods for handling transuranium and low-level waste must be developed; and
- criteria must be agreed upon for deciding when an approach has been demonstrated to be adequate.

Because the waste must remain isolated from the biosphere for hundreds of thousands of years, it is not possible actually to demonstrate the integrity of any form of physical containment. Therefore, storage sites must be found where geological isolation can be guaranteed with high assurance.

At present, knowledge of sub-surface media is not adequate to assess or predict the effectiveness and stability of an underground repository with the degree of certainty required. To do so will require extensive research in the basic and applied geosciences, including geochemistry, geomechanics, and hydrogeology. "Worst-case accident" assessments must be made by fault-tree methods of proposed waste-management systems and sites to focus research programs on the most critical problems and uncertainties. A number of other disciplines will be required for this work.

The socio-political aspects of the problem are among its most critical elements, and must be seriously addressed. Research must identify the underlying causes of public attitudes to nuclear power, and to nuclear waste particularly. The interaction between technical and political issues is strong: for example, the "solution" to the waste-storage problem may be a technical issue, but public confidence that human institutions can be relied on to implement the technical solution is a social issue. Both issues must be resolved if the nation is to be able to count on nuclear energy as a viable long-term option.

The LBL waste-management program is already substantial (Geosciences and Waste Isolation in Chapter 3). The Laboratory believes that the level and breadth of the program should be expanded, both because of the critical importance of the problem and because the Laboratory and U.C. Berkeley campus, working together, could bring to bear on it a unique combination of intellectual and technical resources. Components from the geosciences would be strengthened, specialists from the fields of materials and transuranium chemistry would be added, and a policy-related element, heavily involving the social sciences, would be initiated.

3. High Resolution Electron Microscopy Center

The characterization of microstructure by the direct identification of individual atoms, point defects, and their environment is a unique scientific challenge that will have immediate impact and far-reaching consequences for many fields of materials science, physics, chemistry, and biology.

High voltage, high resolution electron microscopes (HREM) can now provide resolution beyond the critical barrier of the interatomic distance in solids. This opens up the entire field of study of atomic configurations, and consequently expands many fields of research. It is not impossible that with the development of such instrumentation, atomic motion may be studied directly.

Important advances in high-resolution electron microscopy are being achieved in Japan and Europe by the use of special microscopes having accelerating voltages up to 1 MeV. In the absence of any competitive manufacturing capability or any large established electron optics research laboratories in this country, it is essential that this powerful new level of technology be made available to the numerous electron microscopists in DOE laboratories and throughout the United States.

It is proposed that a National Facility for High Resolution Electron Microscopy be established at the Laboratory, including collaborative arrangements with Arizona State University and Stanford University. Initially, the facility would function with commercially available instruments: a 500-keV HREM, two feeder microscopes and two experimental microscopes. The objectives of the National Facility would be: (1) to attain the highest available resolution levels in transmission electron microscopy and to direct the application of these methods to the many scientific problems whose solutions require atomic level detail; (2) to assist scientists in the application of the most advanced characterization techniques in their various fields of research; (3) to promote further research into the fundamental development of high-resolution methods, and (4) to educate potential users of high-resolution techniques in the necessary theoretical and experimental background.

4. Surface Science and Catalysis Facility.

Research in surface science and catalysis is critical to the solution of many problems of energy supply development, including especially solar energy, fusion, and energy storage technologies. Such research is highly interdisciplinary. At LBL and U.C. Berkeley, seven academic disciplines are involved--chemistry, chemical engineering, physics, metallurgy, ceramic science, nuclear, and mechanical engineering. The proposed Surface Science and Catalysis Facility would greatly increase the effectiveness of this research program by coordinating and integrating these diverse elements.

The program will address fundamental problems involved in synthesizing liquid and gaseous fuels from coal by homogeneous and heterogeneous catalysis. The structure of surfaces, surface-chemical reactions, and reaction mechanisms will be studied. Emphasis will be on the identification of factors controlling catalyst activity, selectivity, and resistance to poisoning. New catalysts to be studied include organometallic complexes, small metallic clusters, and bimetallic alloys. This work also supports the search for precious metal substitutes.

The investigation of surface structure and surface composition is concerned with the arrangement of atoms in the topmost layer of solids. Low energy electron diffraction analysis at LBL recently elucidated the atomic arrangement of several hydrocarbons absorbed on platinum surfaces. A systematic study of the behavior of imperfect surfaces is expected to yield new insights into the nature of catalytic activity. The scattering of molecular beams from surfaces, where they undergo chemical reactions, provides new information about the partitioning of chemical energy in surface reactions.

Photon-assisted chemical reactions on semiconductor surfaces, of interest for photochemical energy conversion, will be investigated as an extension of present work with titanium oxide crystals. It is possible that hydrogen and hydrocarbon synthetic fuels can be produced by this route with sunlight from water and carbon dioxide.

The study of high-temperature surface reactions is concerned with the behavior of nuclear fuel and containment materials, and with corrosion-erosion of materials in advanced coal gasification reactors.

ENERGY RESEARCH (ER)

Director of
Energy Research

OPERATING FUNDS - BUDGET OUTLAY (BO)

(dollars in millions)

LBL

B & R Activity		FY 1978	FY 1979 PB	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984
AK 01 01	Nuclear Science	2.0	2.2	2.4	2.5	2.6	2.7	2.8
AK 01 02	Materials Sciences Research	4.5	4.9	5.9	6.7	7.1	7.8	8.0
AK 01 03	Chemical Sciences Research	4.4	4.9	5.3	5.7	6.0	6.3	6.5
AK 01 04	Engr., Math. & Geosciences	1.1	1.4	1.6	1.7	1.8	1.9	2.0
	Subtotal Basic Energy Sciences	12.0	13.4	15.2	16.6	17.5	18.7	19.3
* HK 02 05	High Energy Physics-Subtotal	10.2	10.6	12.0	13.0	14.0	15.0	15.5
HK 03 01	Medium Energy Physics	0.7	0.7	1.0	1.0	1.0	1.1	1.1
HK 03 02	Heavy Ion Physics	14.3	15.6	17.0	18.0	18.8	19.6	20.1
HK 03 03	Nuclear Theory	0.6	0.6	0.8	0.9	1.0	1.0	1.0
	Subtotal Nuclear Physics	15.6	16.9	18.8	19.9	20.8	21.7	22.2
	Total Energy Research	37.8	40.9	46.0	49.5	52.3	55.4	57.0

* Includes High Energy Physics contribution to the Heavy Ion Fusion program, joint funded under HK 02 05 03 and JF 01 01 02. High Energy Physics contribution not included in FY 1979 President's Budget.

The escalation factor used for FY 1980 over FY 1979 is 8%. The out-year amounts (FY 1981-1984) are in constant FY 1980 dollars.

ENERGY RESEARCH (ER)

Director of
Energy Research

MANPOWER - FULL TIME EQUIVALENT (FTE)

LBL

B & R Activity		FY 1978	FY 1979 PB	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984
AK 01 01	Nuclear Science	40	39	40	42	43	44	45
AK 01 02	Materials Sciences Research	120	123	138	153	161	168	170
AK 01 03	Chemical Sciences Research	100	106	108	115	120	123	125
AK 01 04	Engr., Math. & Geosciences	20	24	26	28	30	32	34
	Subtotal Basic Energy Sciences	280	292	312	338	354	367	374
* HK 02 05	High Energy Physics-Subtotal	220	198	208	220	235	245	250
HK 03 01	Medium Energy Physics	16	16	17	17	17	18	18
HK 03 02	Heavy Ion Physics	292	282	295	300	305	310	314
HK 03 03	Nuclear Theory	13	12	15	17	19	19	19
	Subtotal Nuclear Physics	321	310	327	334	341	347	351
	Total Energy Research	821	800	847	892	930	959	975

* Includes Heavy Ion Fusion program, joint funded by HK 02 05 03 and JF 01 01 02. High Energy Physics contribution not included in FY 1979 President's Budget.

ENERGY RESEARCH (ER)

Director of
Energy Research

CAPITAL EQUIPMENT - BUDGET AUTHORITY (BA)
(dollars in millions)

LBL

B & R Activity		FY 1978	FY 1979 PB	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984
35 AK 01	Basic Energy Sciences	0.9	1.0	3.5	2.6	2.6	2.6	2.6
35 HK 02	High Energy Physics	3.2	5.4	6.1	2.4	2.4	2.4	2.4
35 HK 03	Nuclear Physics	1.3	2.7	2.3	1.6	2.1	1.9	1.9
35 HK 90	Equipment - Other	1.2	1.0	1.5	1.5	1.5	1.2	1.0
Total Energy Research		6.6	10.1	13.4	8.1	8.6	8.1	7.9

ENVIRONMENT (EV)

Assistant Secretary for Environment

OPERATING FUNDS - BUDGET OUTLAY (BO)

(dollars in millions)

LBL

B & R Activity		FY 1978	FY 1979 PB	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984
GK 01 01	Overview & Assessment	1.0	0.9	1.0	1.1	1.1	1.2	1.2
GK 01 02	Biomed. & Environ. Res.	4.8	4.7	5.3	5.7	6.0	6.0	6.0
	Subtotal GK	5.8	5.6	6.3	6.8	7.1	7.2	7.2
HK 01 01	General Life Sciences	1.7	1.6	1.9	2.1	2.3	2.3	2.3
HK 01 02	Biomed. Applications	4.5	4.4	5.3	5.7	6.0	6.0	6.0
	Subtotal HK	6.2	6.0	7.2	7.8	8.3	8.3	8.3
	Total Environment	12.0	11.6	13.5	14.6	15.4	15.5	15.5

The escalation factor used for FY 1980 over FY 1979 is 8%. The out-year amounts (FY 1981-1984) are in constant FY 1980 dollars.

ENVIRONMENT (EV)

Assistant Secretary for Environment

MANPOWER - FULL TIME EQUIVALENT (FTE)

LBL

B & R Activity		FY 1978	FY 1979 PB	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984
GK 01	Environmental R & D	121	110	116	124	127	128	128
HK 01	Life Sciences Res. & Biomed. Appl.	73	68	77	85	88	88	88
	Total Environment	194	178	193	209	215	216	216

ENVIRONMENT (EV)

Assistant Secretary for Environment

CAPTIAL EQUIPMENT - BUDGET AUTHORITY (BA)

(dollars in millions)

LBL

B & R Activity		FY 1978	FY 1979 PB	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984
35 GK 90	Environmental Res. & Dev.	1.2	1.0	1.9	2.1	1.9	1.8	2.0
35 HK 01	Life Sciences Res. & Biomed.Appl.	0.3	0.2	2.2	1.7	1.7	1.7	1.7
	Total Environment	1.5	1.2	4.1	3.8	3.6	3.5	4.7

ENERGY TECHNOLOGY (ET)

Assistant Secretary for Energy Technology

OPERATING FUNDS - BUDGET OUTLAY (BO)

(dollars in millions)

LBL

B & R Activity		FY 1978	FY 1979 PB	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984
AA 01	Mines Research & Development	0.0	0.0	0.2	0.3	0.4	0.4	0.4
AA	Other - Coal	0.3	0.2	0.3	0.4	0.5	0.5	0.5
	Subtotal AA	0.3	0.2	0.5	0.7	0.9	0.9	0.9
AB	Petroleum - Subtotal AB	0.2	0.4	0.5	0.6	0.6	0.6	0.6
AD 02	Technology Support	0.5	0.6	1.0	1.0	1.0	1.0	1.0
AD 03	Solar Electric	0.1	0.1	0.3	0.3	0.3	0.3	0.3
	Subtotal AD	0.6	0.7	1.3	1.3	1.3	1.3	1.3
AE 01	Engr. Res. & Development	1.6	1.4	1.6	1.3	1.3	1.3	1.3
AE 02	Resource Explor. & Assess.	2.2	2.9	3.0	2.7	2.7	2.7	2.7
AE 03	Hydrothermal Tech. Appl.	1.5	2.2	2.1	1.9	1.9	1.9	1.9
AE 06	Environmental Control	0.9	1.9	1.8	1.6	1.6	1.6	1.6
	Subtotal AE	6.2	8.4	8.5	7.5	7.5	7.5	7.5
AF 01 01	Confinement Systems	2.1	1.7	0.0	0.0	0.0	0.0	0.0
AF 01 02	Development & Technology	0.0	0.1	0.3	0.3	0.3	0.3	0.3
AF 01 03	Applied Plasma Physics	1.3	1.4	2.5	7.5	8.0	9.0	11.0
AF 01 04	Reactor Projects	5.0	4.0	2.7	0.0	0.0	0.0	0.0
	* Subtotal AF	8.4	7.2	5.5	7.8	8.3	9.3	11.3
AG 04	Adv. Isotope Sep. - Subtotal AG	0.2	0.2	0.4	0.4	0.5	0.6	0.7
AJ 01	Fuels from Biomass - Subtotal AJ	0.4	0.3	0.8	0.7	0.6	0.6	0.6
C8 01	Energy Storage	0.3	0.3	0.8	0.9	0.9	0.9	0.9
C8 02	Energy Conversion	0.2	0.0	0.6	0.6	0.6	0.6	0.6
	Subtotal C8	0.5	0.3	1.4	1.5	1.5	1.5	1.5
	Total Energy Technology	16.8	17.7	18.9	20.5	21.2	22.3	24.4

* Does not include neutral beam work for LLL Magnetic Fusion program - included in WFO.

The escalation factor used for FY 1980 over FY 1979 is 8%. The out-year amounts (FY 1981-1984) are in constant FY 1980 dollars.

ENERGY TECHNOLOGY (ET)

Assistant Secretary for Energy Technology

MANPOWER - FULL TIME EQUIVALENT (FTE)

LBL

B & R Activity		FY 1978	FY 1979 PB	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984
AA 01	Mines Research & Development	0	0	3	5	7	7	7
AA	Other - Coal	8	3	5	7	9	9	9
	Subtotal AA	8	3	8	12	16	16	16
AB	Petroleum - Subtotal AB	5	7	11	13	13	13	13
AD 02	Technology Support							
AD 03	Solar Electric							
	Subtotal AD	12	11	16	16	16	16	16
AE 01	Engr. Res. & Development							
AE 02	Resource Explor. & Assess.							
AE 03	Hydrothermal Tech. Appl.							
AE 06	Environmental Control							
	Subtotal AE	58	58	58	51	51	51	51
AF 01 01	Confinement Systems	36	25	0	0	0	0	0
AF 01 02	Development & Technology	1	1	6	6	6	6	6
AF 01 03	Applied Plasma Physics	42	36	82	102	106	110	115
AF 01 04	Reactor Projects	56	37	36	0	0	0	0
	Subtotal AF	135	99	124	108	112	116	121
AG 04	Adv. Isotope Sep. - Subtotal AG	4	3	4	5	6	7	8
AJ 01	Fuels from Biomass - Subtotal AJ	10	7	17	15	13	13	13
C8 01	Energy Storage	9	8	16	18	18	18	18
C8 02	Energy Conversion	4	0	12	12	12	12	12
	Subtotal C8	13	8	28	30	30	30	30
	Total Energy Technology	245	196	266	250	257	262	268

ENERGY TECHNOLOGY (ET)

Assistant Secretary for Energy Technology

CAPITAL EQUIPMENT - BUDGET AUTHORITY (BA)

(dollars in millions)

LBL

B & R Activity		FY 1978	FY 1979 PB	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984
35 AA	Coal	0.1	0.0	0.2	0.2	0.2	0.2	0.2
35 AB	Petroleum	0.0	0.0	0.0	0.1	0.1	0.1	0.1
34 AD	Solar	0.0	0.0	0.1	0.1	0.1	0.1	0.1
35 AE	Geothermal	0.1	0.0	0.2	0.2	0.3	0.3	0.3
35 AF	Fusion	0.4	0.1	0.6	1.0	0.8	0.8	0.9
35 AG	Advanced Isotope Separation	0.1	0.0	0.2	0.2	0.2	0.2	0.2
35 C8	Conservation	0.0	0.0	0.2	0.2	0.2	0.2	0.2
	Total Energy Technology	0.7	0.1	1.5	2.0	1.9	1.9	2.0

CONSERVATION AND SOLAR APPLICATIONS (CSA)

Assistant Secretary for Conservation and Solar Applications

OPERATING FUNDS - BUDGET OUTLAY (BO)

(dollars in millions)

LBL

B & R Activity		FY 1978	FY 1979 PB	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984
AD 01	Thermal Applications	0.7	1.5	1.4	1.4	1.4	1.4	1.4
BD 01	Heating & Cooling Demonstration Program	0.3	0.0	0.0	0.0	0.0	0.0	0.0
C3 01	Buildings & Community Systems	4.2	2.2	5.0	5.0	5.0	5.0	5.0
C4 01	Industry	0.1	0.1	0.1	0.1	0.1	0.1	0.1
* C5 01	Transportation Energy Conservation	0.3	0.3	1.5	3.2	2.3	2.3	1.9
C8 08	Appropriate Technology	0.1	0.1	0.2	0.0	0.0	0.0	0.0
	Total Conservation & Solar Applications	5.7	4.2	8.2	9.7	8.8	8.8	8.4

* Includes demonstration project dual mode vehicle.

The escalation factor used for FY 1980 over FY 1979 is 8%. The out-year amounts (FY 1981-1984) are in constant FY 1980 dollars.

CONSERVATION AND SOLAR APPLICATIONS (CSA)

Assistant Secretary for Conservation and Solar Applications

MANPOWER - FULL TIME EQUIVALENT (FTE)

LBL

B & R Activity		FY 1978	FY 1979 PB	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984
AD 01	Thermal Applications	15	22	21	21	21	21	21
BD 01	Heating & Cooling Demonstration Program	1	0	0	0	0	0	0
C3 01	Buildings & Community Systems	45	38	45	45	45	45	45
C4 01	Industry	2	2	2	2	2	2	2
C5 01	Transportation Energy Conservation	4	5	9	19	14	14	11
C8 08	Appropriate Technology	2	2	4	0	0	0	0
	Total Conservation & Solar Applications	69	69	81	87	82	82	79

CONSERVATION AND SOLAR APPLICATIONS (CSA)

Assistant Secretary for Conservation and Solar Applications

CAPITAL EQUIPMENT - BUDGET AUTHORITY (BA)

(dollars in millions)

LBL

B & R Activity		FY 1978	FY 1979 PB	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984
35 AD 01	Solar	0.1	0.2	0.1	0.2	0.2	0.2	0.2
35 C3 90	Buildings & Community Systems	0.1	0.0	0.8	0.3	0.3	0.3	0.3
35 C5 90	Transport Equipment	0.0	0.0	0.1	0.1	0.1	0.0	0.0
Total Conservation & Solar Applications		0.2	0.2	1.0	0.6	0.6	0.5	0.5

OTHER ACTIVITIES

Other DOE Programs

OPERATING FUNDS - BUDGET OUTLAY (BO)

(dollars in millions)

LBL

B & R Activity		FY 1978	FY 1979 PB	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984
FK 02 01	Data Collection/Validation	0.4	0.7	0.8	1.0	1.0	1.0	1.0
* JF 01	Inertial Confinement Fusion	0.9	0.9	3.2	4.1	3.0	2.5	2.5
KK 02	General Systems Studies	0.2	0.2	0.3	0.3	0.3	0.3	0.3
KN 01	Program Direction-Mgmt.Support	0.0	0.1	0.1	0.1	0.1	0.1	0.1
KN 02 10	Technical Information Services	0.3	0.3	0.5	0.6	0.6	0.6	0.6
KN 02 40	University Programs	0.1	0.1	0.4	0.4	0.4	0.4	0.4
Total Other DOE Programs		1.9	2.3	5.3	6.5	5.4	4.9	4.9

* From FY 1980 through FY 1984 funding could increase significantly if there is a favorable decision to proceed with a Heavy Ion Demonstration Experiment. This project is funded jointly under Inertial Confinement Fusion and High Energy Physics. See HK 02 05.

The escalation factor used for FY 1980 over FY 1979 is 8%. The out-year amounts (FY 1981-1984) are in constant FY 1980 dollars.

OTHER ACTIVITIES

Other DOE Programs — MANPOWER - FULL TIME EQUIVALENT (FTE) — LBL

B & R Activity		FY 1978	FY 1979 PB	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984
FK 02 01	Data Collection/Validation	13	13	13	17	17	17	17
* JF 01	Inertial Confinement Fusion	15	13	35	45	45	35	30
KK 02	General Systems Studies	5	5	8	8	8	8	8
KN 01	Program Direction-Mgmt.Support	0	1	1	1	1	1	1
KN 02 10	Technical Information Services	8	8	11	12	12	12	12
KN 02 40	University Programs	4	3	12	12	12	12	12
Total Other DOE Programs		45	43	80	95	95	85	80

* From FY 1980 through FY 1984 funding could increase significantly if there is a favorable decision to proceed with a Heavy Ion Demonstration Experiment. This project is funded jointly under Inertial Confinement Fusion and High Energy Physics. See HK 02 05.

OTHER ACTIVITIES

Other DOE Programs

CAPITAL EQUIPMENT - BUDGET AUTHORITY (BA)

(dollars in millions)

LBL

B & R Activity		FY 1978	FY 1979 PB	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984
* 35 JF 01	Inertial Confinement Fusion	0.2	0.2	0.3	0.3	0.3	0.3	0.3

* From FY 1980 through FY 1984 funding could increase significantly is there is a favorable decision to proceed with a Heavy Ion Demonstration Experiment. This project is funded jointly under Inertial Confinement Fusion and High Energy Physics. See HK 02 05.

DOE PROGRAMS

SUMMARY RESOURCE REQUIREMENTS

Resource	FY 1978	FY 1979 PB	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984
Operating Funds (BO M$)	74.2	76.7	91.9	100.8	103.1	106.9	110.2
Manpower (FTE)	1374	1286	1467	1533	1579	1604	1618
Capital Equipment (BA M$)	9.2	11.8	20.3	14.8	15.0	14.3	15.4

Reimbursable Work for
Other Federal Agencies

OPERATING FUNDS - BUDGET OUTLAY (BO)
(dollars in millions)

LBL

B & R Activity	FY 1978	FY 1979 PB	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984
WN 02 Cost of Work for Others							
Department of Defense	0.4	0.3	0.2	0.2	0.3	0.3	0.3
Dept. of Health, Education & Welfare	0.6	0.9	0.9	1.0	1.0	1.0	1.0
National Science Foundation	1.0	1.3	1.7	1.6	1.8	1.5	2.8
Department of Labor	1.6	1.0	1.0	1.0	0.9	0.8	1.7
National Regulatory Commission	0.1	0.2	0.1	0.0	0.0	0.0	0.0
Others	1.5	1.2	1.0	1.0	1.0	1.2	1.0
Total WFOFA	5.2	4.9	4.9	4.8	5.0	4.8	6.8

Work for Other
DOE Programs

OPERATING FUNDS - BUDGET OUTLAY (BO)
(dollars in millions)

LBL

Activity	FY 1978	FY 1979 PB	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984
Commercial Waste Management	5.8	5.2	5.5	6.0	6.0	6.0	6.0
* LBL/LLL Joint Programs	4.5	4.6	6.0	6.0	6.0	6.0	6.0
Work for Others	10.0	10.0	9.0	7.0	6.0	6.0	6.0
PEP Construction	4.0	2.2	0.4	0.0	0.0	0.0	0.0
Total Work for Other DOE Programs	24.3	22.0	20.9	19.0	18.0	18.0	18.0

* Funded through LLL.

This report was done with support from the Department of Energy. Any conclusions or opinions expressed in this report represent solely those of the author(s) and not necessarily those of The Regents of the University of California, the Lawrence Berkeley Laboratory or the Department of Energy.

TECHNICAL INFORMATION DEPARTMENT
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720