

FIVE-YEAR SUMMARY REPORT ON THE
UCSD ENERGY CENTER
(July 1, 1974, to June 30, 1979)

1. HISTORY

The UCSD Energy Center commenced operation informally during the fall of 1973 and was designated an organized research unit at UCSD as of July 1, 1974. The purposes for which the Energy Center was established are well defined by the following statement abstracted from the October 1973 draft proposal to establish this ORU:

"The purpose of a UCSD Energy Center is to strengthen interdisciplinary programs of research and teaching, as well as to provide graduate and post-doctoral students with added research opportunities, facilities and assistance.

The establishment of a UCSD Energy Center will serve important educational, research, and public-service functions which are not satisfactorily met by the existing departments or other organized research units at UCSD. An opportunity exists in the San Diego area to solve fundamental problems deriving from the interrelated physical, biological, economic, political, and social consequences of man's need for energy. The importance of energy problems arises from factors which include: i) the key role of energy supply in the functioning and growth of industrial society, ii) the finite supply of fossil-fuel resources, iii) the environmental side effects of energy production and use (air, water and thermal pollution), iv) risks associated with nuclear-energy production (radioactive release, diversion of fissionable material for military use), v) the danger that planning in the energy area, which has a controlling effect on many other areas of planning, will be ruled by considerations which are too narrow or biased to reflect the public interest."

S. S. Penner, Professor of Engineering Physics in the Department of Applied Mechanics and Engineering Sciences, was asked to assume overall responsibility for coordination and development of the UCSD Energy Center plan. There have been no budgetary allocations made for the support of faculty or staff members associated with the Energy Center. Instead, involvement in studies has followed the principle that faculty participation is only effective when it is accomplished in accord with individual preferences, competence and availability, depending on the subject matter under investigation. A loosely-knit group of Energy Center Associates was created (see Appendix I) by soliciting expressions of interest from faculty members and research personnel whose activities and areas of competence were consonant with the purposes, teaching functions, and research programs supported by the Energy Center. Throughout the first five years of operation, no salary funds (except limited support for secretarial services) have been solicited by or granted to the UCSD Energy Center from UC sources.

The development of the UCSD Energy Center was greatly aided by a program-initiation grant, which was received from the Gulf Oil Foundation during 1973. Several graduate fellowships were established by grants received from the High Temperature Reactor Associates and the San Diego Gas and Electric Company.

2. INSTRUCTIONAL PROGRAMS

Early emphasis of Energy Center efforts was placed on course development.

Since the beginning of the 1974-75 academic year, the following courses have been offered on a regular basis:

AMES 34: A Freshman-level course dealing with Energy: Demands, Resources, Technology and Policy. This is a survey course on energy stressing the following topics: the manner in which our energy demands are defined at the local, regional, national and international levels; the total (currently used and potential)

resources available for satisfying energy demands; highlights of technological challenges concerning new energy production and utilization techniques; energy policy, with emphasis on potential environmental and economic impacts.

- FS 119A: An interdisciplinary, upper-division course on Energy: Demands, Resources, Technology and Policy. Past and estimated future energy demands. Renewable and non-renewable energy resources. Economic impact of energy use. Environmental impact of energy use. Energy conservation in manufacturing, transportation, home use. Energy policy.
- FS 119B: An interdisciplinary, upper-division course on Energy: Non-Nuclear Energy Technologies. Oil recovery from tar sands and oil shale. Coal production, gasification, liquefaction. The hydrogen economy. Energy storage systems. Techniques for direct energy conversion. Solar-energy utilization. Energy from windmills. Tidal-and-wave-energy utilization. Hydroelectric power generation. Hydrothermal energy. Geothermal energy from hot rocks. Electrical power production, transmission and distribution.
- FS 119C: An interdisciplinary, upper-division course on Energy: Nuclear Energy Technologies and Energy Policies. A brief survey of energy demands and resources. Available nuclear energy: physical background, thermal dynamics, atomic and nuclear physics; fission and fusion processes: physics of fission reactions, engineering aspects, safety and environmental effect of fusion; scaling laws and start-up criteria; laser fusion; magnetic confinement; equilibrium instability; energy policies.

In addition, at least one course per year is being offered at the advanced graduate level on selected energy technologies (e.g., coal gasification and liquefaction, solar energy, geothermal energy, fusion power, fault-tree analysis of nuclear reactor safety, etc.). Faculty members from several departments have

been regular participants in these interdisciplinary offerings. The course material that has been used in AMES 34, FS 119A, 119B and 119C is described in the following publications:

Energy, Volume I: Demands, Resources, Impact, Technology, and Policy, 373 pages, by S. S. Penner and L. Icerman, Addison-Wesley Publishing Company, Reading, Mass., 1974; reprinted in 1976 and 1979. This volume is currently being completely revised and updated.

Energy, Volume II: Non-Nuclear Energy Technologies, 673 pages, by S. S. Penner and L. Icerman, Addison-Wesley Publishing Company, Reading, Mass., 1975; reprinted with revisions in 1977; reprinted in 1979.

Energy, Volume III: Nuclear Energy and Energy Policies, 713 pages, by S. S. Penner, K. A. Brueckner, R. J. Cerbone, A. Hochstim, J. P. Howe, L. Icerman, M. Z. Nagel, W. B. Thompson, and B. J. West, Addison-Wesley Publishing Company, Reading, Mass., 1976.

Some related interdisciplinary courses at UCSD, most of which antedate establishment of the UCSD Energy Center, deal with such topics as Technology, Ecology, Morality; Quantitative Aspects of Social and Environmental Problems; Transportation: A Technology in Its Societal Setting; Society and the Sea; Management of the Air Environment; Chemistry and the Air Environment; etc.

The UCSD Energy Center does not accept or process applications for graduate students. All inquiries concerning admission to graduate work must be submitted directly to the responsible UCSD departments.

3. ENERGY-RELATED RESEARCH

It is proper to note that essentially all research in the physical, engineering, biological, and social sciences is energy-related. In this sense, all of the investigations performed by all of the many distinguished UCSD faculty members under

their own grants and contracts are important in furthering the objectives of the Energy Center. The following examples of these studies will serve to indicate the scope of activities with readily identifiable bearing on important current issues:

Geothermal resource development for use in the San Diego region.

Environmental effects of large nuclear farms; coastal and off-shore siting of nuclear reactors.

Predictive air-quality model for land use, transportation and energy planning; physico-chemical models of regional air pollution; short-term statistical predictions; air-basin time-response studies.

Measurements of rate constants for elementary reaction steps in natural-gas combustion.

Development of superconducting materials for use at higher temperatures.

Hydrogen storage in rare-earth metals.

Fundamental combustion and fire-control studies; the effect of turbulence on combustion processes.

Development of in situ procedures for the recovery of fossil fuels.

The use of biological systems for the direct production of hydrogen on exposure of water to solar radiation.

Development of new insulating materials for energy conservation.

Petrochemicals and energy use.

Geophysical aspects of energy utilization.

With support from the San Diego Gas and Electric Company, from the U.S. Department of Energy, and from the San Diego Naval Electronics Laboratory, associates of the UCSD Energy Center have developed an integrated program dealing with energy conservation and including the following topics: systems management of passive energy-conserving devices in residential units, fenestration devices for energy conservation, passive solar energy technologies in energy conservation, ceiling insulation in energy conservation, improved lubrication for energy conservation, electric load management, and life-cycle costing in energy conservation.

These programs, for which total funding during 1979 exceeds \$120,000, have involved experimental measurements on components, field measurements on model homes, field evaluations and data analysis of consumer acceptance and of field performance for energy-conserving devices, and analysis, evaluation, and publication of results.

University research with more conventional orientation has been performed by all of the faculty members associated with the UCSD energy-conservation studies (see Table 1 for details).

Since March of 1979, the Fossil Energy Research Working Group of DOE (FERWG-II) has been administered through the UCSD Energy Center. FERWG-II deals with an assessment of national programs and long-term research needs relating to coal liquefaction. It follows a study on coal gasification under FERWG-I (administered by the Mitre Corporation). S. S. Penner has served as Chairman of FERWG since its inception. FERWG is commissioned by the DOE Director of Energy Research and by the Assistant Secretary for Energy Technology. FERWG is a joint university-industry group and has been charged with the responsibility of (a) maintaining active surveillance of developing U.S. energy technologies dealing with fossil-fuel utilization and (b) advising the Director of Energy Research and the Assistant Secretary for Energy Technology on programmatic needs, especially long-term support for process and fundamental research. The FERWG activities involve a heavy schedule of on-site inspections and dialogue with development personnel and engineering and process supervisors. These exceedingly time-consuming activities represent a major challenge to define improvements in the country's most urgent and most costly energy programs.

Other UCSD faculty members have made important contributions to a wide gamut of energy-related studies, including energy-policy analyses, energy use in food production, novel applications of tidal and wave energy and of salinity gradients for power generation, the chemistry of geothermal resource management, superconducting power lines, laser-fusion processes, magnetic confinement in fusion

Table 1. Publications of the UCSD Energy Center from September 1976 to the present.

1. Energy, Volume I: Demands, Resources, Impact, Technology, and Policy, Reprinted in revised form during September 1976.
2. Energy, Volume III: Nuclear Energy and Energy Policies, S. S. Penner, K. A. Brueckner, R. J. Cerbone, A. Hochstim, J. P. Howe, Larry Icerman, Michael Z. Nagel, W. B. Thompson, Bruce J. West, Addison Wesley Publishing Co., Reading Mass. First published during September 1976.
3. S. S. Penner, J. M. Bernard and T. Jerskey, "Laser Scattering from Moving, Polydisperse Particle Systems in Flames. I. Theory," Acta Astronautica 3, 69-91 (1976).
4. S. S. Penner, J. M. Bernard and T. Jerskey, "Laser Scattering from Moving, Polydisperse Particle Systems in Flames. II. Preliminary Experiments," Acta Astronautica 3, 93-105 (1976).
5. S. S. Penner, "Construction of Nuclear Reactors to Obtain Desired Electricity-Generating Capacity," Energy 1, 45-52 (1976).
6. W. M. Heffington, G. E. Parks, K. G. P. Sulzmann, and S. S. Penner, "High-Temperature Absorption Coefficient of Methane at 3.392 μ ," JQSRT 16, 839-841 (1976).
7. J. R. Clinton, Solar Energy: Home Use in San Diego, J. R. Clinton, San Diego, December 1976.
8. A. S. Schneider, "Elasticity of Demand for Gasoline Since the 1973 Oil Embargo," Energy 2, 45-52 (1977).
9. C. W. Bullard and A. V. Sebald, "Effects of Parametric Uncertainties and Technological Change on Input-Output Models," The Review of Economics of Statistics, Harvard University, Vol. LIX, No. 1, pp. 75-81, February 1977.
10. John P. Howe, editor and contributor, "Transfer of Nuclear Technology," Annals of Nuclear Energy, Vol. 4 (Nos. 6-8), 1977.
11. W. M. Heffington, G. E. Parks, K. G. P. Sulzmann, and S. S. Penner, "Studies of Methane Oxidation Kinetics," 16th International Combustion Symposium, pp. 997-1011, The Combustion Institute, Pittsburgh, Pa., 1977.
12. "A Simplified Analysis of the Consumer's View of Life-Cycle Costing for Home Insulation and Solar Heating" by S. S. Penner and M. Brambley, Energy Center Report, February 1977.

Table 1. (continued)

13. "Capital-Cost Estimates for Installing Energy-Conserving Devices" by R. Schmalensee, Energy Center Report, February 1977.
14. "Devices for Improving Energy-Utilization Efficiencies of Fuels Burned in Residential Fireplaces" by S. S. Penner and M. Brambley, Energy Center Report, March 1977.
15. "Societal Acceptance of New Technologies: Case Histories of Contrasting Developments" by S. S. Penner, J. P. Howe, A. Beerbower, A. Sebald, and J. R. Clinton, Energy Center Report, May 1977.
16. "Study of Energy Conservation in Motor-Driven Compressors and Blowers at U.S. Naval Regional Medical Center, San Diego" by A. Beerbower, Energy Center Report, July 1977.
17. J. M. Bernard and S. S. Penner, "Determination of Particle Sizes in Flames from Scattered Laser Power Spectra," pp. 411-420 in Experimental Diagnostics in Gas Phase Combustion Systems, Vol. 53 of Progress in Astronautics and Aeronautics, American Institute of Aeronautics and Astronautics, New York, N.Y., 1977.
18. W. M. Heffington, G. E. Parks, K. G. P. Sulzmann, and S. S. Penner, "High-Temperature Emissivities of Complex Gas Mixtures in the 4.8 μ Region," JQSRT 18, 361-363 (1977).
19. S. S. Penner, "A Monitoring Program to Measure Changes in the Mean Atmospheric Temperature of the Earth," JQSRT 19, 549-553 (1977).
20. S. S. Penner, K. G. P. Sulzmann, W. M. Heffington, and G. E. Parks, "Equilibrium and Nonequilibrium Radiation Observed in Shock-Tube Studies of Methane Oxidation," JQSRT 19, 173-194 (1978).
21. S. S. Penner, K. G. P. Sulzmann, G. E. Parks, and J. M. Kline, "Shock-Tube Measurements of Ignition and Post-Induction Kinetics of Low-Btu Gas Mixtures," 11th International Symposium on Shock Tubes and Waves, pp. 351-358, University of Washington Press, Seattle, Washington, 1977.
22. Energy, Vol. II: Non-Nuclear Energy Technologies by S. S. Penner and L. Icerman, 2nd printing, revised and updated, 718 pages, Addison-Wesley Publishing Co., Reading, Mass., 1977.
23. A. M. Schneider, "San Diego Meteorology and Its Implications for Air Pollution," chapter in Geologic Hazards in San Diego, edited by Patrick L. Abbot and Janice K. Victoria, San Diego Society of Natural History, San Diego, 1977, pp. 75-79.

Table 1. (continued)

24. A. V. Sebald and A. Hoddad, "Robust State Estimation in Uncertain Systems: Combined Detection-Estimation with Incremental MSE Criterion," IEEE Transactions on Automatic Control, Vol. AC-22, No. 5, October 1977, pp. 821-825.
25. M. R. Brambley and S. S. Penner, "Fenestration for Energy Conservation. I. Shading Coefficients and Other Useful Relations for Estimating Heat Gain through Fenestration," Energy Center Report, October 1977.
26. S. S. Penner, "Critical Observations on the National Energy Plan (NEP)," Energy Center Report, November 1977.
27. "The AGARD Propulsion and Energetics Panel: 1952-1977," by S. S. Penner, AGARD Advisory Report No. AR-111, 24 pages, Technical Editing and Reproduction, Ltd., Harford House, 7-9 Charlotte St., London W1P 1HD, England, 1978.
28. S. S. Penner and J. M. Bernard, "Relationship between Energy Conservation, GNP and Energy Consumption," The Indian and Eastern Engineer, 119th Anniversary Number, pp. 83-85 (1978).
29. M. R. Brambley and S. S. Penner, "An Economic Analysis of the Use of Shading Devices to Conserve Energy During the Cooling Season in San Diego County Using Monthly Climatic Data," Energy Center Report, April 1978.
30. M. R. Brambley and S. S. Penner, "A Conservative Economic Analysis of the Use of Shading Devices to Conserve Energy During the Cooling Season," Energy Center Report, March 1978.
31. A. V. Sebald, J. R. Clinton and F. Langenbacher, "Effects of Controls on Water Wall Performance," Proceedings of Second National Passive Solar Energy Conference, Philadelphia, PA, March 1978.
32. A. V. Sebald and F. Langenbacher, "A Statistical Measurement of the Heating Season Effectiveness of Ceiling Insulation in San Diego," UCSD Energy Center Report, March 1978.
33. A. M. Schneider, "San Diego Meteorology and Its Implications for Air Pollution," Environmental Southwest, pages 6-10, Spring 1978, No. 481.
34. A. M. Schneider and T. Takenawa, "Short-Term Hourly Load Forecasting in Electric Power Systems," Energy Center Reports, No. 1 March 1978, No. 2 May 1978.
35. A. V. Sebald and A. Hoddad, "State Estimation for Singularly Perturbed Systems with Uncertain Perturbation Parameter," IEEE Transactions on Automatic Control, Vol. AC-23, No. 3, June 1978, pp. 464-469.

Table 1. (continued)

36. Brambley, M. R. and S. S. Penner, "Fenestration Devices for Energy Conservation. I. Energy Savings During the Cooling Season," Energy Center Report, July 1978. [Also published in Energy 4, 1-25 (1979).]
37. Takenawa, T. and A. M. Schneider, "Report No. 3: Short-Term Hourly Load Forecasting in Electric Power Systems," Energy Center Report, July 1978.
38. Clinton, J. R., "Simulation Analysis of Solar Water Heating with Applications to the San Diego Region," Energy Center Report, August 1978.
39. Clinton, J. R., "Passive Solar Heating with Thermal Storage Walls," Energy Center Report, August 1978.
40. Brambley, M. R. and S. S. Penner, "Fenestration Devices for Energy Conservation. II. Fenestration Performance During the Heating Season," Energy Center Report, August 1978. [Also published in Energy 4, 27-31 (1979).]
41. Penner, S. S., R. Schmalensee and M. R. Brambley, "Life-Cycle Costing for Consumers of Energy-Conserving Devices," Energy 3, 415-419 (1978).
42. Sebald, A. V., "Impact of Controls on Backup Energy Consumption in Passive Solar Heated and Cooled Buildings," Final Report to U.S. DOE, Conservation and Solar Applications, Solar Heating and Cooling R&D Branch, Contract No. EM76-S-04-4221, Energy Center, UCSD, La Jolla, CA (1978).
43. Sebald, A. V., "Spectral Estimation with Poisson Sampling," Final Report, Contract No. N66001-78-C-0102, 1978.
44. Sebald, A. V. and J. R. Clinton, "Impacts of Controls on Backup Energy Consumption in Passive Solar Heated and Cooled Buildings," Invited paper, Proceedings of the 1978 U.S. DOE Solar Energy Contractors Meeting, Washington, D. C., 1978.
45. Schneider, A. M., "A New Tax on Gasoline: Estimating Its Effect on Consumption," Science 202, November 17, 1978, pp. 755-757.
46. Schneider, A. M., T. Takenawa and Dean Schiffman, "Report No. 4: Short-Term Hourly Load Forecasting in Electric Power Systems," Energy Center Report, December 1978.
47. Penner, S. S. and P. Chang, "On the Determination of Log-Normal Particle-Size Distributions Using Half-Widths and Detectabilities of Scattered Laser Power Spectra," JQSRT 20, 447-460 (1978).

Table 1. (continued)

48. Brambley, M. R. and S. S. Penner, "Performance Characteristics for Two Selected Fenestrations in the Transition Region of San Diego County," Energy Center Report, January 1979.
49. Sebald, A. V., "Toward a Computationally Efficient Optimal Solution to the LQG Discrete Time Dual Control Problem," IEEE Transactions on Automatic Control, Vol. AC-24, No. 4, 1979. Also presented at the 1978 IEEE Conference on Decision and Control, San Diego, January 1979.
50. Sebald, A. V., J. R. Clinton and F. Langenbacher, "Control Considerations in the Trombe Wall," Proceedings of the Third National Passive Solar Energy Conference, San Jose, CA, January 1979 (to appear in Solar Energy).
51. Penner, S. S., "Critical Observations on the U.S. National Energy Plan (NEP)," Energy 4, 33-46 (1979).
52. Simnad, Massoud T. and John P. Howe, "Materials for Nuclear Fission Power Reactor Technology," Chapter 2, Materials Science in Energy Technology, Ed. by G. G. Lebowitz and M. S. Whitingham, Academic Press, New York, 1979.
53. Howe, John P., Book Review of The Concept of Energy by E. J. Hoffman, Ann Arbor Science Publishers (1977), Nuclear Science and Engineering (Am. Nuc. Soc.) 69 (No. 3, Mar. 1979), 45.
54. Howe, John P., Book Reviews of The Menace of Atomic Energy by Ralph Nader and John Abbotts, W. W. Norton and Co. (1979), and of A Guide to Nuclear Reactors by Anthony V. Nero, Jr., University of California Press (1979), San Diego Union, April 22, 1979 (Book Section).
55. "Assessment of Long-Term Research Needs for Coal-Gasification Technologies," Fossil Energy Research Working Group, Dr. S. S. Penner, Chairman, The Mitre Corporation, Metrek Division, 1820 Dolley Madison Blvd., McLean, VA 22102, 192 pages, April 1979.
56. Sulzmann, K. G. P., J. M. Kline and S. S. Penner, "Empirical Determinations of the Effective Absorption Coefficients for the NO γ -Bands at 2259 A and the ν_3 -Fundamental of N₂O at 4.52 μ ," JQSRT 21, 475-482 (1979).
57. Sebald, A. V. and A. H. Haddad, "On the Performance of Combined Detection Estimation in Convex Uncertainty Spaces," IEEE Transactions on Automatic Control, Vol. AC-24, No. 4, 1979.

energy, chemistry of coals, combustion processes, methods for the analysis of complex chemical kinetic processes, etc.

4. PUBLIC SERVICE FUNCTIONS

In accord with the principle that public-service functions constitute an important focus for faculty effort, very many of the UCSD faculty members serve on the advisory boards of national, statewide and regional governmental agencies. Examples of these activities are the following: National Science Board; advisory committees of the U.S. Department of Energy and of the congressional Office of Technology Assessment; State of California committees dealing with energy and resources; the Quality of Life Board of the City of San Diego; the EPRI advisory committee; the U.S. Advisory Committee for the International Institute of Applied Systems Analysis; energy advisory committees for senior congressional, senatorial, and administration committees; etc.

Sponsored studies have included workshops dealing with such topics as in situ recovery of shale oil, the social impact of energy use, and resource estimates for copper. Among the scientific journals edited by UCSD faculty members is Energy, The International Journal (Pergamon Press), now in its fourth year of publication.

The UCSD campus has served as a regional focus for professional seminars, special lectures, and symposia dealing with important public issues such as energy. Examples of these activities during the 1974-75 academic year were a Third College Symposium on Solar Energy: Future Prospects and Present Reality and a Conference on Limits to Non-Growth sponsored by the UCSD Program in Science, Technology and Public Affairs; during the years 1976-68, members of the President's Office of Science and Technology Policy advisory group on research directions in the Department of Energy met on the UC campus; since 1977, the DOE Fossil Energy Research Working Group has been convened repeatedly at UCSD.

5. FUTURE DIRECTIONS

While the instructional and public service functions of the UCSD Energy Center have had significant nationwide impacts, the research contributions have not served to solve the country's most urgent energy problems. No university-based group will, in fact, have a significant impact over a short period of time in this area. Without university support for staff and without complete redirection of research activities by a significant number of faculty members, the research activities must remain of a type that can pass peer review on the campus, support graduate research of a classical variety in well defined disciplinary fields, and satisfy customers whose time scales are incommensurate with established university proceedings.

With very limited resources, the UCSD Energy Center has selected for past emphasis energy conservation and passive solar technologies as the most immediately useful areas of activity on which to focus. It is likely that the completion of the FERWG studies at UCSD will be followed by major emphasis on fossil-fuel research dealing especially with coal conversion and coal utilization. Novel programs (e. g. , OTEC bottoming cycles in San Diego County, novel versions of OTEC, and other unconventional programs) have been assessed periodically but the time for implementation has not been judged appropriate.

A major expansion of Energy Center activities at UCSD may not be desirable and will require substantial support from university sources, especially for dedicated research staff.

APPENDIX I.ENERGY CENTER ASSOCIATES AND ENERGY-RELATED RESEARCH

| <u>Associate</u> | <u>Energy-Related Research Interests</u> |
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| J. R. Arnold, Professor of Chemistry: | energy policy |
| G. Arrhenius, Professor of Oceanography: | shale-oil recovery, energy from the oceans; |
| T. Barnett, Academic Administrator, NORPAX: | climatic impacts of escalating energy use; |
| K. A. Brueckner, Professor of Physics: | laser-induced fusion reactions; |
| J. Clinton, Lecturer, AMES: | solar-energy applications; |
| R. D. Emmerson, Assistant Professor of Economics: | cost minimization, regional planning; |
| C. H. Gibson, Associate Professor of Engineering Physics and Oceanography: | climatic impact of energy use; |
| E. Goldberg, Professor, Geological Research Division: | environmental impact assessments; |
| M. Goodman, Professor of Chemistry: | synthetic fuels, petrochemicals; |
| A. Gordon, Adjunct Professor of Engineering Chemistry: | air pollution and environmental impact assessments; |
| A. Hochstim, Visiting Professor of Engineering Physics: | fusion reactors; |
| J. P. Howe, Adjunct Professor of Nuclear Engineering: | fission and breeder reactors; |
| J. D. Isaacs, Professor of Oceanography: | wave energy, salinity power, OTEC; |
| N. O. Kaplan, Professor of Chemistry: | photosynthetic production of H ₂ ; |
| W. Kohn, Professor of Physics: | photovoltaics; |
| G. Krishnamoorthy, Associate Professor of Civil Engineering, California State University at San Diego: | energy conservation, structural designs; |
| S. Lakoff, Professor and Chairman, Political Science: | societal impacts of energy-use curtailments; |
| L. Liebermann, Professor of Physics: | photovoltaics; |
| P. A. Libby, Professor of Fluid Mechanics: | heat transfer and secondary cycles; |
| R. H. Lovberg, Professor of Physics: | magnetic confinement and fusion reactors, MHD; |

Associate

J. H. Malmberg, Professor of Physics:
 B. T. Matthias, Professor of Physics:
 W. D. McElroy, Chancellor and Professor of Biology:
 H. W. Meldner, Assistant Adjunct Professor of Physics:
 W. H. Munk, Professor of Geophysics:
 W. Nachbar, Professor of Applied Mechanics:
 J. Namias, Research Meteorologist:
 D. B. Olfe, Professor of Engineering Physics:
 H. Oesterreicher, Assistant Professor of Chemistry:
 S. S. Penner, Professor of Engineering Physics:
 W. Ramm, Assistant Professor of Economics:
 R. R. Revelle, Professor of Political Science and Director Emeritus, Scripps Institution of Oceanography:
 R. E. Roberson, Professor of Engineering Sciences:
 M. Rotenberg, Professor of Applied Physics:
 P. D. Saltman, Vice Chancellor for Academic Affairs and Academic Personnel and Professor of Biology:
 A. Sebald, Assistant Professor of Engineering Sciences:
 W. R. Schmitt, Associate Specialist in Oceanography:
 A. M. Schneider, Professor of Engineering Sciences:
 S. Schultz, Professor of Physics:

Energy-Related Research Interests

fusion reactors, MHD;
 superconductivity and superconducting power lines;
 biomass production;
 laser fusion and thermonuclear neutron capture;
 ocean-atmosphere interactions and the impact of energy use on climate change;
 nuclear-reactor sitings;
 climatic impact of escalating energy use;
 thermal plumes, climate changes;
 energy storage;
 energy conservation, energy technologies, climatic impact of escalating energy use;
 economic efficiency of energy use;
 energy use in food production;
 transportation systems and energy use;
 demographic studies, social systems;
 biomass production;
 energy conservation, utility-systems optimization;
 wave energy, salinity power;
 energy conservation, electric-load forecasting;
 solar-energy applications, photovoltaics;

AssociateEnergy-Related Research Interests

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|---|---|
| K. E. Shuler, Professor of Chemistry: | sensitivity analysis for complex systems, chemical kinetics; |
| H. Suhl, Professor of Physics: | photovoltaics, catalysis; |
| K. G. P. Sulzmann, Research Engineer: | energy technologies, energy conservation; |
| W. B. Thompson, Professor of Physics: | magnetic confinement and fusion reactors; |
| T. G. Traylor, Professor of Chemistry: | petrochemicals; |
| C. W. Van Atta, Professor of Engineering Physics and Oceanography: | climatic impact assessments, ocean engineering; |
| W. Vernon, Associate Professor of Physics: | solar-energy applications; |
| F. A. Williams, Professor of Aerospace Engineering: | combustion research; |
| K. R. Wilson, Associate Professor of Chemistry: | environmental-impact assessments; |
| H. F. York, Professor of Physics: | geopolitical aspects of energy use. |